
STUDY OF BEAMS UNDER VARIOUS LOADS

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ABSTRACT

The unknown and unclarified capabilities of structural elements are always a black mark even you have the knowledge of understanding and analyzing the structures and its performances. To understand the aircraft structures, loads acting on them and the deformation/failures of these structures, one should know the physics behind these structures. To simply the various loads acting on the aircraft structures, lets specifically consider the main structural element of aircraft wing which takes majority of the loads, which is wing spar of an aircraft. As we already know wing of an aircraft represents the cantilever beam which allows us to learn the loads acting and calculate them. In this case study, we will study, compare and analyze the cantilever beam, simply supported beam and overhanging beam which are subjected to point loads and uniformly distributed loads.

We use the beam theory, analytical and numerical solutions to compare the beams resulting in finding the efficiency in taking the load and the beams behavior under different loads. We have hand-calculated and ANSYS software generated solutions, which were compared and analyzed making the experiments ease for engineers who would like to know the actual engineering behind the structures. Bending moment, shear force diagram and bending moment diagram are compared with the analytical answers using the theory and formulae, and the numerical answers using ANSYS static structural under point loading and UDL. The animated results of deformation of the beams produced using ANSYS are helpful to visualize and understand the physics more than just reading the data. The results more precisely talk about their own beam pros, field of use and applications in engineering and real-life scenarios.

KEYWORDS: Wing spar, bending moment, aircraft structures, distributed loads, point loads, cantilever beam, simply supported beam.

INTRODUCTION

Beams are the most primarily used structural elements in any field of engineering, which is typically horizontal, designed to resist loads applied perpendicular to its length by bending. They transfer weights to supports and vary by support type and type of load applied. This study talks about the three supports of beams, which are cantilever, simply supported and overhanging beams. Each beam is having their own advantages and uses, yet the comparison is made to study the beams of the same dimensions of different supports under various loads. The comparison is important for optimal design selection, understanding behavior under load, analyzing complex structures, ensuring safety and durability. In essence, comparing these beams types is not about finding a better beam, but about understanding their mechanical properties to choose and design the most appropriate and safe structures for any given engineering application.

Here, in this study, we have compared the three main types of beams (cantilever, simply supported and overhanging beams) which are subjected to two types of loads (point, uniformly distributed), with the same dimensions given to all the three types of beam elements. Comparison is done with analytical and numerical methods of FEA & ANSYS which includes graphical data, statistical data and calculated data. This study and analysis is to understand the wing spar internal stresses which makes us understand the deformation or bending of this structural element of wing of an aircraft. Since we know wing spar takes all the majority of the loads acting on the wing and protect the structural integrity, we need to understand the wing spar behavior at student level by considering cantilever beam and different loads. Other beams are also being studied in this paper for the comparison with cantilever beam and understand their own advantages.

Beam theory has become a fundamental tool for analyzing structural elements that are subjected to transverse loads. We all know the Euler Bernoulli beam theory which connects relation between applied loads, internal shear forces, bending moments, stresses and deflections for slender structural members. Many structures textbooks provide the formulation for cantilever, simply supported and over hanging beams under various loading conditions which forms the analytical basis for understanding bending specified structural behavior. I believe that the importance of shear force diagrams (SFD) and bending moment diagrams (BMD) in clarifying the internal response of beams from several studies and textbooks are made clear and good explanations.

METHODOLOGY

This experiment explains how an element carries loads and how load affect the element under types of supports and loads. Cantilever and simply supported beams are used in this experiment to compare the types of loads which explains the beam's behavior with respect to the loads acting on the elements. This helps people perform experiments for efficient mechanical strength carrying elements for engineering applications.

Using the theoretical and numerical applications to solve these experimental trails and to compare the best out of these elements and to see the behavior of the elements with respect to the loads. Ansys static-structural is used in these experiments and theory to find the graphs for efficient element with respect to the same magnitude force acting on different beams. The new generation engineers suffer with the trail and error methods that used to find the efficient beam for constructions in mechanical and civil engineering fields making their efforts in investing in the time to find this efficient calculations and graphs in comparison with different beams.

This helps the journals, researchers to make sure that these beams are particular and only used for these particular engineering applications in daily life. Both the beams are compared with point and uniformly distributed loads and the different beams are cantilever and simply supported beams.

A rectangular geometry beam is built in Ansys geometry with the dimensions of length 1 meter, breadth of 0.1 meter and width of 0.01 meter.

