FSEL

PROCEDURE FOR

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 (Ref 7.1)* and ASTM A615-16 *Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement (Ref. 7.2).* 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 reinforcing bar testing. Should any alteration be needed, consult with FSEL staff beforehand.

Based on the original calibration records for this test machine, the peak error in force output was 1.30 kN (290 lb). An error of this magnitude could affect calculation of stresses for smaller diameter bars. If precise test results are needed for small diameter bars, a test frame with less force capacity may be preferable.

1.1. Student Responsibilities for Testing:

- Read and understand the requirements of this procedure
- Provide reinforcing bar samples
- Provide shim materials for gripping small diameter bars
- Cleaning machine after testing

1.2. Staff Responsibilities for Testing:

- Read and understand the requirements of this procedure
- Provide students with keys to control and accessories cabinets
- Assist students with testing as needed

2. EQUIPMENT AND TOOLS

▪ MTS C64.206 Test Machine ▪ MTS 634.25F-24F Extensometer ▪ Grips

▪ Ladder ▪ Rubber Bands or Springs ▪ USB drive ▪ Shimming Materials Small Bars

3. MATERIALS

▪ Steel Samples ▪ Grease

4. PERSONAL PROTECTIVE EQUIPMENT

- Safety Glasses
- Safety Shoes
- Hardhat
- Hearing Protection
- Disposable Rubber Gloves

5. DETAILED PROCEDURE

5.1. Identify the reinforcing bars to be tested and cut them to a length of approximately 30 in.

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 and ASTM A370 requires an 8 in. or 200 mm minimum gage length. Using a specimen of a length different from 30 in. could affect the loading rate for the specimen. Remove any burs or sharp edges that may result from cutting the bars.

5.2. 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.

5.3. 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.

5.3.1. 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.

5.3.2. Add the gage length extender to the extensometer.

The default gage length of the extensometer is 50 mm (1.969 in.). This gage length can be extended to 200 mm (7.874 in.) by inserting a gage length extender. Note that the standard gage length per ASTM A370 is either 8 in. or 200 mm. A technical drawing

showing the installed extender bar is inside the extender case (Reference 7.3). Note that the gage length extender has a correct and an incorrect orientation. Ensure that all parts are installed on the extensometer as shown in the drawing.

5.3.3. Install the knife edges appropriate for the specimen being tested.

For round specimens, the straight knife edges should be used. Drawings of the knife edges are provided at left in Figure 1.

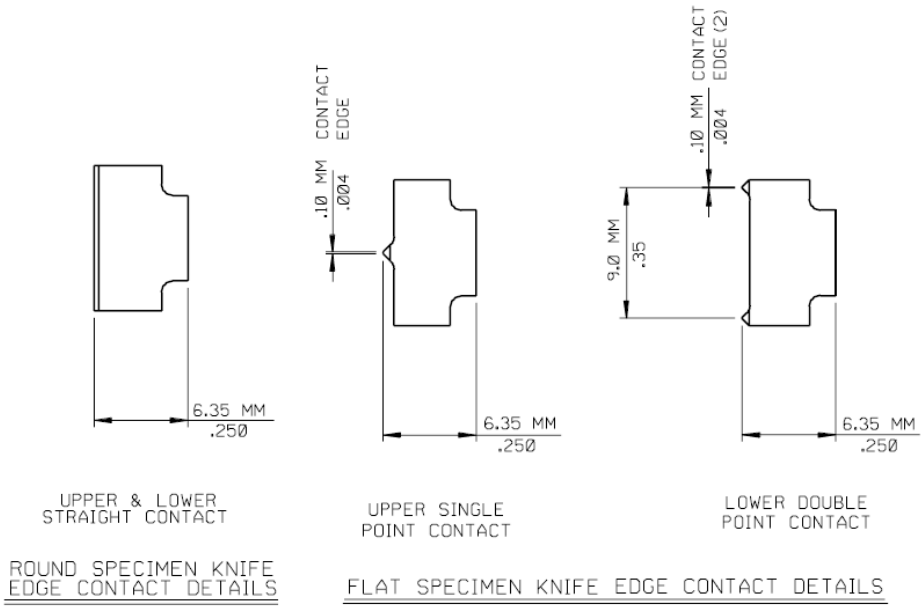

Figure 1 – Knife Edges for round specimens (left) and flat specimens (right) (Ref. 7.5

