# MSL Lab Experiment # 4

# Beam Bending Experiment and Analysis

A) Reading Materials & Homework:

* Review beam bending in any Strength of Materials or Elements of Mechanical Design text.
* Homework HW#4: In this lab you will conduct 3-point bend experiments (see figure on page 2) on beams of rectangular cross-section with one dimension approximately twice the other. A ‘baseline’ test is first conducted in which the cross-section is oriented such that the beam’s height is one-half its width. By what factor does the central deflection increase/decrease if each of the following changes is made from the baseline case (consider each individually)?

 a. Load is decreased 8-fold

 b. Modulus of elasticity is increased by a factor of 30 the original modulus

 c. Beam length is increased 50%

 d. Beam is rotated 90o about axis along its length, so height is now twice its width

 e. Beam height is increased by 25% without any change in beam width.

B) Goals of this Experiment:

1. Understand basic steady stress beam loading process.
2. Apply a simple beam loading theory to practical applications.
3. Learn to use computer software package to predict deformation behavior of beams.
4. Understand the dependence between deflection and force, cross-sectional area, beam material and support separation distance.
5. Understand the importance of using a model with experimental backup for extrapolation to non-simple geometry.

C) Lab Experiment:

Several long beams with a rectangular cross section made from Polycarbonate and Aluminum alloy will be analyzed and tested under the following conditions. Use units of in. and lb.

## A Summary of Test Conditions (they will be negative and min. in the test)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Number | Material | Cross Section, 0.250 x 0.500 in. | Separation Distance, in. | Max. Load, lbs.  |
| 1 | Polycarbonate | 0.500 in. height | 4 in. |  10 lbs. |
| 2 | Polycarbonate | 0.250 in. height | 4 in. |  10 lbs. |
| 3 | Aluminum Alloy | 0.250 in. height | 4 in. |  10 lbs. |
| 4 | Aluminum Alloy | 0.250 in. height | 4 in. |  80 lbs. |
| 5 | Aluminum Alloy | 0.250 in. height | 6 in. |  80 lbs. |
| 6 | Aluminum Alloy | 0.500 in. height | 6 in. |  80 lbs. |

E=350,000 psi for polycarbonate and 107 psi for aluminum. Use cross-head speed of 0.1 in./min for the polycarbonate and 0.01 in/min for aluminum.

1. Measure actual cross-section of each sample. Place and secure the test sample in the Instron Machine bracket, as shown below in Fig. 1. Run the Instron Machine per instructions provided in class regarding load limits and use of the deflectometer. Record by hand all the data (cross-head displacement, displacement at the middle of the beam sample from the deflectometer/extensometer) at the maximum load from the registers on the Instron console, as well as throughout the loading using the data acquisition program.
2. Perform hand-calculations of beam deflection you expect using the actual measured cross-section dimensions. Compare these predicted values to those actually observed in the experiment. Which measurement (crosshead displacement or deflectometer/extensometer) is more near to these predicted values, and what is the source of error that makes the other measurement incorrect?


#### Figure 1- A simple beam bending experimental set-up

1. In each of the six cases, perform a hand-calculation of the tightest/smallest radius of curvature experienced by the beam’s neutral plane. What must the yield strength of the polycarbonate be, at least, to ensure all deflections in cases 1 and 2 remain elastic? What must the yield strength of the aluminum be for all deflections in cases 3-6 to be elastic?
2. Consider now the new wider beam made of aluminum provided and shown in Figure 2 below. The beam is uniform b=0.5” wide into page, but varying thickness h. (a) Place a downward acting center force; and then instead, (b) an off-center force (at the distance 1.8 in. from the left-hand end) with a magnitude of 300 lbs. downward (set the machine to a minimum of -300 lbs. and the loading rate to 0.01 in./min) and measure the beam deflection directly under the load. Note that beam provided has an overhang and small radii of curvature at the inside corners to avoid stress concentration; you will make the supports symmetric to the load and beam in part (a) at a distance of 5” (12.7 cm) [distances are scribed onto the surface of the beam]; in part (b), you have to move the supports increasing the right-hand support to a setting 6.4” (16.256 cm) [remember that the base is calibrated in cm support span of a symmetric placement; this second placement is asymmetric], and the left-hand support 3.6” (9.144 cm).

2.0"

1.5"

1.5"

0.5"

0.125"

0.125"

##### Figure 2 – Side view of the wider modified beam.

1. Create an Excel spreadsheet to compute the displacement, slope and stresses under the prescribed conditions shown above in Part C 1 using the following procedure:

(a) Create a column representing the axial position along the beam (x) in inches starting at the left support discretizing the beam length into 100 equal sized elements. Insert a data point just after the middle location of the beam at xmid, at position xmid+10-6 in, to capture the abrupt change in shear load at this location.

(b) Create a column of the shear load (V) in lbs, which is ½ the applied load until the middle of the beam, and then becomes -½ the applied load just past the beam center.

(c) Create a column of the bending moment (M) in inch-lbs by integrating the shear load using the trapezoidal rule and initiating the bending moment M=0 at x=0. Specifically, use the following relationship,



where the subscripts indicate the increment along the beam (row number in Excel). Verify that the moment is zero at each end and the correct value is in the center of the beam (within tolerance of calculation) to check your calculation.

(d) Create a column of (M/EI) in units of in-1. Use actual cross-section dimensions measured from your samples in computing I.

(e) Integrate M/EI along the length of the beam using a similar procedure as given in step (c) above to find the angular deflection  in radians. Since you don’t know the angular deflection at x=0, initially set it to zero. After integration, take the angular deflection computed at the center of the beam, and set the angular deflection at x=0 to be minus this value, and recomputed the angular deflection column. Now, the angular deflection should be zero at the center of the beam, which is correct because of symmetry.

(f) Integrate  along the length of the beam to find the displacement in inches. The deflection at x=0 should be zero, since this is the location of a support. Verify that the deflection at the end of the beam (the other support) is also zero (within tolerance of the calculation).

(g) Create a column of the maximum stress, at the bottom of the beam (y=-h/2), along the length of the beam.

Plot the displacement, slope, and stress vs. x. Do each of the 6 cases; printing the resulting plots and include them in the lab reports. Do the predicted central deflections match the theoretical hand-calculations?

1. Create a model in your Excel spreadsheet for the aluminum test sample as shown in Figure 2. Assume that the simple supports are located at the ends of the beam’s 5” length (neglecting the overhang). Predict and compare what the deflection of the test sample will be for this particulargeometry with the experiment done in Part 5.

Hint: For the case with the off-center load, you can no longer assume symmetry (angular deflection at the center equal 0). Just set the angular deflection zero at x=0, and recognize that the computed angular deflection will be off by a constant (i.e. , where  is the computed angular displacements and *K* is a constant). Then, the computed deflections will be off by *Kx* after integrating. Find *K* so that the deflection at the right-hand-side is zero and correct the displacement accordingly.

7. What are the stresses for the inside corners of the actual specimen; you will need to measure the radius of the inside corner and use a stress concentration factor (note that sharp inside corners are always to be avoided to prevent an infinite theoretical stress), what would the factor of safety be from the 0.2% yield strain at this corner?

8. Fully discuss all possible sources of error involved in this experiment and analysis.