BME 315 Biomechanics

Measurement of bone strength and stiffness via 3 point bending

Preliminaries:

Review your studies of bending. Also, review beam equations pertaining to 3 point bending. Experiment details and background are provided on the class web site; paper copies will be available in the lab. The specimens for bending are taken from animal bone. Begin by cutting bone pieces from the tissue provided. The “grain” of the bone runs along the specimen length.

Set-up

Safety These machines are strong (10,000 pound capacity) and can be dangerous. Be aware of your own and your classmates’ fingers and limbs before starting and running a test. Keep body parts away from grips during testing. When the specimen breaks, pieces can go flying. Therefore, remember to wear goggles (provided) during each test.

Test set up Make sure the contact points in the three point bend jig are set an appropriate distance apart for the specimen you have.

Three Point Bending Test

Dissect the bone from the surrounding tissue. Use gloves and be careful; cut away from yourself. Measure the maximum and minimum width at the middle of the bone.

Orient the specimen so that the widest surface is in contact with the metal fixtures, otherwise the specimen will rotate during the test. Put paper towels under the specimen so that soft tissue does not contaminate the test frame.

Conduct a bending test to specimen fracture using the detailed methods provided in the lab. Repeat for each specimen.

Measure the wall thickness of the specimen and record this information in the class data sheet, along with other comments concerning the failure. Comments should include if the test slipped, or if the specimen did not fail at mid-span. If the failure was not at mid-span, further describe what occurred.

Analysis

1. Calculate the maximum normal stress in the specimen using equations provided on the other side of the page or in detail sheets. Plot the maximum normal stress versus the deflection for all of the specimen from your lab section. Include all specimens on the same figure.
2. Evaluate the normal stress versus deflection curves for each of the specimen and determine the yield strength (end of linear region of the stress/deflection curve) and the ultimate strength (maximum stress). Make a table (to be included in the Appendix of your report) showing the yield and ultimate strength for each of the specimens.
3. Calculate the average and standard deviation of yield strength and ultimate strength. If there are data that you feel are outliers (i.e. slippage within the test fixture, failure at a location other than mid-span, etc.) do not include them in your calculation and justify why you chose to do so.

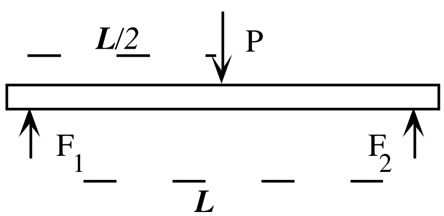
4. Determine the modulus of elasticity *E* (Young's modulus). Requisite equations are provided in class and in the lab detail sheets. Plot the modulus of elasticity versus deflection from the linear region of the stress versus deflection curve. Include all the specimens on one figure. Be sure to only use the portion of the data in which linearly elastic behavior occurs.
5. Calculate the average modulus of elasticity for each specimen (your plots will show a range) and include these values on your table.
6. Calculate the average and standard deviation of the modulus of elasticity for all of the specimens. Again, if there is an outlier, do not include this in your calculations and justify why you chose to do so

<u>Questions</u>

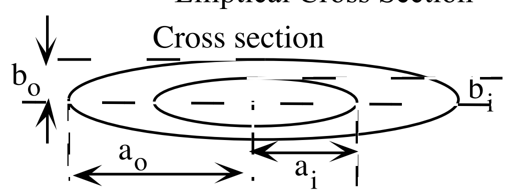
1. How do the values of Young's modulus, yield strength, and ultimate strength that you measured compare to values given in your book or other published data? Some references are provided in the detail sheet. Comment on possible reasons for differences that exist.
2. Would you classify the wet bone as brittle or ductile? How about the dry bone? Why is there a difference in material properties between wet and dry bone? Why might one want to know the properties of both wet and dry bone?
3. Discuss your observations from the tests and the observed failures. Was the failure a result of tensile or compressive stresses? Why?
4. What are the main sources of error in our measurements? Consider some of the assumptions we made (cross-section geometry, neutral axis, contribution of trabecular bone, slenderness of specimen, etc.). How might this affect the calculations we have made?
5. How does the modulus, yield strength, and ultimate strength compare to other materials such as steel and titanium? What are some practical implications of this (i.e. if we are designing joint replacements or fixturing devices)?
6. What is the strain at yield and at fracture? Are these values reasonable?

Calculation of Material Properties From Three-Point Bending

Three Point Bending



Elliptical Cross Section



$$\delta_{max} = \frac{PL^3}{48EI} \qquad \sigma = \frac{My}{I} \qquad \sigma = E\varepsilon \qquad I_{xx} = \frac{\pi}{4}(a_o b_o^3 - a_i b_i^3) \qquad I_{yy} = \frac{\pi}{4}(b_o a_o^3 - b_i a_i^3)$$

$Area = \pi ab$

Displacement of force P is δ.

To calculate the elastic modulus E, stress σ and strain ε:

(1) Measure the specimen dimensions. Approximate the cross section as an ellipse.
(2) Apply known loads and displacements in three point bending.
(3) Knowing displacement (max at center) and applied load, determine E in the linear range.
(4) To calculate stress use the bending stress formula, with the maximum moment M = PL/4.
(5) Knowing E and σ, calculate strain ε using Hooke's Law σ = Eε.