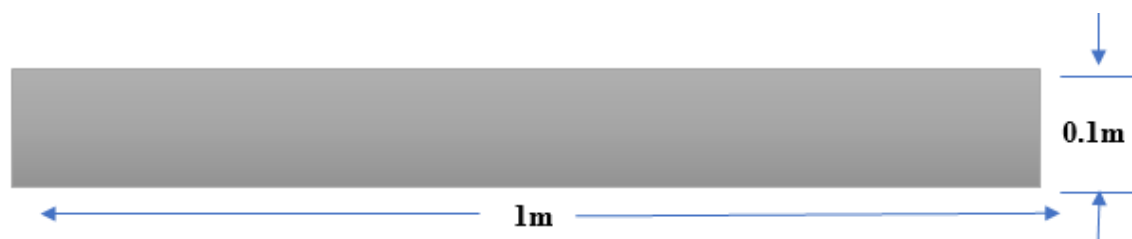


Fig a: Dimensions of beam considered in the experiments.

1.1. Cantilever Beam

We know that beam is a structural member which takes the transverse loads, bending loads and bending moment perpendicular to the axis of beam. When one end of the beam is fixed and other end is free, where we can add loads at the free end to check the bending moments and shear forces acting. Here we perform the experiment where cantilever beam undergoes both point loads and uniformly distributed loads (UDL). Understanding in both analytical and numerical methods to compare the graphs of bending moment and shear forces with respect

to point and uniform distributed loads. Though the cantilever beam deflection is graphically different compared to point load and UDL, unless the deflections are plotted on graph, or huge and measured precisely, we generally see a common smooth deflection in cantilever beam with respect to the point and UDLs, this is because the boundary conditions and loads are same to the different loads acting.



Fig b: A simple cantilever beam representation.

The precision comes in the graphical and tabular data which tell us the concentrated strain energy in the point load whereas distributed strain energy in the UDL.

An aircraft wing behaves like a cantilever beam, study and analysis of a cantilever beam from basic bending moment, reactions and shear forces can help to understand and solve the problems and analysis of an aircraft wing. Since the aircraft wing spars are acting like a cantilever beam within wing standing tall rather lying flat, we would see the particular load bearing and load bends the beam about the strong axis.

1.2. Overhanging Beam

An overhanging beam is a combination of a simply supported beam and a cantilever beam which is supported by roller supporter between two ends. At least one end of the beam projects beyond its support. Further continuing, we can simply understand it in this way that if it extends on one side then we call it single overhanging and extended both sides, then we call it a double overhang. We can see the difference in bending moments, as in this beam case, unlike a simple beam which bends downward generally when loads acted also known as sagging, but here overhanging beam experiences negative bending also called hogging at the

supports and positive bending called sagging in middle. Talking about the stability and deflection of overhanging beam, the weight on the overhanging part can actually help reduce the deflection at the main span between the supports by acting as a counterweight.

Considering the overhanging beam in this experiment for comparison is to find the structural efficiency and its point of contraflexure. We have learned that the bending direction changes from sagging to hogging, there is a specific point on the beam where the bending moment is zero found out to be the point of contraflexure. Over a cantilever beam, we commonly see this overhanging and simply supported beams in the general use and daily uses of life. And these are often more efficient than simple beams because they distribute the internal stress more evenly across the entire length. Most often in balconies, roof eaves and bridge decks where the road extends past the piers.

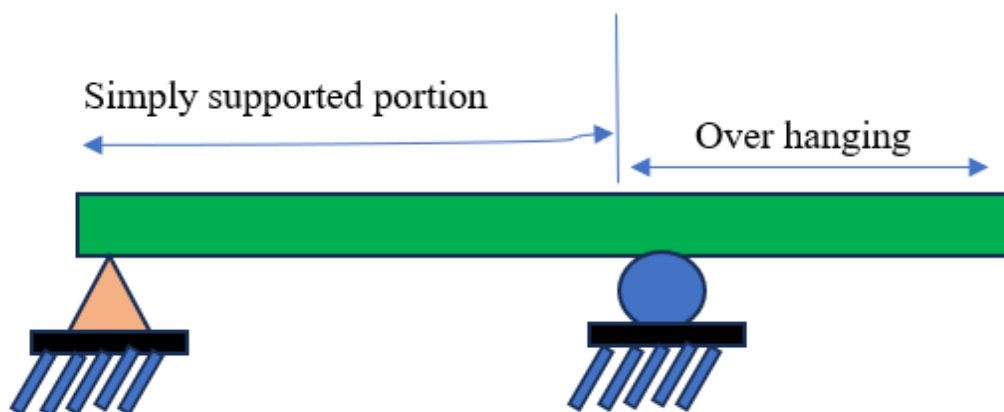


Fig c: A simple image of how an overhanging beam looks.

