BME 315 Biomechanics
Experiment 5, fall 2006
Use of screw-driven testing machines to measure bone strength and stiffness

Preliminaries:

Read the section in the book about 3 point bending. Also, review beam equations pertaining to 3 point bending. The specimens for bending are taken from rib bone. Begin by cutting pieces from the ribs provided. Cut surfaces for compression specimens should be as flat and as parallel as possible, to reduce the effects of surface indentation which may obtrude in your interpretation of results. The "grain" of the bone runs along the specimen length. For human Haversian bone, properties in the longitudinal (bone axis) direction differ from those in the transverse directions, which are essentially equivalent. For bovine plexiform bone, properties in the longitudinal, circumferential, and radial directions are all different. Remember to bring a 3.5" disk to class so you can save your data.

Set-up

Tests Do several tests: 3 point bending and compression. Some instructions for operating the system are given in the *Basic Test Set-up* manual next to each machine. This packet will include instructions for saving your work to a disk. After all tests, the graph of the displacement vs. load will be displayed. After each test, save the data (including the curve) under a filename you will remember. Follow the *Basic Test Set-up* to save the data to your disk.

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.

3 Point Bending Test

Choose the 3pntBME315 or another bending method from the computer menus. You will indicate to the computer that you will use a new sample each time. Enter the necessary measurements prompted by the computer (i.e. width and thickness of the specimen, rate of the test, etc. Make sure that the specimen is placed correctly in the machine. Be sure to record the exact distance between the two lower points of the test jig. Carefully lower the crossbeam point onto the bone so it is just barely not touching the specimen before running the test.

Compression Test

Choose CompressionBME315 or another compression modality as your test method. Run the test as before, following the procedure given by the computer. Lower the crossbeam carefully until it is almost touching the bone. After the test, collect the data as before.

Analysis

(1) Plot the load vs. displacement for all tests. What is the maximum stress in the bone before yield and before failure using 3 point bending? What is the maximum strain? How do these figures compare with other materials such as aluminum and mild steel? Does it compare to the results of the compression test?

(2) What is Young's modulus for the bone? Again, compare with other materials. Were the compression surfaces of the bone perfectly flat? What effect does surface flatness have in your interpretation?

(3) How much energy is required to break the bone using 3 point bending? How much is required for compression. Why is there a difference?
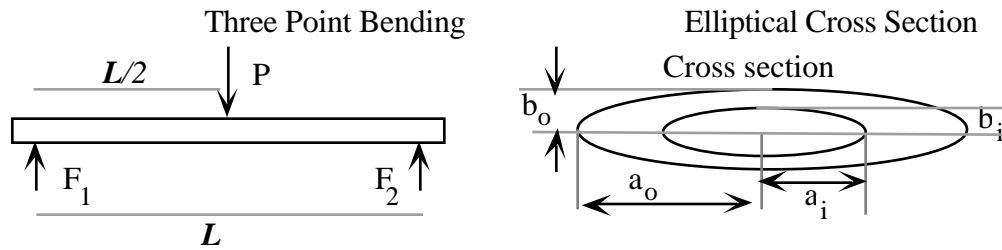
Questions   (please make a clearly identified section in your report for these)

(1) Would you say the bone is brittle or ductile? Why? Was the bone fully wet during testing? Could that make a difference? Is fresh bread different from dry stale bread in its mechanical properties? Both bread and bone contain polymers of biological origin.

(2) In the 3 point bending test, the analysis assumes a slender beam in bending. Do you think your specimen was sufficiently slender to warrant that assumption? Why should the slenderness matter? Is the bone cortex thickness important in data interpretation? What if it were very thin?

Please attach this sheet to your report.

Calculation of Material Properties From Three-Point Bending

Three Point Bending   Elliptical Cross Section

Cross section

$$\delta_{max} = \frac{PL^3}{48EI} \qquad \sigma = \frac{My}{I} \qquad \sigma = E\varepsilon$$

$$I_{xx} = \frac{\pi}{4}(a_o b_o^3 - a_i b_i^3) \qquad I_{yy} = \frac{\pi}{4}(b_o a_o^3 - b_i a_i^3)$$

$$Area = \pi ab$$

Displacement of force P is δ.

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

(1) Measure the geometric properties of the specimen. Approximate the cross section as an ellipse.
(2) Apply known loads and displacements in three point bending. Data export contains these.
(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/2.
(5) Knowing E and σ, calculate strain ε using Hooke's Law σ = E ε.