# Bend Testing Cast Beams

## Equipment

| Qty | Description | Part Number |
|---|---|---|
| 1 | Materials Testing Apparatus | ME-8236 |
| 1 | Bending Accessory | ME-8237 |
| 1 | Structures Cast Beam | ME-6983 |
| 1 | Calipers | SE-8710 |

## Introduction

A Three-Point Bend Test is performed on Plaster of Paris cast beams as shown in Figure 1. As a downward force (F) is applied in the middle of the beam, the flex (Δx) is recorded. The ratio (F/Δx) is measured directly from the slope of the F vs. Δx graph, and is used to calculate the Flexural Elastic Modulus for the material. The maximum load force at fracture is measured, and is used to calculate the Modulus of Rupture.

*Figure 1: Three-point Bend Test*

This experiment uses the Cast Beams from the PASCO Structures System. You will need Plaster of Paris, and utensils like cups and spoons to mix the plaster. The beams need to be made before lab to allow them to cure. Typical cure times are from several hours to several days. You will also need a hacksaw to cut each beam to a length of about 10 cm, so they will fit between the drive screws.

# Theory

## Flexural Elastic Modulus

A test sample is supported by two anvils separated by a length (L) as shown in Figure 2. A load (F) is applied in the middle, an equal distance from each anvil, and the resulting flexure (Δx) is measured. The ratio (F/Δx) is the stiffness of the sample, and depends on the length. It also depends on the shape and area of the sample cross-section, as well as the material.

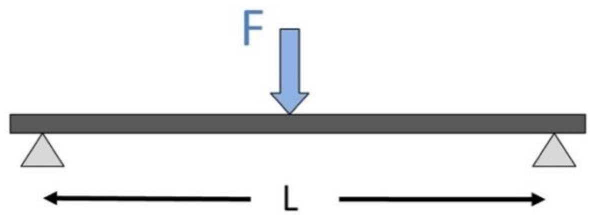



*Figure 2: Three-Point Bending Test*

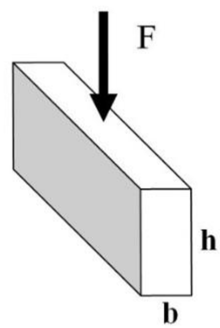
If "E" is the Flexural Elastic Modulus for the material, and "I" is the Area Moment of Inertia for the sample, then

$$\frac{F}{\Delta x} = \frac{48\,IE}{L^3} \qquad (1)$$

The Area Moment of Inertia depends on the cross-sectional shape and area of the sample. For a beam with a rectangular cross-section

$$I_{rectangle} = \frac{1}{12} bh^3 \qquad (2)$$

where the height (h) is the dimension that is parallel to the applied force, and the base (b) is the dimension perpendicular to the applied force, as shown in Figure 3. Combining, yields




$$\frac{F}{\Delta x} = \frac{4bh^3E}{L^3} \qquad (3)$$

## Modulus of Rupture

The bending stress at a perpendicular distance (y) from the neutral axis is given by the Flexure Formula,

$$\text{Bending Stress} = \frac{My}{I} \qquad (4)$$

For a rectangular beam the bending moment (M) at mid-span is 1/4 FL, and the perpendicular distance (y) is h/2. Combining with Eqn. (4) and Eqn. (2), yields

$$\text{Bending Stress} = \frac{3FL}{2bh^2} \qquad (5)$$

When the applied force (F) is the load force at fracture, then Eqn. (5) calculates the Maximum Bending Stress, which is also called the Modulus of Rupture.