5.3.4. Choose a method to attach the extensometer to the specimen being tested.

There are three methods to attach the extensometer to the 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 7.4. Choose rubber bands of the appropriate size to ensure firm contact between the knife edges of the extensometer and the 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.) sample to form the connection. The spring can be positioned at one of four locations to ensure the proper gripping pressure. Consult Reference 7.5 to identify the correct spring position.

Coil Springs: Coil 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 specimen. Guidance on the proper spring length can be found in Reference 7.6.

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

The extensometer should not be attached to the coupon until after the coupon is installed in the test machine. See Article 5.6.

5.3.5. 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 gray cabinet near the machine.

5.4. Initialize the computer and data acquisition system.

5.4.1. 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.

5.4.2. Start the MTS TestWare Elite Software.

Double click on the MTS TestWare Elite icon (

) on the desktop. Log in to the software as "FSEL Student" with the password: daq.

5.4.3. Load the test protocol.

Click on "Custom Templates" on the left side of the screen. Double-click on "FSEL Rebar Testing Template" to load the test protocol.

5.4.4. Create a folder for your test data.

On the computer desktop, there is a folder titled "TestData". Create folder for your project within that folder. It is also recommended that you create a subfolder titled as the day of testing in YYYYMMDD format. These folders will help organize files for all projects.

5.4.5. Save the test data.

To avoid overwriting the test protocol at a later stage, it is recommended that you save the test at this stage of the procedure using MTS' proprietary format. Click on File → Save As → Test… and navigate the folder created in Article 5.4.4. It is recommended that you rename this file to something specific to your project.

5.4.6. Reset interlocks.

Reset the interlocks by clicking the reset button ( *). Interlocks are safety features that prevent the machine from applying load unless the system is ready. If an interlock is tripped, the box to the right of the reset button will be red and there may 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 illuminate at any point in the test process, contact any FSEL staff member for assistance.

5.4.7. 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.*

5.5. Install the test specimen in the test machine.

5.5.1. 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†	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

5.5.2. 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, they must be secured by tightening the cap screw on the retaining tab.

If using flat grips, as opposed to vee grips, alignment aids will be needed to ensure the specimen is placed co-axially with the axis of motion of the test machine. The alignment aids are small, stainless steel "L" shaped pieces that mount to the grips using two screws. With the grips placed on a table, place the specimen in the grips such that it is centered. Loosely place the alignment aids on the grips. With the specimen centered, tighten the screws to fix the alignment aides in the proper position.

Note that while there are four alignment aids, only two are needed. One should be placed on the top grip and one on the lower grip such that they are on opposite sides of the specimen, i.e. top left and bottom right or vice versa.

5.5.3. Unlock the control pod attached to the test frame.

Press the 🔓 button on the control panel at the right side of the test frame. The green light on the button should illuminate.

5.5.4. 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 if they are to be used. Turn the upper knob to the grip position () while making sure hands and fingers are clear of the grips.

5.5.5. 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 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.

5.5.6. 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.

5.5.7. 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 5.5.5. Turn the lower knob to the grip position ( ) while making sure hands and fingers are clear of the grips.

5.5.8. 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 compressive load induced by raising the lower grips. Do not zero this load.

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

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

5.6. Install the extensometer on the specimen.

5.6.1. Using the method identified in Article 5.3.4 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 not contact the transverse ribs of the bar.

5.6.2. Zero the extensometer reading.

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

5.6.3. Remove the restraining pin from the extensometer.

Check the extensometer reading after removing the pin. If the reading varies more than about ±0.05 in., reinsert the pin and go back to Article 5.6.1.

