Basics of Mechanical Engineering-1

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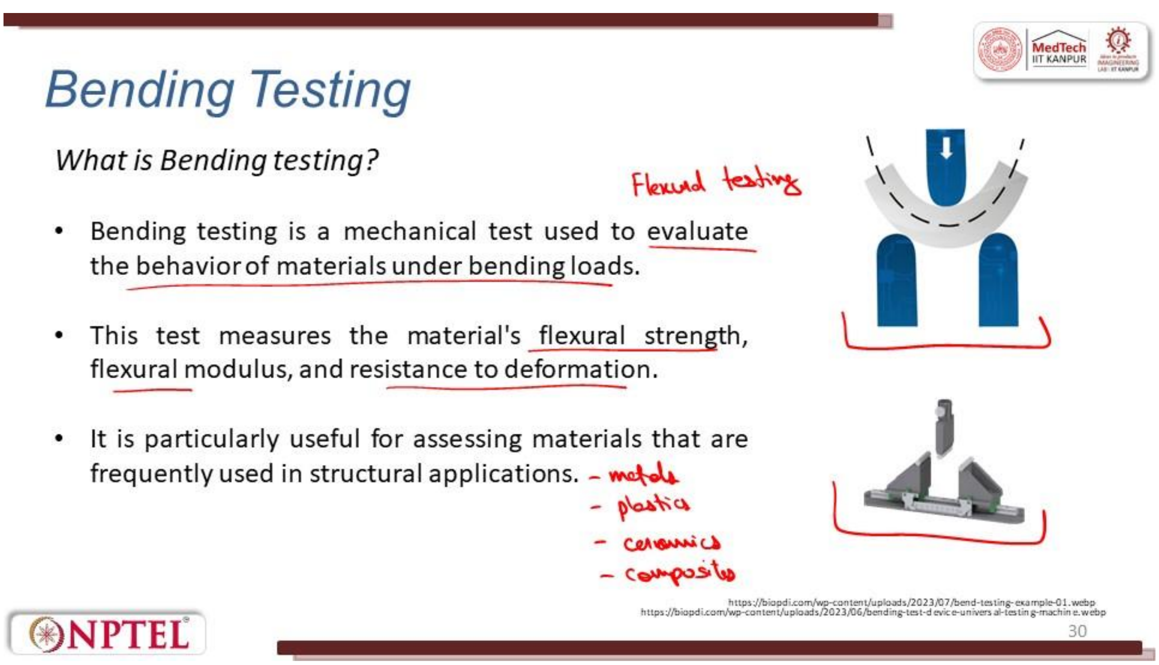
Week 09

