

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

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MIT
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LABORATORY ASSIGNMENT NUMBER 2

TENSILE TESTING AND STRESS STRAIN PROPERTIES OF STEEL

Purpose: You will learn about:

- (1) Measurement techniques for direct tension testing
- (2) Operation of servo hydraulic testing machine
- (3) Tensile properties of common steel
- (4) Errors associated with testing techniques and data interpretation

Organization:

- Meeting A 30 min. pre-scheduled *Group* Instruction
- Meeting B 60 min. *Subgroup* testing
- Meeting C 30 min. *Individual* observation
- Data Will be posted the day of the 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
- Read ASTM E8 *Standard Test Methods of Tension Testing of Metallic Materials*

Overview:

The direct tension test is used to measure many mechanical properties such as Young's modulus, proportional limit, yield strength and tensile strength. A wide range of materials (rubber to steel) can be tested if the appropriate grips are employed and proper equipment is used to measure displacements. During this assignment, we will explore the behavior of steel in tension and the effects of specimen geometry (cross sectional area and length), measurement errors and cyclic loading.

We will be using tensile specimens that have been machined from standard threaded rod. The center section of the rod has been machined down to a constant cross section. The length of rod having this constant section is referred to as the *specimen gauge length*. It is the section experiencing the largest tensile stress and hence the part of the rod undergoing most of the deformation. It is important to have this cross section constant so the stress and strain is as uniform as possible.

The specimens are loaded in tension using a constant rate of displacement and the reaction force is measured with a force transducer (load cell). Displacements will be measured using two different techniques. The cross head displacement is measured using

a Linear Voltage Displacement Transducer (LVDT) mounted inside the actuator. We must assume this displacement is equal to the integrated strain over the specimen gauge length. This calculation ignores the deformations of the load frame and the specimen grips. The actual 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*. You must calculate this dimension from the calibration of the extensometer and the first reading of each test.

We will be testing four specimens during this laboratory. These specimens will be designated **standard, thin, thick** and **long**. Three specimens will be tested which have different cross sections to provide comparisons of force effects. Our objective is to see if the steel properties change with cross section. The fourth specimen will be longer than the standard length but will have the same cross section. Comparison of this specimen with the standard length will allow you to compare the effects of machine deformations.

During Meeting A, we as a *Group* will spend the time learning how to use the testing machine and set up the measurement system. During Meeting B, each *Sub-group* will perform the test on one of the four test specimens. Each test must include at least four unload/reload cycles. One in the linear elastic range, one just after the proportional limit, one after the yield point, and one at large strain. The test specimens will be put on display. After the last group has performed the test, each person must return to the lab and examine all the test specimens. This is meeting C. The data sheet with the initial measurements and the digital data files will be posted immediately after the last test session.

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 gauge 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 gauge 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 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 gauge 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 specimen at about 0.05 cm/min for the 2 inch gage length. Adjust the displacement rate for each specimen to have about the same strain rate.
- Once the specimen yields (based on the shape of the load versus displacement curve) increase the displacement rate.
- For the last specimen (No. 4) you need to measure at least three unload-reload curves. Based on your observations from previous specimens, pick the locations for the loops. At each selected strain level, reverse the displacement direction using a rate of 0.05 cm/min. Unload the specimen to about 50 kN and then reload at the same rate. You should increase the displacement rate between loops to save time.
- Watch the specimen closely. Once a well defined neck develops, remove the extensometer to prevent damage.
- After the specimen fails, measure the diameter at the point of failure and the final gauge length.

Definitions:

Tensile Stress, σ , 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.

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 stress at which the stress strain relationship deviates from linearity (this requires a somewhat subjective determination).

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

Tensile Strength; σ_t , is the maximum tensile stress at any point along the stress strain curve. It gives the maximum force carried by the specimen.

True Tensile Strength; σ'_t , is the maximum value of the actual tensile stress in the steel. This accounts for the reduction in the cross section as load is applied. We do not measure the cross section during the test therefore we can only compute the actual tensile stress from the final measured cross section. We will assume that this is the True Tensile Strength.

Report:

Your report should contain the following items.

- A graph of the stress strain curve for your test specimen showing both the extensometer and actuator based results. You may want to show an additional graph without the unload reload cycles.
- A graph of the initial portion of the stress strain curve (say up to 1% strain) for your test specimen showing both the extensometer and actuator based results. This graph should show the initial elastic region, the proportional limit, and the yield point.
- A combined graph for the two specimens having different gauge length based only on the extensometer results. Do not show the unload reload cycles.
- A combined graph for the three specimens having different cross sections based only on the extensometer results. Do not show the unload reload cycles
- A combined graph for the four loading curves of your specimen based on the extensometer results and scaled to compare the small strain values.
- A summary table of the elastic modulus, proportional limit, yield stress, reload modulus, tensile strength, true tensile strength, elongation, and area reduction.
- A sketch of the failure geometry and note any significant observations.
- One set of example calculations for your test (one measurement point).
- The data sheet.
- One page of computer calculations and raw data.

Answer the following questions

How does the machine deflections alter the results?

Does the elastic modulus depend on specimen geometry?

How does the unload reload loop change as the strain level increases for specimen four?

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DATA SHEET

DATE _____ All dimensions in _____ Group No. _____ Lab No. _____

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<u>Device</u>	<u>Force</u>	<u>Actuator Disp.</u>	<u>Extensometer</u>
<i>Calibration Factor</i>	_____	_____	_____
<i>DAQ Channel</i>	_____	_____	_____
<i>Input Voltage</i>	_____	_____	_____
<i>Calibration Reference Point</i> _____			

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

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

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

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

1.103 Lab No. 2

Diameter of Neck _____

Final Length _____

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