FSEL TENSILE TESTING OF REINFORCING BARS

1. PROCEDURE OVERVIEW

This FSEL test standard is used to determine the tensile properties of reinforcing bars. The testing is in general conformance with ASTM A370-15 *Standard Test Methods and Definition for Mechanical Testing of Steel Products* and ASTM A615-16 *Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement*. Appendix 9 to ASTM A370 specifically addresses tensile testing or reinforcing bars.

The procedure below uses the MTS C64.206 test machine along with a pre-programmed test procedure. The pre-programmed test procedure should be adequate for most rebar testing. Should any alteration be needed, consult with FSEL staff beforehand.

- 1.1. Student Responsibilities for Testing:
 - Read and understand the requirements of this procedure
 - Provide reinforcing bar samples
- 1.2. Staff Responsibilities for Testing:
 - Read and understand the requirements of this procedure
 - Provide students with keys to control cabinet and accessories cabinet
 - Assist students with testing as needed

2. EQUIPMENT AND TOOLS

- MTS C64.206 Test Machine
 MTS Extensometer
 Grips
 Ladder
- Rubber Bands or Springs
 USB drive
 Grease
- Shimming Materials for No. 3 or Smaller Bars

3. PERSONAL PROTECTIVE EQUIPMENT

Safety Glasses
 Safety Shoes
 Hardhat
 Disposable Rubber Gloves

4. DETAILED PROCEDURE

4.1. Identify the reinforcing bars to be tested and cut them to appropriate length.

The number of samples is to be determined by the research team. Typically, three samples are tested for each bar size used in the test program. The grips for the test machine are 7 in. long

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and ASTM A370 requires an 8 in. gage length. It is recommended that the bar sample be cut to approximately 24 in. long. Remove any burs or sharp edges that may result from cutting the bars.

4.2. Obtain the keys to the control cabinet and the cabinet containing the MTS test accessories.

The key to the control cabinet is located in the gray storage cabinet in the lab manager's office. All FSEL staff members have a key to the accessories cabinet.

4.3. Prepare the extensometer for testing.

The extensometer and its accessories are contained in two black plastic cases locked in the gray cabinet near the test machine. The larger case contains the extensometer, a user manual, a plastic bag with drawings, and a small plastic case that contains spare parts, tools, rubber bands, and springs. The smaller case contains three extension bars and a small plastic case with additional parts and tools.

4.3.1. Place the set pin in the extensometer.

The set pin is used to hold the extensometer at a fixed opening distance prior to attaching the extensometer to the specimen. This pin prevents over-extending or over-compressing the instrument during setup.

4.3.2. Add the gage length extender to the extensometer, if needed.

The default gage length of the extensometer is 50 mm (1.969 in.). This gage length can be extended to 100 mm (3.937 in.), 150 mm (5.906 in.), or 200 mm (7.874 in.) by inserting a gage length extender. Note that the standard gage length per ASTM A370 is 8 in. (203.2 mm). A technical drawing showing the installed extender bar is inside the extender case (Reference 6.3). Note that the gage length extenders have a correct and incorrect orientation. Ensure that all parts are installed on the extensometer as shown in the drawing.

4.3.3. Make the electrical connection between the extensometer and the MTS test controller.

The free end of the wire coming out of the control console is zip-tied to the southwest column of the test frame. This wire end should be connected to an intermediate wire that will then connect to the wire attached to the extensometer. The intermediate wire should be stored in the locked gray cabinet near the machine.

4.4. Initialize the computer and data acquisition system.

4.4.1. Power on the system.

Obtain the key to the control cabinet from a staff member. Unlock the tray containing the computer keyboard and mouse. The power switch to the computer is behind an additional locked panel. The key to this locked panel is typically left in place and should be visible after unlocking the keyboard tray.

To power on the data acquisition, press the white toggle switch to "I." The green light on the control panel below the switch should illuminate. To power on the pump, press the white button labeled as on exterior of the control cabinet. The white button should illuminate and the pump should be audibly running.

If the red or yellow lights on the front of the control cabinet illuminate at any point in the test process, contact and FSEL staff member for assistance.

4.4.2. Start the MTS TestWare Essential Software.

Double click on the MTS TestWare Elite icon (we) on the desktop. Log in to the software as "FSEL Student" with the password: daq.