The overhanging beams under point loads, show two types of bending, middle – downward (sagging) and the near support – upward bending (hogging) as we discussed previously. And bending moments are positive in middle and negative near supports. The point of contraflexure is where moment is zero and curve changes its sign. Talking about the key observation is that load beyond support creates reverse bending. And the same beam under UDL loads, the bending is smoother curve and still sagging in center and hogging near supports. The bending moment is generally a parabolic and both positive-negative zones are the visible deflection takes. The key observation here is overhanging acts like counterweight.

1.3. Simply Supported Beam

The simply supported beam is a beam which is supported at both the ends which typically uses a pin and roller support. The beam can rotate at supports but cannot move vertically. The maximum bending moment occurs at the centre of the beam span. This type of beam distributes load between two supports, reducing stress concentration. The bending moment is zero at the supports and reaches maximum at the centre, while shear force is highest at the supports. While in simple design it is easy to analyse and install and the roller support allows the beam to move horizontally with temperature changes. The limitations of this beam is that it lacks capacity to resist high negative moments at the end.



Fig d: A simple image of how a simply supported beam looks

The simply supported beam under point loads generally acts at centre, beam bends smoothly downward, maximum deflection at centre and shape looks like a symmetric curve looks alike in U shape. And generally bending moment is maximum at centre, and zero at support, while the shape of BMD is triangular and deflection is smooth symmetric curve. Here the key observation load is concentrated and stress concentrated a centre. Whereas beam under UDL, beam bends more uniformly, while still max deflection at centre and curve looks smoother and wider. The tangible properties with bending moment is maximum at centre and parabolic distribution while shear force is linear variation. The key observation that we generally notices is load is spread and stress is distributed.

The more accurate results are seen in the below results section and conclusions are discussed.

2. Comparison of Beam Types

Here, in this study, we can see different types of beams are compared to understand the beams under various loads. Though all the beams are maintained the same geometry and materials, the way they are supported makes a big difference which results in different bending and deflections. As we discussed the cantilever beam is fixed at one end and free at the other, due to this, all the loads are taken by the fixed end. Because of this the maximum bending and deflection happens at the fixed ends. So, when the load is applied on the cantilever beam, it bends more as we move towards the free end while the maximum deflection occurs at the tip of beam. This is kind of similar to how an aircraft wing behaves in general physics, but naturally there are many loads and wing acts as simply supported and cantilever at points of wing sections.

The simply supported beam, which is supported on both the ends, when the load is shared between two supports, so the stress is not concentrated at one point like in a cantilever beam. Also, the beam bends downwards and the maximum deflection occurs at the center. The bending is more balanced and symmetric compared to the cantilever beam, due to this the simply supported beams are commonly used in bridges and building structures. Followed by an overhanging beam, which is slightly different and it is similar to a simply supported beam but extends beyond one or both supports. This causes extra length beyond support and beam shows two types of bending where one part bends downward just like a normal beam and the other part near the support bends upwards. This creates a change in bending direction, which is called the point of contraflexure. The overhanging part can sometimes reduce the deflection in the main span by acting like a counterweight.

One part bends downward like a normal beam, while the part near the support can bend upward. This change in bending direction is called the point of contraflexure. Sometimes, the overhanging part can even reduce the bending in the main span by acting like a counterweight.

From comparing all three types, it is clear that how the beam is supported plays a major role in how it behaves. Even if the same load is applied, the bending, stress distribution, and deflection will change depending on the support conditions.

In this experiment, all beams were tested with the same dimensions and loads. This helps make sure that any difference in results is only because of how the beams are supported, not because of size or material. The graphs and ANSYS results made it easier to see these differences clearly and understand which type of beam is suitable for different engineering uses.