Lecture 37

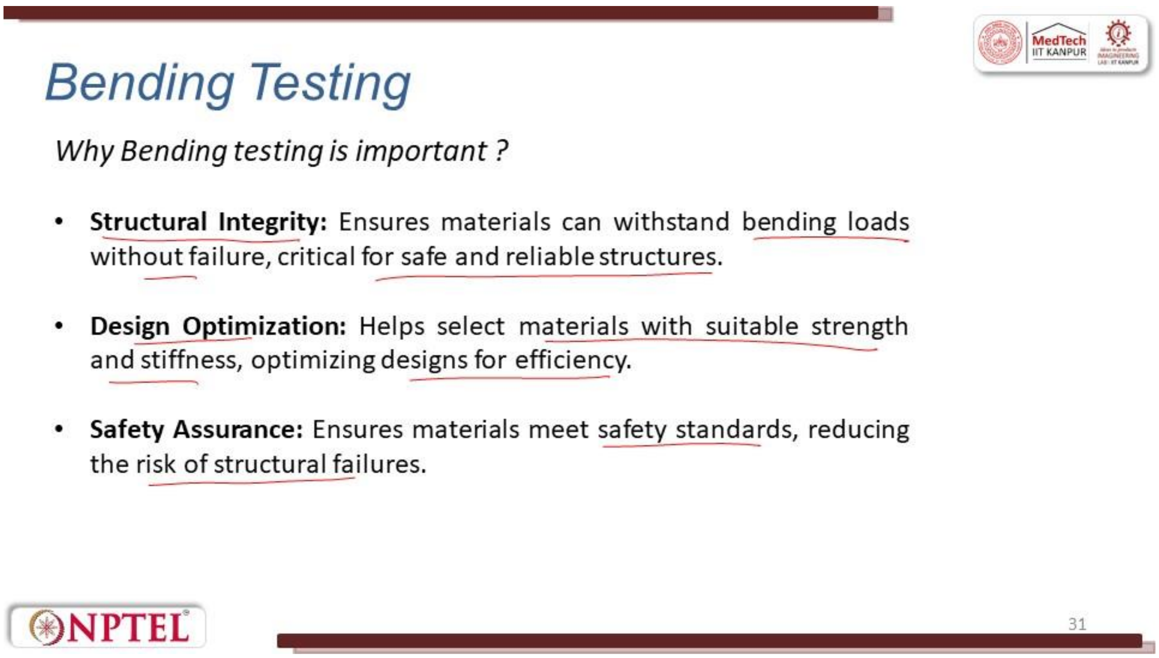
Testing for bending

Hello friends, welcome to the next lecture in the lecture series on Testing in Solid Mechanics. We have discussed in detail about the tension test, about the compression test in the last two lectures. I will talk about Testing for Bending in this lecture. This is course Basics of Mechanical Engineering-1 which is quoted by Prof. J. Ramkumar and Dr. Amandeep Oberoi. I am Amandeep.

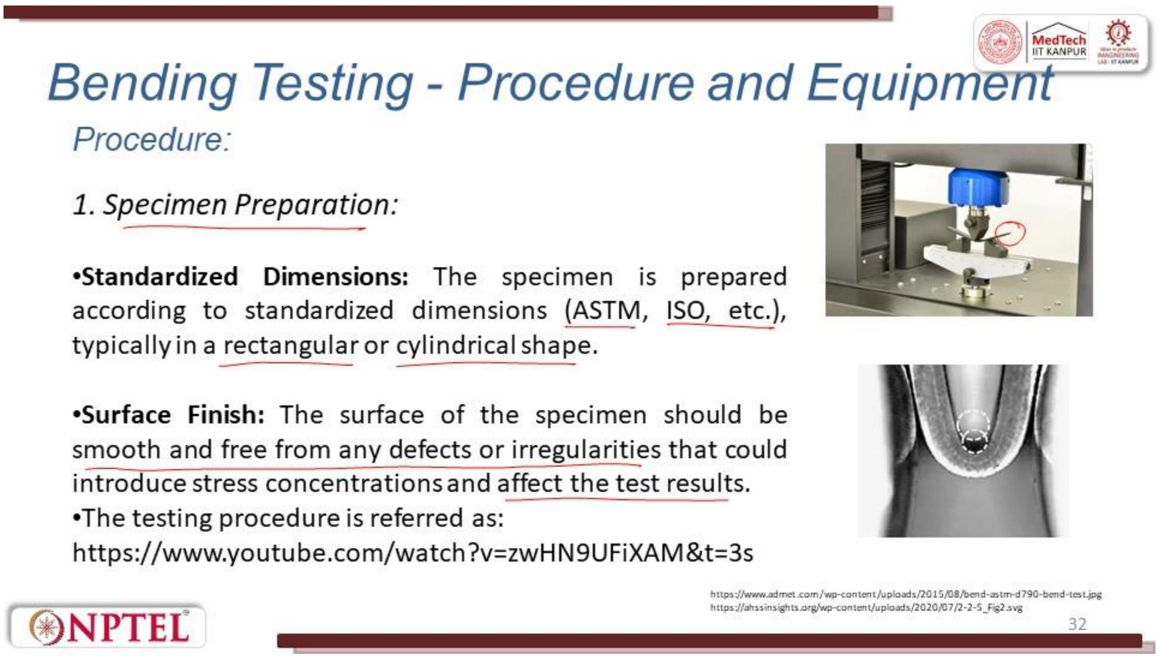


Here, let us try to see first what is Bending Testing. Bending testing is a mechanical test used to evaluate the behavior of materials under bending loads. So, this test measures the materials flexural strength and resistance to deformation. So, that is why it is also known as Flexural testing. It is particularly useful for assessing materials that are frequently used in structural applications.

Materials, it could be metals, it could be plastics, it could be ceramics or even composites. We will talk about how this test is conducted. This is a specimen holding area.