4.4.3. Load the test protocol.

Click on "Custom Templates" on the left side of the screen. Double-click on "MTS STH ASTM A370 Metals Tension with Extensometer Removal" to load the test protocol.

4.4.4. Input the correct length for the "Extensometer Gage Length" and "Initial Marked Gage Length."

These values should be 1.969 in., 3.937 in., 5.906 in., or 7.874 in. based on the extensometer initial length. All other values on this screen should be left as the default values.

4.4.5. Reset interlocks.

Reset the interlocks by clicking the reset button (). Interlocks are safety features that prevent the machine from applying load. If an interlock is tripped, the box to the right of the reset button will be red and there will be additional red indicators in the "Status" portion of the menu bar.

If any red indicators re-appear after clicking the reset button, contact FSEL technical staff for assistance. If the red or yellow lights on the front of the control cabinet

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illuminate at any point in the test process, contact and FSEL staff member for assistance.

4.4.6. Set the test platen position to the correct initial position.

Click on the button and enter 0.5 in. to move the test table to 0.5 in. of upward displacement. This initial movement will ensure the bar does not get jammed in the test frame should anything go awry.

- 4.5. Install the test specimen in the test machine.
 - 4.5.1. Select the correct grips for reinforcing bar to be tested.

Select the correct grips for reinforcing bar testing based on the table below.

Bar Size	Grip Type	Size Range (in.)
#3* & #4	Flat^{\dagger}	0.39 to 1.57
#5, #6, & #7	Vee	0.59 to 0.98
#8, #9, #10, & #11	Vee	0.98 to 1.57
#14	Vee	1.57 to 2.17
#18	Vee	2.17 to 2.76

*Shim plates will be needed to grip a #3 bar [†]Alignment aids are needed on flat grips

4.5.2. Install the grips into the machine.

The back sides of the grip plates should be lightly-coated with grease before insertion into machine. Rubber gloves are recommended when handling the grease. The grips are keyed to slide into the upper and middle crossheads of the test machine. After the grips are in place, the must be secured by tightening the cap screw on the retaining tab.

If alignment aids are needed per Article 4.5.1, they should be installed before the grips are inserted into the machine. Alignment aids must be installed so that they do not create any conflicts with each other or with the grips.

4.5.3. Insert and grip the bar in the upper crosshead.

Hold the bar between the upper grips such that the end of the bar is approximately flush with the upper edge of the grips and centered within the "vee" portion of the grips or is held tight to the alignment aids in the case of a #3 bar. Press the \square button on the control panel at the right side of the test frame. The green light on the button

should illuminate. Turn the upper knob to the grip position (👧) while making sure hands and fingers are clear of the grips.

4.5.4. Raise or lower the middle crosshead to the correct position to grip the lower end of the specimen.

Press the or button to raise or lower the the middle crosshead. The crosshead should be raised until the lower end of the specimen is approximately 3-6 in. from contacting the crosshead. The final position of the middle crosshead will be checked later in this procedure. Note that the lower grips will move upward to engage the specimen.

If the middle crosshead is raised or lowered too much, it will trigger limit switches that will create interlocks, which stop the test machine.

4.5.5. Tare the force.

Near the lower left corner of the screen, the current force measured on the system is displayed. Right-click on the value and chose "Zero signal" to define the zero force point prior to gripping the lower end of the bar specimen. The number will drift slightly, but should remain near 0 kips.

4.5.6. Grip the specimen in the lower crosshead

The bar should be suspended by the upper grips and the lower crosshead should be raised per Article 4.5.4. Turn the lower knob to the grip position (\bigotimes) while making sure hands and fingers are clear of the grips.

4.5.7. Inspect position of lower grips.

The lower grips should have risen to grip the specimen. The lower end of the specimens should be within 1 in. of the lower end of the lower grips. If this is not the case, ungrip the lower end and raise or lower the middle crosshead as needed.

The test machine will likely indicate a moderate compressive load (-0.5 to -1.0 kip). This load is real and represents the load induced by raising the lower grips. Do not zero this load.