3. RESULTS

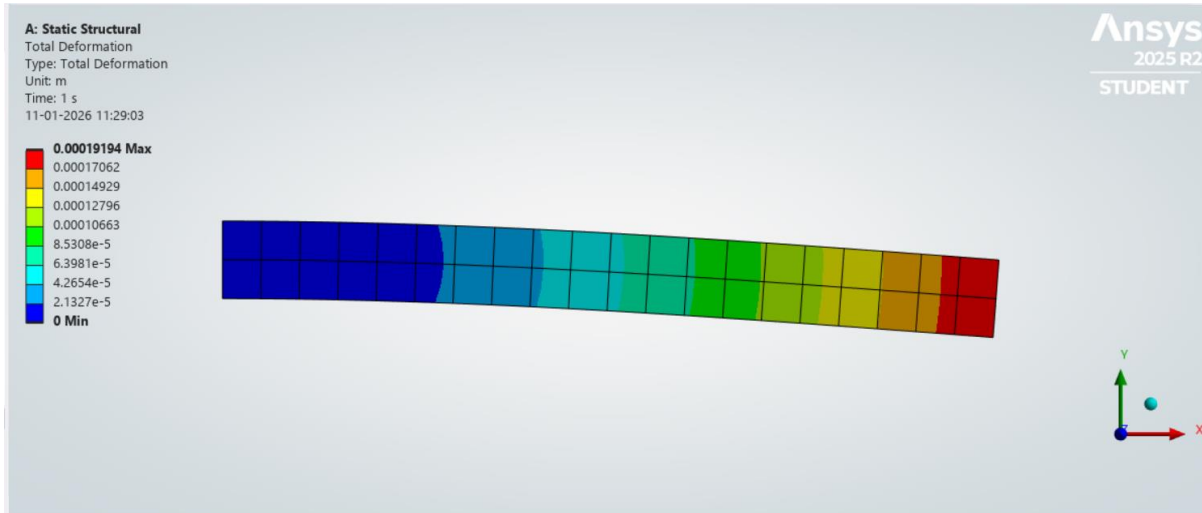


Fig e: Cantilever beam subjected to point load.

Maximum Deflection of cantilever beam with respect to point load on the free end of 100N.

Observation: the cantilever beam with the point load has a deformation of linear bending.

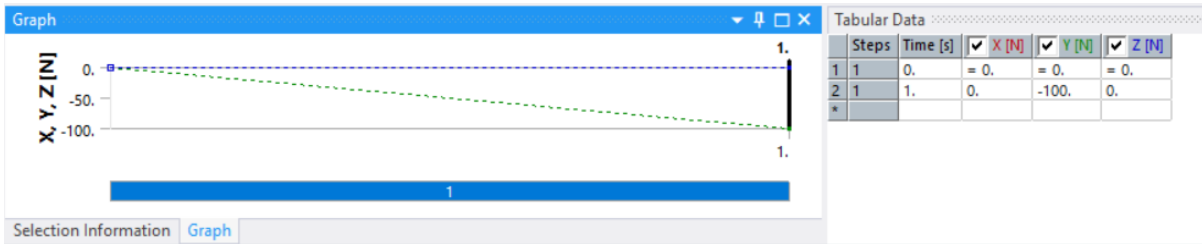


Fig f: Bending Moment Diagram – Graphical Representation. (linear graph)

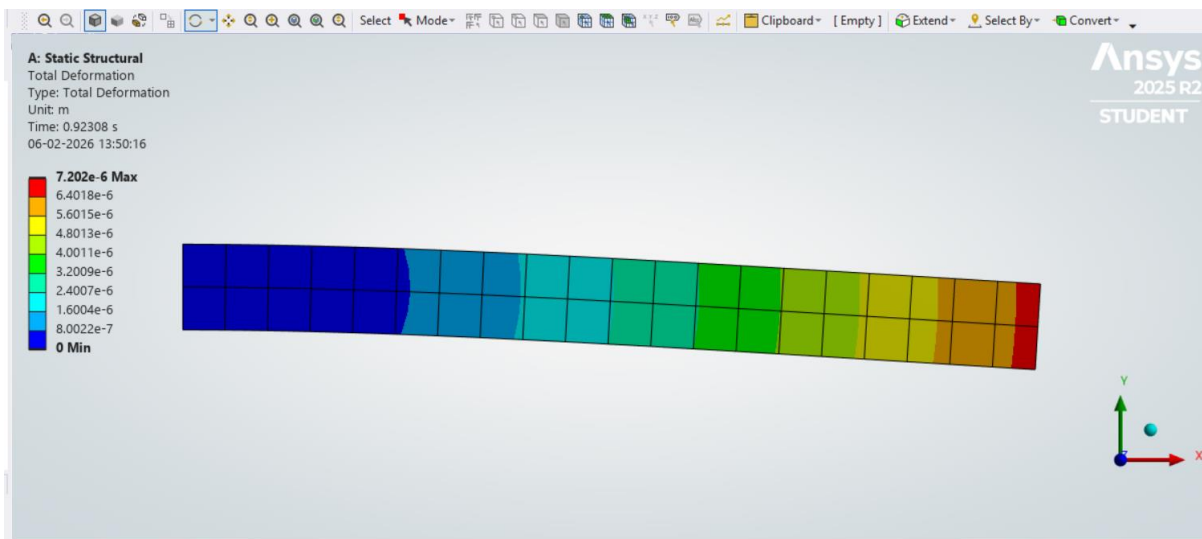


Fig g: Cantilever beam subjected to UDL.

