1.103 CIVIL ENGINEERING MATERIALS LABORATORY (1-2-3)

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                                                                           Spring 2004

LABORATORY ASSIGNMENT NUMBER 3

TENSILE TESTING: COMPARISON OF COMMON MATERIALS

Purpose: You will learn about:
          (1) Measurement techniques for direct tension testing
          (2) Tensile properties of common materials
          (3) Various types of post yield behavior
          (4) The effects of strain rate sensitivity

Organization:
  - Meeting A   90 min. *Subgroup* testing
  - Meeting B   30 min. *Individual* observation after 3/11/03
  - Data   Posted after each *Subgroup* meeting

Reading:
  - Read this handout and know what you will be doing in the lab
  - Look up the elastic modulus, proportional limit, yield strength and tensile strength of steel, cast iron, brass, aluminum, plastic, wood, and glass.
  - Read ASTM E8   *Standard Test Methods of Tension Testing of Metallic Materials*

Overview:
        In the second laboratory, we learned about the method of performing tension tests on standard steel threaded rod. Measurements were made to illustrate the effects of machine compressibility factors, area of the specimen and length of the specimen. During this assignment, you will test specimens made of various materials to explore the differences in basic material properties such as elastic modulus, proportional limit, yield stress, and strength. The materials can be broadly grouped as either brittle or ductile.
        We will be using tensile specimens made of hot formed steel, cold formed steel, cast iron, brass, aluminum, and plastic which have been machined from standard threaded rod. The wooden specimen is machined to fit into flat ended grips. It was fabricated from a dowel rod. The glass rod is epoxied into a piece of threaded aluminum rod to provide a means of gripping.
        The specimens are loaded in tension using a constant rate of displacement (based on the cross head transducer) and the reaction force is measured with a force transducer (load cell). The specimen strain is measured by an extensometer that is attached directly to the gauge section of the specimen. This device measures the displacement over the

extensometer gauge length (about 25.4 mm). You must calculate the actual gauge length from the calibration of the extensometer, the reference point of the extensometer and the first reading of each test. For each test, we will record the cross head displacements, extensometer, and force. You only need to use the cross head displacement in situations when the extensometer goes out of range. When this happens, you must select a new actuator zero such that the actuator strain matches the extensometer strain at the point where the extensometer is no longer useful. Then use the actuator strain for large stain range of the curve.

Each *Subgroup* will test three specimens of your choice. One specimen must be from the brittle category (cast iron, glass or wood). You will load the brittle specimen monotonically to failure using a slow strain rate. For the ductile specimens, you should perform one unload reload loop at about 1% strain. You will also vary the strain rate during the test to look for rate sensitivity.

Procedure:
> *Preparation:*

- Set up the data acquisition system and record on the data sheet the channel numbers, the transducers and the calibration factors. Check to be sure that everything is working correctly.
- Number the specimens.
- Measure the diameter and specimen gauge length of each specimen. The gage length is measured to the base of the taper.
- Determine the gauge length of the extensometer with the caliper. The gauge length should be measured with the locking pin in position. Record the input and output voltages corresponding to the gage length.

> *For Each Specimen*

- Zero load cell.
- Screw the specimen into the grip.
- Put the bottom grip into the crossbar adapter and lock in place with load pin.
- Slowly raise the actuator to insert the top grip into the upper adapter and lock in place with the pin. Be sure the load cell still reads the correct zero value.
- Attach the extensometer to the specimen such that the gage is in the mid-point of the specimen.
- Adjust the extensometer such that the output is close to the value corresponding to the gauge length.
- Apply a small seating load by lowering the actuator (20 kN).
- Record starting value of displacement transducer which measures the actuator displacement.
- Start the data acquisition system with a 1 sec reading rate. Be sure to specify a large enough data file. Remember you can BYPASS data storage and change reading rate anytime during the test to maintain a manageable data size.

- Deform the ductile specimens at about 0.4 mm/min at the start of the test to get sufficient data in the elastic range. You will need to load more slowly for the brittle specimens.
- For the plastic specimens, perform one unload-reload loop at about 1% strain. Do this while at the higher strain rate.
- Once the specimen yields on the reloading segment double the sampling rate to 0.5 seconds.
- Now you will look at the strain rate sensitivity by following this loading schedule.

Strain rate	Duration
0.4 mm/min	30 seconds
0.8 mm/min	15 seconds
1.6 mm/min	10 seconds
0.8 mm/min	15 seconds
0.4 mm/min	30 seconds

- Finally, you can increase the rate and continue to failure.
- Watch the specimen closely. Look for texture changes on the surface where the strain becomes concentrated.
- After the specimen fails, measure the diameter at the point of failure and the final gauge length.

Definitions:

Tensile Stress,   is the force measured by the load cell divided by the initial cross sectional area. Note that this is the nominal stress and that the actual stress is much larger because the area reduces during the test. For each specimen compute the final actual stress using the measured area after failure.

Specimen Strain, ε , is the extensometer deformation divided by the extensometer gauge length. This is best estimate of the engineering strain.

Apparent Strain, ε_a , is the actuator displacement divided by the specimen gauge length. This value ignores the apparatus deformations and can be seriously in error.

Young's Modulus, **E** , is the slope of the linear regression line through the data up to the proportional limit.

Proportional Limit, σ_p , is the nominal stress at which the stress strain relationship deviates from linearity (this requires a somewhat subjective determination).

Yield Stress, σ_y , is the nominal stress at which the material begins to undergo significant deformation without much change in stress (depending on the details of the stress strain behavior this can also be rather subjective).

Report:
Your report should contain the following items.
- A graph of the stress strain curve for a specimen from each material (nine total) based on the extensometer (and actuator when necessary) results.
- A graph of the initial part of the stress strain curve for each test specimen (nine total) based only on the extensometer results to illustrate the modulus, proportional limit, and yield stress. (Can be a combined graph or one per test).
- A graph of strain rate versus the strain (use the same strain scale as for the first graph) for the ductile specimens. Notice that the actual strain rate varies continuously due to the fact that it is controlled by the cross head displacement transducer. You can use a moving window to smooth the variations in the strain rate data. This will make trends more obvious.
- A combined plot showing the percent increase in stress ($\Delta\sigma / \sigma$ slow) as a function of the strain rate for the ductile specimens. To compute the percent change in stress you need to approximate (by hand on the first graphs of the stress strain curve) the curve for the slowest strain rate and then determine the increase at a given strain for the faster rates. Pick an average value for both the increase in stress and the strain rate for the graph. This will be a very approximate estimate to show the effects of rate sensitivity.
- A summary table of the elastic modulus, proportional limit, yield stress, reload modulus, tensile strength, elongation, and area reduction.
- A sketch of the failure geometry and note any significant observations.
- One set of example calculations (one measurement point).
- The data sheets.
- One page of computer calculations and raw data.

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TENSILE TESTING AND STRESS STRAIN PROPERTIES OF STEEL

DATA SHEET

DATE _____   All dimensions in _____   Group No. _____   Date _____
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Device	Force	Actuator Disp.	Extensometer
Calibration. Factor	_____	_____	_____
DAQ Channel	_____	_____	_____
Input Voltage	_____	_____	_____

Calibration Reference Point _____

Material Type _____   Gauge Length _____   File Name _____
Diameter _____ , _____ , _____ , _____   = _____
Zero Load _____   Zero Actuator Disp. _____   Zero Extensometer _____
Diameter of Neck _____   Final Length _____

Material Type _____   Gauge Length _____   File Name _____
Diameter _____ , _____ , _____ , _____   = _____
Zero Load _____   Zero Actuator Disp. _____   Zero Extensometer _____
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