## Setup: Making Cast Beams

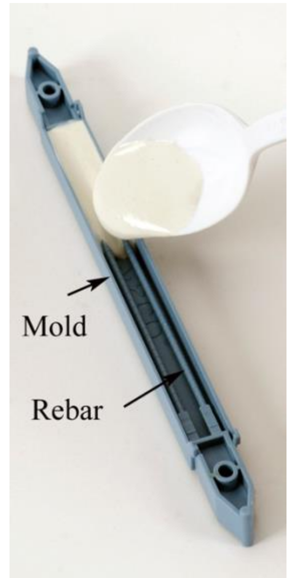



*Figure 3: Making Cast Beams*

1. Snap the rebar into the mold (see Figure 3). Pour all of the beams from the same batch. Tap the sides to remove bubbles.

2. Make several beams so that you can see how much the beams vary in strength. You can also allow some of the beams to dry for a longer time, to observe the effect of curing time on strength.

3. Do not remove the beam from the mold until the plaster is dry. Allow a cure time of at least a few hours.

## Setup: Installing Bending Accessory

You will probably want to make a Compliance Calibration (using the Calibration Rod) before attaching the Bending Accessory! A max force of 500 N is adequate for this experiment.

1. The ME-8237 Bending Accessory consists of two major parts: The upper load anvil and the lower base with the two support anvils. The load anvil sticks up through the cross-head and is held in place by the knurled cap nut. The base (for the support anvils) fastens directly to the load cell using the two cap screws as shown in Figure 1.

2. Each anvil is captured by the T-slot in the base, and their separation should always be adjusted so that the Load Anvil is centered between them. Use calipers to make this alignment as accurate as possible. Set the anvil spacing between 5 and 6 cm. Carefully measure the length (L) from the top of the camber on each anvil. You can also just measure between the vertical surfaces, and calculate L by including the 1.5 mm radius on each anvil. Record this value.

3. Cut the plastic ends from your cast beam, leaving a 9 to 10 cm length.

4. Measure the cross-sectional dimensions of the beam and record.

5. Place the beam across the support anvils as shown in Figure 1. Turn the crank counter-clockwise until the load anvil is ***almost*** touching the sample.

## Procedure: Taking Data

1. Connect the Materials Testing Machine to a computer using a USB interface. In PASCO Capstone, create a table and create two user-entered data sets: The first set is called Slope and has units of N/m; the second set is called Max Force and has units of N.

2. In PASCO Capstone, create a graph of Force vs. Position. Also create a Digits display and select Force.

3. Note: Your data will look better if you use the normal procedure to "seat" the test sample, but do NOT use a preload over 5 N: The force needed to fracture the beams can be less than 100 N!

4. Make sure the plastic Safety Shields are in place.

5. Click on Record and turn the crank counter-clockwise. Continue until the beam fractures, then click on Stop. It is not necessary to completely destroy the beam.

6. Repeat the procedure for the other beams to be tested.

7. For each of your beams, use a linear curve fit to find the slope. This is the stiffness ($F/\Delta x$) of the length of beam you are testing. Record your values in the table.

8. For each of your beams, measure and record the maximum load force at fracture.

## Analysis: Flexural Elastic Modulus

1. In PASCO Capstone, add two user-entered data sets to the table: The first set is called E and has units of GPa; the second set is called Rupture Mod and has units of MPa.

2. For each of your beams, use Eqn. (3) to calculate the Flexural Elastic Modulus (E) and record in the table.

3. For each of your beams, use Eqn. (5) to calculate the Modulus of Rupture and record in the table.

4. How much variation is there in your beams? Compare your average values to those listed in reference data tables.

## Procedure: Further Study

1. Re-test a fractured beam, this time taking it to destruction. What differences do you see?

2. Make a new set of beams, but do not test all your beams at the same time. Perform the testing over several hours, or even over several days, to observe the effect cure time has on the strength.

3. Test new beams using a different anvil spacing. What effect would you expect this to have on your calculations of the Flexural Elastic Modulus and the Modulus of Rupture.

4. Test new beams bending them in the "weak" direction. What effect would you expect this to have on your calculations of the Flexural Elastic Modulus and the Modulus of Rupture.

5. Remove one or both of the rebar before casting the beam.