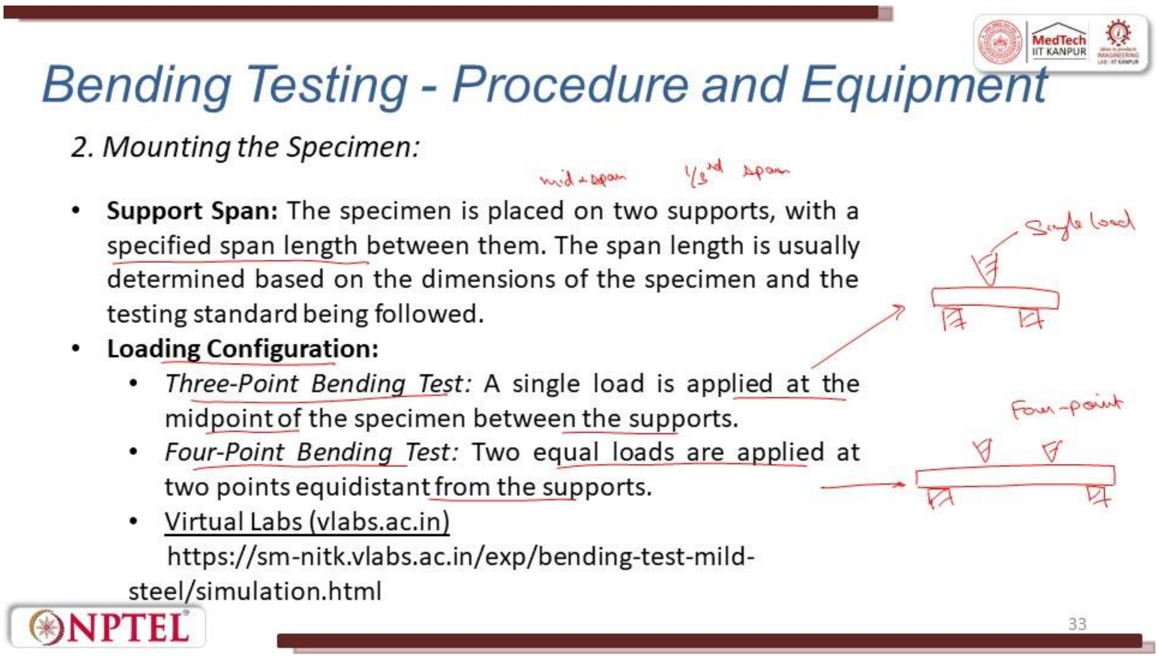


Why Bending test is important? First point is for Structural integrity. It ensures materials can withstand bending loads without failure critical for safe and reliable structures. For Design Optimization, it helps to select materials with suitable strength and stiffness optimizing designs for efficiency. Safety Assurance, it ensures materials meet safety standards reducing risk of structural failures. Now let us now try to see the Procedure for Bending Testing.



First step is Specimen Preparation. Standardized Dimensions again based upon certain standards ASTM or ISO standards are there based upon which the specimens are majorly here rectangular, it could be cylindrical depending upon the test that we are conducting. This is a rectangular specimen, it could be a cylindrical specimen, the demonstration that I will show you in the virtual environment would be a specimen that is a round shape that is a cylindrical specimen would be there.

Then we have Surface Finish. Surface Finish of the specimen should be smooth and free from any defects or irregularities so that it does not introduce any stress concentrations and does not affect the test results. So, there is a YouTube video. I will show you the video. Let me go through the procedure first.



Mounting the Specimen, there is a Support Span. So, it could be mid span or it could be one by third span when I am talking about the three point test or three point bending test. Specimen is placed on two supports with a specified span length between them.

The span length is usually determined based on the dimensions of the specimen and testing standard being followed. So, it depends whether the specimen that we are selected for the testing is very thin or is it very solid and thick one. So, if it is a heavy specimen, the span length could be If it is a small specimen, spare length could be smaller. So, there are generally two configurations of loading. First is Three-Point Bending Test.

A single load is applied at the midpoint of the specimen between the supports. For instance, it is something like this. This is our specimen and a single load is applied here. This is called as Three-Point Bending test. Then comes a Four-Point Bending test.

Two equal loads are applied at two points equidistant from the supports. So, here what we have specimen is there which could be it is a landier and load is applied at two equidistant places. So, this is Four-Point Bending test. We will go through the simulation video as well.

Bending Testing - Procedure and Equipment

3. Application of Load:

- **Controlled Loading Rate:** The load is applied at a constant rate, as specified by the testing standard. The rate is controlled by the crosshead speed of the testing machine.
- **Data Recording:** The testing machine records the applied load and the corresponding deflection (bending) of the specimen continuously.

Application of Load is the next step. Controlled Loading Rate. The load is applied at a constant rate specified by the testing standard. The rate is controlled by the cross-head speed of the testing machine. Generally, it is universal testing machine that is used here. Testing machine records the applied load and corresponding deflection that is bending of the specimen continuously.