4.5.8. Remove control from the handset and restore control to the control console.

Press the \square *button on the handset to restore control to the control console. The green light on the button should turn off.*

- 4.6. Install the extensometer on the specimen.
 - 4.6.1. Choose a method to attach the extensometer to the bar being tested.

There are three methods to attach the extensometer to the bar sample:

<u>Rubber Bands (Preferred Method)</u>: Rubber bands of various sizes can be attached to the small wire hooks on the sides of the extensometer as shown on Reference 6.4. Choose rubber bands of the appropriate size to ensure firm contact between the knifeedges of the extensometer and the bar specimen.

<u>Quick Attachment Spring</u>: A steel attachment spring is attached to the extensometer connection points. This spring wraps around small diameter (<0.5 in.) to form the connection. The spring can be positioned at one of four locations to ensure the proper gripping pressure. Consult with Reference 6.5 to identify the correct spring position.

<u>Springs:</u> Springs can be used in place of rubber bands as described above. The spring length should be sized to ensure firm contact between the knife-edges of the extensometer and the bar specimen. Guidance on the proper spring length can be found in Reference 6.6.

Whichever method is chosen, MTS recommends a contact force between the knife edges and the specimen of approximately 600 g (1.33 lb) per contact point.

4.6.2. Using the method identified in Article 4.6.1 attach the extensometer to the specimen.

After connecting the extensometer, ensure it is tightly attached to the specimen. To avoid slippage, the knife edges of the extensometer should be not contact the transverse ribs of the bar.

4.6.3. Zero the extensometer reading.

Right click on the extensometer reading and select "Zero signal."

4.6.4. Remove the restraining pin from the extensometer.

Check the extension extension of the reading after removing the pin. If the reading varies more than about ± 0.05 in., reinsert the pin and go back to Article 4.6.2.

4.6.5. Re-zero the extensometer.

This step will establish the final zero value for upcoming elongation measurements.

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4.7. Begin loading the specimen.

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- 4.7.1. Make sure that all personnel and materials are free of the test machine and will not be affected by machine movements.
- 4.7.2. Click the start button to execute the test protocol.

Click the button to begin the test.

4.7.3. Enter the nominal specimen diameter in inches.

The nominal diameter will be used for on-screen calculations of stress. This value will not affect the recorded data. Note that the test will begin immediately after this value is entered. Make sure all personnel are at a safe distance from the test machine and everything is ready for testing.

4.7.4. Observe the real-time stress vs. strain curve on the screen to ensure that the test is proceeding normally.

If the displayed data do not appear correct, stop the test by pressing one of the red stop buttons or by clicking stop in the control software.

4.7.5. When the extensometer nears its measurement limit, remove it and reinsert the locking pin.

The test protocol will pause the test when the extensometer reaches a value of 0.8 in. Carefully remove the extensometer from the bar and replace the locking pin. Place the extensometer in a safe place for the remainder of the test.

Note that handling the extensometer will introduce aberrant data to the test record and to the data displayed on the screen. These aberrant data are normal and will need to be removed from the finished data file after completion of the test.

4.7.6. Click start to resume the test protocol.

After clicking the button, the test will resume and load the bar to fracture. After fracture, the machine will freeze all movement.

4.7.7. After the bar has fractured, ensure that the machine has stopped all movement.

The break detection feature of the software should pause the machine immediately upon bar failure. If this is not the case, stop the test machine by pressing one of the red stop buttons or by clicking stop in the control software.

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4.8. Export test data.

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- 4.8.1. Create a project folder within the "TestData" folder on the computer desktop.
- 4.8.2. Export the test data to a text file.

After the test is complete, the software will change views to show a load vs. deflection plot of the test. On the left side of the screen each test run will be listed. Right click on the run to be exported and choose "Export Raw Data."

4.8.3. Complete the information on the pop-up window to complete the export.

For the "Folder Path" select the folder that was created in Article 4.8.1. For the "Folder Save" option, it is recommended to create a new folder. Add all necessary signals to the "Signal List" by clicking the "+" button at the right of the window.

4.8.4. Confirm export has complete.

After performing the export in Article 4.8.3, navigate to and open the file to confirm the data have been written to the disk.

- 4.9. Remove the failed specimen from the grips.
 - 4.9.1. While holding onto the upper portion of the failed specimen, release the top grips.

