EMA 611 Advanced Mechanical Testing of Materials, University of Wisconsin

Experiment 1: Tests with screw-driven testing machines

Pre-lab assignment Review your prior work (if any) with the screw-driven instruments.
Review the web notes on comparison of materials.
Bring a worm free USB memory stick to each class.
Review the web notes on graphs.

<u>**§1 Materials**</u>. Materials provided may include rectangular wood bars about 3/4" in cross section, wood coffee stirrers, cylindrical polymer (polymethyl methacrylate or PMMA) rods, a brass cube and a foam cube.

<u>**§2 Set-up**</u>. Measure the dimensions of the specimens provided. Weigh each specimen. Record the specimen number, if any. Write down the temperature and humidity in the room at the beginning and end of the session. Write down the spacing between growth rings at each end of the wood specimens. Read the instructions for use of the computer control and load frame. For foam, estimate the cell size. Wear **safety glasses** when testing. Instructions for the test frame are provided.

Remark: The meter display of force and displacement can be controlled by right-clicking on the number. One can zero the meter, or change the number of significant figures.

<u>**§3 Stiffness test**</u> For wood, determine Young's modulus but do not break the specimen yet. Keep below a load of 100 pounds for bend, 10" span. Specifically, terminate the test before that load is reached. Use three-point bend tests with span 5" and 10". For the 10" span, repeat the test with the specimen rotated about its axis by 90°. Write down the orientation of the growth rings on the end for each test. If you have time, try again with a substantially different deformation rate.

For foam, use determine Young's modulus and stress strain curve in compression.

To change **grips**, loosen the retaining ring with a spanner wrench. Tools and grips are provided in the back of the test frame. If it is necessary to change grips make sure to tighten the collar toward the screw end not the platen. The pin which holds the bottom grip is spring loaded.

Do a compression test using compression platens.

<u>**§4 Strength test**</u> For wood, conduct a test to failure. If possible, observe the formation of cracks as the test progresses. What is the fracture strength? If you are doing a column compression test, is buckling a problem? Calculate the theoretical buckling load. If you have a short specimen of wood, measure the transverse stiffness and strength. The foam will not break so there is no fracture stress, however the stress-strain curve is nonlinear.

<u>**§5 Analysis**</u>.

§5.1 What is the initial Young's modulus of the material? Compare with known similar materials. Compare Young's moduli obtained from the various tests. Check the modulus from the computer with your own calculations. Compare E, E/ρ, E/ρ^2 of wood with book values for steel, aluminum.

Refer to modulus - density comparison after Ashby, left navigation bar, class web site. Measure specimen mass using scale in front room 1313 or analytical balance in basement room.

§5.2 Plot stress vs. strain for the constant deformation rate tests. Interpret the curve shape. Does the curve shape depend on the material or on experimental conditions? Explain.

<u>**§6 Discussion**</u> Discuss your results, their implications, and comparison with theory.

<u>**§7 Questions**</u> *Answers should go on a separate page in your report.*

§7.1 How does the signal to noise ratio affect your results? Is noise more of a problem for some specimens than others? What governs the signal to noise ratio? How might it be improved?

§7.2 If the moduli determined using different modalities do not agree, what might be the reason?
Discuss the role of anisotropy, heterogeneity, viscoelasticity and boundary conditions.
Are the dimensional tolerances responsible for modulus differences?

§7.3 Estimate the error in your measurement of moduli. Hint: How much noise is there in comparison with the signal? How much do the dimensions vary along the specimen?

§8 Supplement Elementary theory for buckling load P_{cr} for a simply supported column gives:

$$P_{cr} = \pi^2 EI/L^2. \tag{1}$$

For a column with built-in ends constrained so they cannot rotate,

$$P_{cr} = 4\pi^2 EI/L^2. \tag{2}$$

For tubes of Young's modulus E, Poisson's ratio ν, radius R and thickness h, [Bazant, Z. and Cedolin, L., *Stability of Structures*, Oxford, 1991].

$$P_{cr} = \frac{1}{\sqrt{3(1-\nu^2)}} \; E\,h^2 \frac{2\pi h}{R} \; . \tag{3}$$

For cantilever bending of an anisotropic bar, [S. G. Lekhnitskii, "Theory of elasticity of an anisotropic body", Mir, Moscow, 1977] with I as area moment of inertia, P as load, L as length, y as deflection of the centerline, z as coordinate along the centerline.

$$y = [Pa_{33}/6I]\,[2L^3 - 3L^2 z + z^3]. \tag{4}$$

Here a_{33} is the compliance in the 3 direction; $1/a_{33} = E_3$.

For **wood** along the grain E and compressive strength σ_{ult} are proportional to the density ρ [Gibson and Ashby, *Cellular Solids*, Cambridge, 1997]. Across the grain, $E \sim \rho^3$ and $\sigma_{ult} \sim \rho^2$. For **foam**, $E \sim \rho^2$.