Bending Testing - Procedure and Equipment

4. Data Collection:

- **Load-Deflection Curve:** The recorded data is used to generate a load-deflection curve, showing the relationship between the applied load and the specimen's deflection.
- **Elastic and Plastic Deformation:** The curve indicates the elastic region (linear part), where the material deforms but returns to its original shape when the load is removed, and the plastic region (non-linear part), where permanent deformation occurs.

Then we collect the data that is data collection becomes the next step where Load-Deflection Curve is plotted, the recorded data is used to generate a load deflection curve showing the relationship between applied load and specimens deflection. Then we get the Plastic and Elastic grains, the plastic region is one that is non-linear part, the elastic is one that is linear part this you know already.

Bending Testing - Procedure and Equipment

5. Analysis:

- **Flexural Strength:** The maximum stress experienced by the material at its outermost fiber, calculated using the load at failure, the span length, and the specimen dimensions.
- **Flexural Modulus:** The slope of the linear portion of the load-deflection curve, representing the material's stiffness in bending.
- **Failure Characteristics:** Examination of how the material fails, whether by cracking, breaking, or yielding.

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Then what are the certain analysis that we get from this testing? First is the flexural strength, the maximum stress experienced by the material at its outermost fiber calculated using the load at failure, the span length and the specimen dimensions that is flexural strength. Then comes flexural modulus, the slope of the linear portion of the deflection curve.

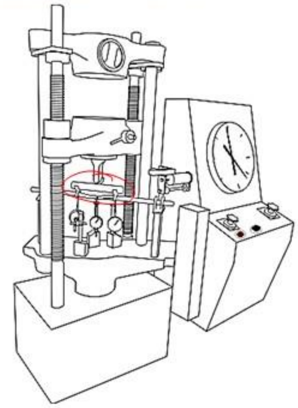
Representing the materials stiffness in bending that is Flexural Modulus. Then comes failure characteristics such as how material fails whether by cracking by breaking or yielding, this all is test here and is analyzed here. The setup is similar to what we had in the tensile and the compression test only the difference would be the loading system here would be different, I will show you that in the video there are three dial gauges which are attached here and this is a three point loading.

Bending Testing - Procedure and Equipment

Equipment:

1. Universal Testing Machine (UTM):

- ***Load Frame:*** The main structure that supports the specimen and the loading mechanism.
- ***Crosshead:*** The movable component that applies the load to the specimen.
- ***Load Cell:*** A device that measures the force applied to the specimen with high accuracy.
- ***Bending Fixture:*** The fixture includes supports and a loading nose (for three-point bending) or loading noses (for four-point bending).



https://sm-nitk.vlabs.ac.in/exp/bending-test-mild-steel/simulation.html

We have a load frame in a Universal Testing Machine. We have a cross head that is movable so that the component applies load to the specimen.

We have a load cell that measures the force. We have a bending fixture. This fixture depending upon three point or four point is designed differently. This includes supports and loading nose.

Bending Testing - Procedure and Equipment

2. Deflection Measuring Devices:

- *Dial Gauge or LVDT (Linear Variable Differential Transformer):* Measures the deflection of the specimen during the test.

3. Temperature Control:

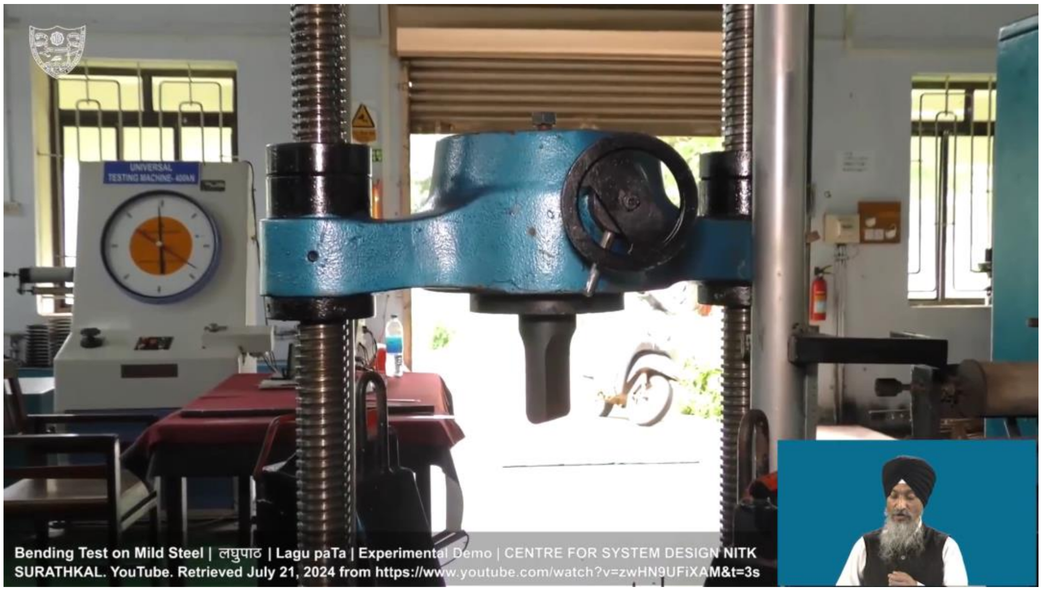
- Environmental Chamber: Used for testing materials at different temperatures to simulate real-world conditions.

