16.001 - Materials & Structures

Unified Materials and Structures Lab 2

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Contents

1 Deflections of a cantilevered beam subject to concentrated loads

In this experiment, your group will be subjecting a cantilevered beam to concentrated loads at various points along the beam span and measuring the beam tip deflections. The purpose of the test is to verify beam theory discussed in class.

To this end, a 3' x 1/4" x 2" aluminum beam (6061) has been clamped at one end and supported against the strong back in the hangar. At the other end, a scale has been rigged to measure deflections in mm. Before starting the test, make sure you confirm the "zero deflection" or reference point. Note that due to the influence of the distributed beam weight, this may not coincide with the zero of the scale.

Divots have been drilled (close to) the end, and at the 1/4, 1/2 and 3/4 mark to hang the weights. In our test, we will only hang weights (1, 2, and 3 lbs) near the free end.

Procedure:

1. Confirm the dimensions of the beam by measuring them as accurately as possible with a caliper.

2. Measure the actual span of the beam from the built-in support to the location of the point of application of the load.

3. For each weight, get a reading of the zero deflection position of the beam on the scale to define your reference point. In this manner, you can ignore the deflections due to the weight of the beam.

4. Hang the weight placing the hook directly on the divot. Do this slowly to avoid dynamic oscillations of the beam.

5. Once the beam is completely settled, take a measurement of the deflection and tabulate the result.

6. Remove the weight and repeat the procedure 3 times. If you see variations, repeat the measurement 2 more times.

7. Repeat the complete procedure for the different weights.

Once you have the complete set of measurements, create a spreadsheet with the tabulated values and add a column with the tip deflections predicted by the theory (you will need to obtain the analytical solution for this problem, please add an appendix to your report with the derivation). Compare theory predictions with test measurements and comment on sources of discrepancies, including an estimation of the magnitude of experimental errors, simplifying assumptions in the theory that might differ from the test. Write a concluding statement on the value of the experiment in validating the theory.

2 Measurement of buckling loads in a slender beam subject to uniaxial compression

In this experiment, your group will be provided a very slender rod made of carbon fiber reinforced polymer (CFRP) composite and attempt to measure the buckling load.

Procedure:

1. Take measurements of the dimensions of the rod. You will need a caliper to measure and confirm the lateral dimensions.
2. Place one tip of the rod on the scale which will be lying on the ground (make sure it reads zero).
3. Orient the rod as vertically as possible and apply a vertical load. This can be done with your bare hand or with a hard surface (a small plank of wood or metal plate).
4. As you increase the load, you can read the applied value on the scale.
5. At some point, you will notice that the rod will buckle sideways and the load will cease to increase. If done carefully and slowly, you will notice that as you continue to push down the reading on the scale varies minimally. Record the value of the load right at the time it ceases to increase.
6. Slowly continue to push down and record any variations of the load.
7. Repeat the test 2 more times.
8. After you are done, repeat the complete procedure but making the following change to the configuration: While one member of the group exerts the load as before, another one grabs the rod as close as possible to its mid-span preventing the lateral motion of that point of the beam. This will try to capture the second buckling mode.

Obtain the theoretical value of the buckling load and the mode shape for the rod taking into account the value of the Young's modulus (the value will be provided once the course staff measures it), the measured dimensions of the bar, and the type of boundary conditions that apply to each test.

In class, we will see that the expression for the theoretical value of the buckling load P_{cr} for a simply-supported column as shown in Figure 1 is given by

$$P_{\text{cr}} = \frac{n^2 \pi^2 EI}{L^2}$$

where $n = 1, 2, \ldots$ is the index of the buckling mode, E is the Young's modulus of the beam, I is the constant moment of inertia of the beam's cross-section, and L is the length of the beam. The corresponding mode shape is

$$\bar{u}_2(x_1) = A \sin\left(n\pi \frac{x_1}{L}\right)$$

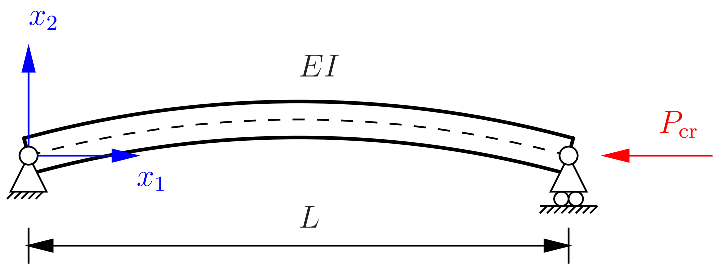

Figure 1: Simply-supported column buckling in mode $n = 1$ due to the compressive force P_{cr}.

where A is an undetermined deflection magnitude.

Once you have the complete set of measurements, create a spreadsheet with the tabulated values, and add a column with the value of the buckling load predicted by the theory for this problem; please add an appendix to your report with the derivation. Compare theory predictions with test measurements and comment on sources of discrepancies, including an estimation of the magnitude of experimental errors and simplifying assumptions in the theory that might differ from the test. Write a concluding statement on the value of the experiment in validating the theory.

This test will take place simultaneously with the beam deflections test, see above.

3 Deliverables

Please write up a report containing the following items:

1. Description of the beam bending test, measurements taken in tabular and graphical form, theoretical calculations of the cantilevered beam deflections under the applied load, and a comparison of theory and experiments. Comment on the differences and errors obtained, their magnitude and possible sources.

2. Description of the buckling load test, measurements taken in tabular and graphical form, comparison with the theoretical value of the buckling load. Comment on the differences and errors obtained, their magnitude and possible sources.

4 Logistics

The test will take place in the AeroAstro Building 33 Hangar (same location where you did the truss lab earlier in the term) on November 25^{th} and 26^{th}. The lab will be performed in groups of 5 people over the one hour period, with two groups present for each lab session. For the first half of the period, one group will perform the bending tests while the other will test the buckling of slender beams. Afterwards, the groups will switch, so that everybody obtains data for the two parts of the labs. The sign up link for the timeslots will be distributed soon by the TA.

The reports are due individually, they have to be printed and turned in into the bin of the unified lounge which has the appropriate label.