The cantilever beam here provided with the uniformly distributed load

Observation: The cantilever beam with a UDL would result in the beam deformation of parabolic bending.

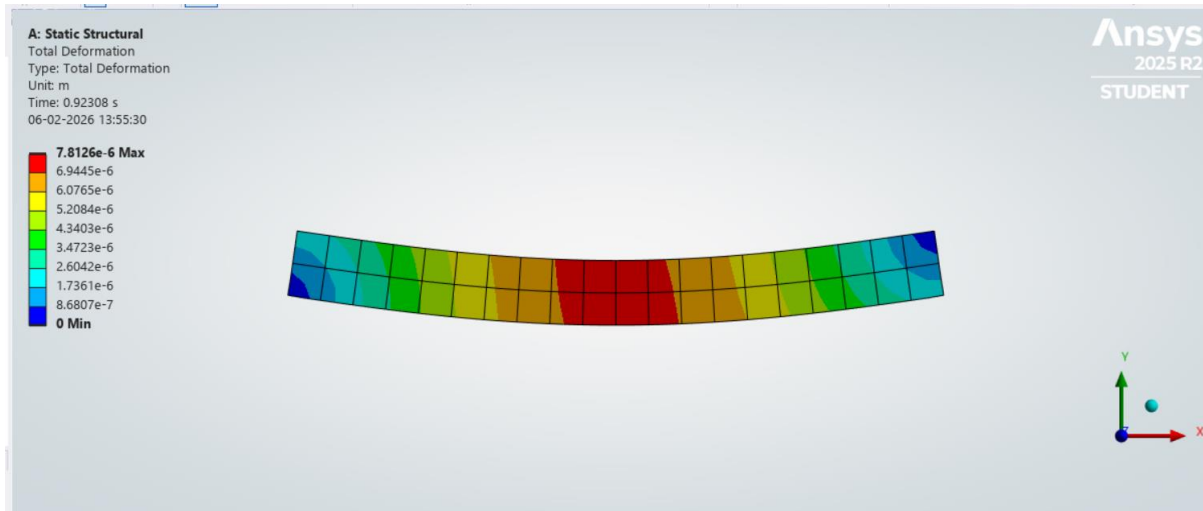


Fig h: Simply supported beam subjected to point load.

4. Application to Aircraft Wing Spar

The basic behavior of beams can be easily connected to how an actual aircraft wing works. In simple terms, the wing spar behaves like a cantilever beam, where one end is fixed to the aircraft body and the other end is free. The lift generated by the air acts along the length of the wing, just like a distributed load on a beam. Because of this, the highest stress is always seen near the wing root, since that part is carrying the load of the entire wing. As we move towards the tip, the load reduces and the bending becomes less, but the deflection increases, meaning the tip bends the most.

By studying these beam cases, it becomes easier to understand how a real wing behaves under different loading conditions. This gives a strong basic idea of how the structure responds, and it also helps as a starting point before going into more detailed analysis using tools like ANSYS or other advanced methods.

5. CONCLUSION

The conclusion states that the cantilever beam with the point load and cantilever beam with UDL would show similar deformation when visualized through animation, yet the graphical representation is differed by reproducing linear graph for point load and a parabolic graph for the UDL. In the Simply supported beam, the point load and uniformly distributed loads are

visualized same deformation because of the dimensions and the common mass acting on them. The deformation seen different unless the dimension is too huge.

When we look at the cantilever beam in the simulation, both the point load and the uniformly distributed load (UDL) seem to bend the beam in a very similar way at first glance. In animation, both cases show a smooth downward curve from the fixed end to the free end. Because of this, visually it may feel like both loads are producing the same type of deformation.

But, when we study the graphs more carefully, the difference becomes clear. In the case of a point load, the bending behaviour follows a linear pattern in terms of how the moment changes along the length. But when the load is distributed (UDL), the bending moment changes gradually along the beam, forming a parabolic pattern. So even though the shape looks similar to the eye, the internal behaviour of the beam is actually different.

For the simply supported beam, something similar happens. Under both point load and UDL, the beam bends downward and the maximum deflection appears near the center. Since the beam size is small and the loads are not very large, both cases look almost identical in the animation. It becomes difficult to visually notice the difference between the two types of loading.

The real difference only becomes noticeable when either the dimensions of the beam are increased or the loads are significantly higher. In such cases, the deflection curves and bending behaviour start to clearly differ. So, for smaller models or normal loading conditions, visual observation alone may not be enough we need graphs and calculations to truly understand how the beam is behaving.