4. Safety Enclosures:

- Protective Shields: Ensure the safety of the operator by containing any fragments if the specimen fractures violently.

Then we have the dial gauge or LVDT, which measures the deflection of the specimen during the test, temperature control, environmental chamber.

If it is a demanding test that is under a specific temperature, we need to sometimes conduct a test at different temperatures. These temperatures could be high temperatures or maybe very low temperatures, up to maybe minus 60 degrees or so. So the Temperature Control System is used for testing materials at different temperatures to simulate real world conditions. Safety Enclosures are always there when we have a temperature control system, safety enclosures are used so that the fragments of the specimen does not harm the operator. Now, let us watch a video on how this test is conducted, then we will go through the simulation part of it.



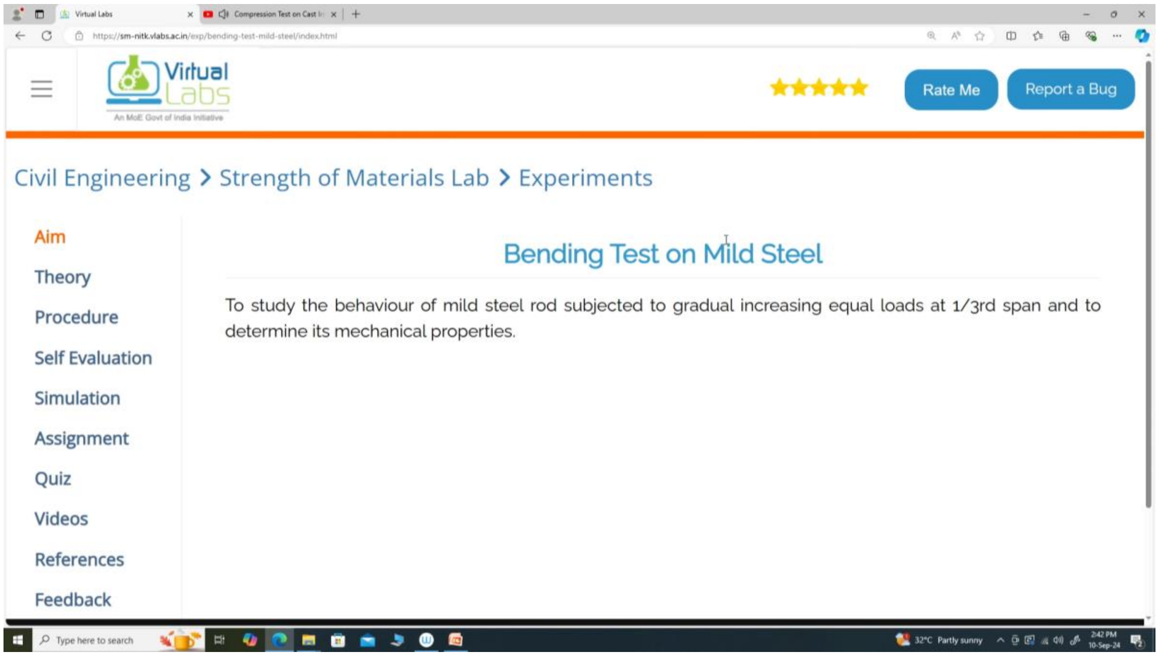
This is a video that is developed by the Centre for System Design, the engineers who have developed the virtual laboratory as well for these kinds of materials that I am using for the demonstration, the simulation as well.