Press the unlock button (ightharpoondown) on the control panel at the right side of the test frame. The green light on the button should illuminate. Turn the upper knob to \int_{1}^{∞} .

4.9.2. While holding onto the lower portion of the failed specimen, release the bottom grips.

Turn the lower knob to 🕎 .

4.9.3. Clean the lower crosshead.

A significant amount of mill scale will have fallen onto the lower grips from the bar specimen during testing. Clean the top surfaces of the lower grips to keep the scale from collecting in or on the jaw mechanism.

4.9.4. Return machine control to the control unit.

Press the \square button on the handset to restore control to the control console. The green light should turn off.

4.9.5. Return the test machine to the original displacement position.

To return to the original displacement position click the dutton after making sure that the machine is free to lower to the original position with any obstruction.

Note that this action will return the test machine to the position at which the last test was started. If multiple tests are being run back-to-back, it may be necessary to lower the test platen further than the displayed displacement and select "Remove Zero." Click and hold the blue down arrow (

- 4.10. To perform additional test(s), return to Article 4.5 and repeat this procedure as needed.
- 4.11. If no more tests are to be performed, shut down the test machine.
 - 4.11.1. Return the test platen to its lowest position.

Click and hold the down arrow button () while monitoring the "Actuator" displayed value. The value should begin decreasing shortly after clicking and holding the button. Continue holding this button until the reading reaches its minimum value and no longer changes.

4.11.2. Save the test.

It is recommended that the all test data be saved in MTS' proprietary format as a backup to the text files saved in Article 4.8 of this procedure. Click on File \rightarrow Save As \rightarrow Test... and navigate the folder created for these tests within the "TestData" folder.

- 4.11.3. Exit the MTS TestWare software.
- 4.11.4. Turn off the pump.

To power of the pump, press the black button labeled as on exterior of the control cabinet. The white button should no longer be illuminated and the pump should no longer be audible.

4.11.5. Turn of the data acquisition system.

To power off the data acquisition, press the white toggle switch to "O." The green light on the control panel below the switch should turn off.

4.11.6. Shut down the computer.

- 4.12. Return the various test fixtures to the storage cabinet and clean the machine.
 - 4.12.1. Remove the grips and return them to the storage cabinet.

The back sides of the grip plates should be cleaned of any excess grease and the remaining surface should be cleaned of any mill scale or other debris before returning them to the cabinet.

4.12.2. Clean the middle cross head.

With the grips removed, additional areas that require cleaning will be accessible. These areas need to be thoroughly cleaned of debris to ensure the gripping mechanism is not compromised.

4.12.3. Remove the gage length extender from the extensometer and return the extensometer and extender to their respective cases.

The extensometer should be returned to the configuration shown in Reference 6.5 for storage in its case. The gage length extenders should also be returned to the proper case for storage. Ensure that all small parts are also returned to the correct cases when the testing is complete.

- 4.12.4. Return all parts to the gray cabinet and lock the cabinet.
- 4.13. Lock the keyboard tray and return the key to an FSEL staff member.

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5. SUPPORTING DOCUMENTS

None.

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6. REFERENCED DOCUMENTS

It is the responsibility of project personnel to ensure that the most recent versions of the referenced FSEL documents are utilized during procedure implementation.

- 6.1. ASTM A370-15: Standard Test Methods and Definition for Mechanical Testing of Steel Products. West Conshohocken: ASTM International, 2015.
- 6.2. ASTM A615-16: Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement. West Conshohocken: ASTM International, 2016.
- 6.3. MTS Technical Drawing 700-000-290 "GL Extend 634.15-4X Long Post Install" Rev A.
- 6.4. MTS Technical Drawing 495732-01 "Extensometer, Sm. Elastic Band Attachment Sys." Rev A.
- 6.5. MTS Technical Drawing 700-001-693 "Extensometer Model 643.25-2X Installation" Rev A.
- 6.6. MTS Technical Drawing 446065-01 "Extensometer Spring & Elastic Band Attachment" Rev B.

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7. RECORD OF REVISIONS

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Revision	Date	Affected Pages	Description
0 1	2016-10-21 2016-11-04	All 1 & 3	Initial Issue Corrected type-graphical error in gage length