So, this is a video on the bending test. So, this is the experimental setup where the objective is to study the behaviour of mild steel rods subjected to gradual increasing equal loads at one-third span and to determine its mechanical properties. So this is you can see a mild steel rod specimen is there that is a long specimen and here the length is 690. We first measure the initial diameter in two perpendicular dimensions.

In two perpendicular directions it is measured and average is taken, then we measure the length and then we mark the specimen for the middle point and the other two points to keep the span at mid span and one by third span. So, here L is 690 mm. So, one-third loading points and the mid-span where the dial gauge has to be placed, this marking is in. This is our bending fixture which has the setup so that the load is applied at the one-third span. Now, dial gauges are also put down there exact at the points where those were marked.

So, there is one dial gauge at the mid span and two dial gauges are there at the one-third spans. So, three dial gauges are now being set here. Now, we will adjust the dial gauge readings to zero and we switch on the machine. Once this machine is switched on, a gradual loading is done. You see the one-third span and the mid-span dial gauges are showing the reading and also there is a load that is being applied here.

So once the specimen is bent now, we stop the experiment and we plot this total load versus dial indicator and we theoretical deflection and average dial reading is also plotted. So that we see what is theoretical and the actual calculations. Then we finally see the diameter model of elasticity, stress at yield point, all these are calculated and we try to finally get the bending modulus. That is we try to get the flexural modulus of our specimen. This was a demonstration video.



Now let us try to see the simulation. This is a virtual laboratory setup where strength of materials experiments bending test on mild steel experiment is opened and we can see the aim is given here to study the behavior of mild steel rods subjected to gradually increasing loads.

It is gradually increasing loads, it is one-third span to determine the mechanical properties. So, theory part is completely given here that we have discussed in the previous lectures. It is the three-point test and this is how we calculate the yield stress, how do we calculate the deflection with respect to A and all these parts you can further go through when you visit this website.

So, let us try to see whether how ready are we to conduct the bending test. So, there are questions here for self-evaluation. In bending test on mild steel dial indicators are used to?

The answers are find force applied, find value of stresses, record the value of deflection and none of these. We need to record the value of deflection, I will mark C as the answer to dial indicators will record the deflection. Then, type of support used to fix the specimen in the bending test on mild steel is, what kind of spot is there? The support that is given is a roller support.

When simply supported beam is subjected to center concentrated load W, then load W occurs at center with value of WL/6 and WL/6 R3/58 x EI, both maximum bending moment and maximum reflection occurs at central cross section. This is correct. The B answer is correct here.

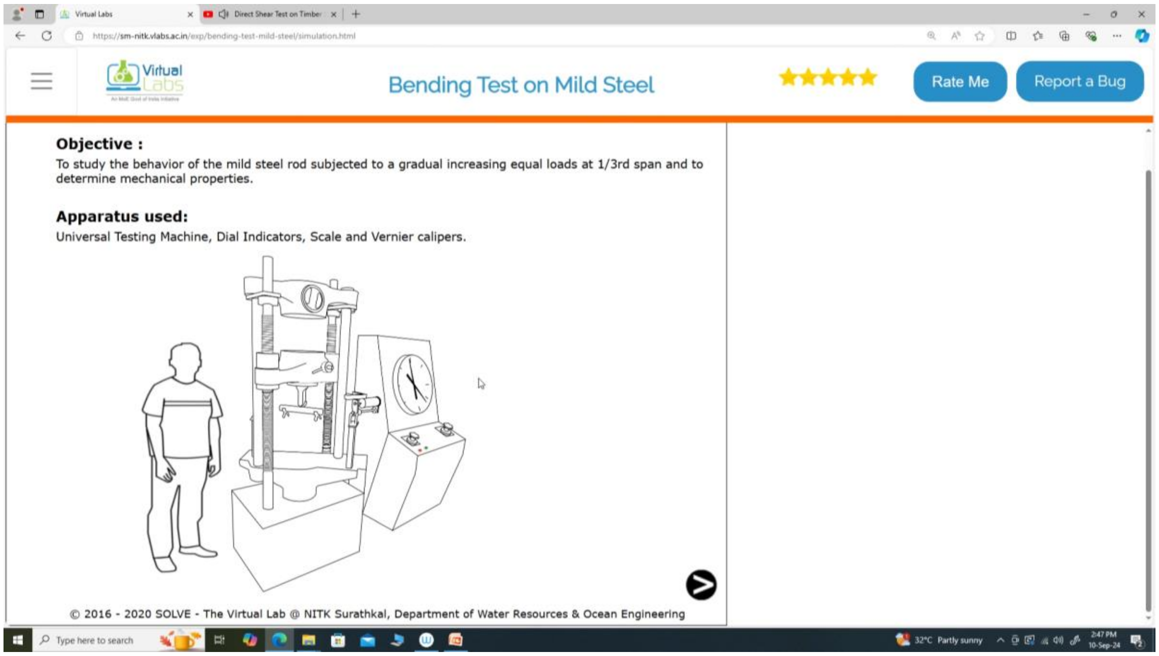
Then the next question is, as compared to uniaxial tension or compression, the strain energy stored in bending is only 1 by 3rd. In simple bending theory, one of the assumption is that material of beam is isotropic assumption means that elastic constants are same in all directions.

So material is isotropic means in all directions, the elastic constants are same. Next question is pick up the correct assumption of theory of simple bending, let us see what assumptions they have given the resultant. Pull or thrust on transverse section of beam is zero. Material of beam is homogeneous and isotropic. Next point is transverse section of the beam remain clean before and after bending.

I think all of them are correct. Yes, all of them are correct. Let us try to mark all of the above are correct. Rod is loaded in tension and pulled until it separates into two pieces. It is described as fracture rather than rupture.

So when it is separated into two pieces, they say it is fracture. No, we should say it false. Let me submit the quiz. 7 out of 7, all the questions are correct. So please go through the quiz time and again.

If you do not mark any answer correct, you can maybe re-answer that because we can submit the quiz multiple times. Then we will go through simulation. In the simulation, let us go through the steps.



Here is the apparatus that is used. So, this is the practice that is used as a fixture already that is here for the bending test, this is three point bending test fixture is there and these are all the parts of the universal testing machine, the cross head, the frame and everything is here.

The first step is we click on the rod and I measure the diameter of the rod using vernier caliper at two points. I move the moving jaw of the vernier caliper and measure the diameter here. So, diameter is 26. Again, we will measure it. I will click it and measure the diameter at another point it is 25.2.

So, average diameter is 25.6 based upon the diameter that is given, I calculate the cross section area that is pi d square by 4 and I calculate the movement of inertia that is pi d power 4 by 64. So, these are the values 514.72, 21072.18. Now, I need to measure the length of the specimen. Length of the specimen is measured using a scale. Then I mark the pointers where the dial gauges are to be mounted or to be contacted with so that the mid span and one-third span is given.

The length is 690 millimeters because the machine that we have here is having limitation to hold the specimen of 690 millimeters maximum. So, this length is marked here. Next step, that is step four, we insert the specimen between the special two-point loading setup with the roller supports, which is being fixed on the lower crosshead of the universal testing machine, adjust all the dial gauges to zero. So let us now fix the specimen here and mount the dial gauges. We set the dial gauges readings to zero as we did it in tension, as we did it in the compression test as well.

Then we'll start the machine and you'll start observing the loading here. So load is being applied the total load dial gauge at mid span is changing here this is dial gauge at mid span point a and point p are one third spans, so both of the points are there we take average of the two points and the loading is happening gradually here. These loads are equal loads. You see 40, 80, 120, 160, 200. It is an increment of 40 kg of the load and this is an equal increment of the load.

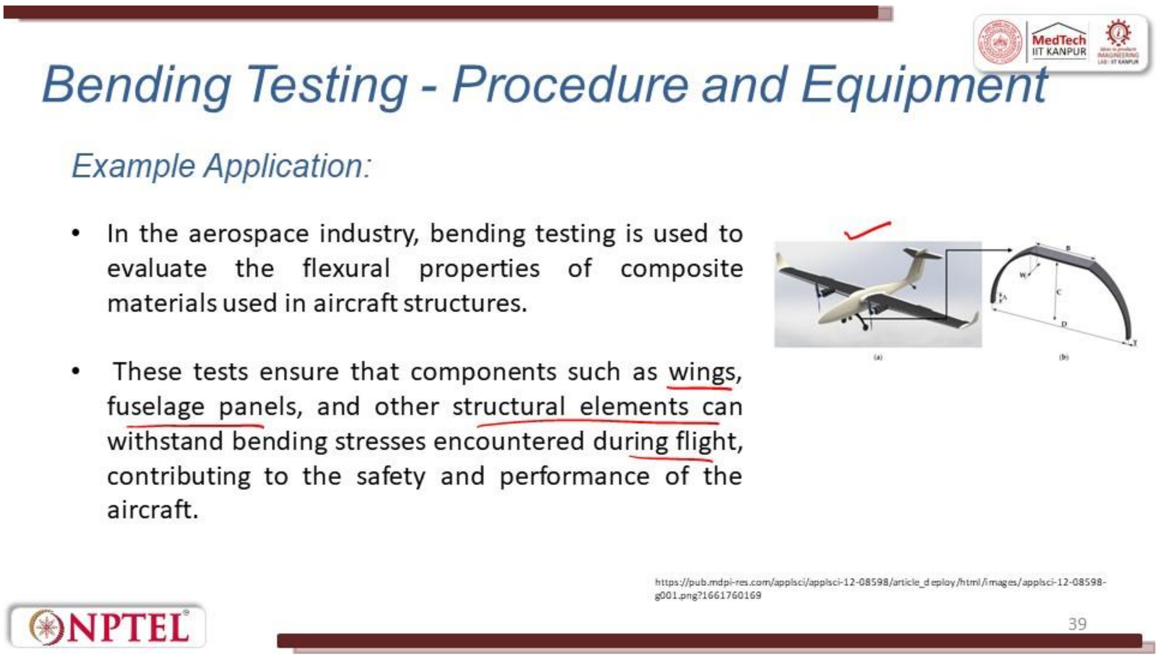
This was also set in the aim or objective of the experiment. Now they say click on the red button to stop the loading process. We stop the loading. Yes, the data is now ready. We can download the data.

You can see the data is downloaded into the excel sheet using this data. Now we can plot our graphs. You see the material is bent here. This is the rod that is bent here. Now we plot total load versus dial indicator reading that is load versus deformation at mid span and we see at this point some around till 640, the line is constant straight line; then only change bending comes here.

So, that is this point elastic deformation is here and then plastic deformation comes, we can also do the slope delta y delta x, we can calculate yes it is showing that yield point is here. Graphical yield point has been gotten here. We can also calculate the yield point. Now, next step is average dial reading versus vertical deflection. So, similarly, we will plot this line, vertical deflection and average dial reading.

Let us see the slope for this as well. Now, we need to calculate the moment of inertia about neutral axis stress at yield point and modulus of elasticity given the diameter of specimen span of the beam slope of deflection plot. I am not calculating it here because I am recording a video, each time you will get a separate reading because this is a simulation, in simulation there is a backhand where random numbers are there and those numbers would be picked based upon the range of the different forces which are there for the specific material. For the specific diameter and this length of the material for the mild steel, small changes will still come in realistic environments to simulate that realistic environment into the simulation, into the virtual environment. Each time you will get different numbers when you conduct or when you go through the simulation, you have to calculate these on the spot.

So, that is how you put the values here, the formulas are also given here, it is moment of inertia about the neutral axis, I is equal to pi into d power 4 by 64 then stress at yield point is m into y by I, then we have modulus of elasticity that is E is equal to 23 into L cube into slope into 9.81 by 1296 into I, these formulas are given you just calculate the values put it here and check whether right or not. These are the correct values that would come. Here we did values that you have and would be displayed. So, this is how the experiment is completed.



Now, there are certain applications of the bending test as well. Here example applications which are given here in the aerospace industry, bending testing is used to evaluate the flexural properties of composite materials used in aircraft structures. So, bending test is a method employed by a genius to quantify the response of materials under direct beam loading.

This is primarily used for materials that encompass as I told polymers, composites even wood. Metals obviously are taken into test all the time. So, although commonly associated with brittleness, these materials are frequently rather ductile because bending we are talking about, we are not talking about how the material fracture, material could also fracture due to the brittle.

So, this enable their application in support structures such as skyscrapers, bridges, even big plastic objects like chairs, all of which encounter flexural stresses. So, in daily use, I am showing only example of the aircraft here.

There are components or the parts of the aircraft such as wings, fuselage panels and other structural elements can withstand bending stresses recorded during flight. So, this contributes to the safety and performance of the aircraft. So, bending test is conducted to replicate a very realistic loading scenario.

That is why we use three-point and four-point bending fixture which exerts stress through the distinct methods. So, based upon these specific criteria, material can undergo testing up to predetermined load or strain threshold or until the specimen experiences complete failure.

The measured properties of this material are flexural stress, flexural strain, flexural modulus, flexural off-shell yield stress and all those are calculated using this test. All those are then determined using this test. So, I have shown you the application of the bending test and how the bending test is conducted.

Now, I will go through the impact test in the next lecture and we will continue the series on the material testing.

Thank you.