5.6.4. Re-zero the extensometer.

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

5.7. Begin loading the specimen.

The maximum crosshead movement rate per ASTM A370 (Ref 7.1) is 1⁄16 in. per minute per inch of distance between the grips. The minimum rate is one-tenth of the maximum rate. This test protocol is pre-programmed to load at a rate that is near the lower end of the ASTM A370 specified range. This rate translates to a crosshead movement rate of 0.1 in. per minute.

5.7.1. Make sure that all personnel and materials are free of the test machine and will not be affected by machine movements.

5.7.2. Click the start button to execute the test protocol.

Click the  *button to begin the test.*

5.7.3. Enter the nominal specimen area in square inches, the specimen name, and the gage length in inches.

The nominal diameter will be used for on-screen calculations of stress. This value will not affect the recorded data. The specimen name is an identifier that is used for your own record keeping. The gage length should likely be the default value of 7.874 in.

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.

5.7.4. 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.

5.7.5. When the extensometer nears its measurement limit or nears the rupture strain of brittle specimens, remove it and reinsert the locking pin.

The test protocol will pause the test when the extensometer reaches a value of 0.8 in. For most tests, the extensometer should be carefully removed from the bar during this pause. After removal, replace the locking pin and place the extensometer in a safe place for the remainder of the test.

For specimens that are known to be especially brittle, it may be necessary to pause the test for extensometer removal prior to the preset 0.8 in. limit.

If extension data beyond the preset 0.8 in. limit are desired, when the testing pauses, the extensometer can be removed from the specimen, reset to its initial gage length, and returned to the specimen per Article 5.6. This process allows for an additional 1 in. of stroke, which can be used to measure a greater range of extensions and develop a more complete stress-strain response. If this repositioning process is used, the user must manually pause the test after the peak stress has been observed but before fracture of the specimen to remove the extensometer.

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 can to be removed from the finished data file after completion of the test.

5.7.6. 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.*

5.7.7. 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.

5.8. Export test data.

5.8.1. 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."

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

Using the pop-up windows save the raw data to the folder created in Article 5.4.4. Add all necessary signals to the "Signal List" by clicking the "+" button at the right of the window. Note that the "Actuator" signal is not always selected by default. The actuator signal is needed to determine elongation at fracture and should be exported along with all other signals.

5.8.3. Confirm export has completed.

After performing the export in Article 5.8.2, navigate to and open the file to confirm the data have been written to the disk.

5.9. Remove the failed specimen from the grips.

5.9.1. Unlock the control pod attached to the test frame.

Press the 🔓 button on the control panel at the right side of the test frame. The green light on the button should illuminate.

5.9.2. While holding onto the upper portion of the failed specimen, release the top grips.

Turn the upper knob to  .

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

Turn the lower knob to  .

5.9.4. 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.

5.9.5. Return machine control to the computer console.

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

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

To return to the original displacement position click the  button 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  button will allow. If this happens, right click on the displayed displacement and select "Remove Zero." Click and hold the blue down arrow () until the position indicates approximately 0.5 in.

5.10. To perform additional test(s), return to Article 5.5 and repeat this procedure as needed.

5.11. If no more tests are to be performed, shut down the test machine.

5.11.1. 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.

5.11.2. Save the test.

It is recommended that the all test data be saved in MTS' proprietary format as a back-up to the text files saved in Article 5.8 of this procedure. Save the test to the same location and file name as used in Article 5.4.5.

5.11.3. Exit the MTS TestWare software.

5.11.4. 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.

5.11.5. Turn off 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.

5.11.6. Shut down the computer.

5.12. Return the various test fixtures to the storage cabinet and clean the machine.

5.12.1. 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.

5.12.2. 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.

5.12.3. 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 7.5 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.

5.12.4. Return all parts to the gray cabinet and lock the cabinet.

5.13. Lock the keyboard tray and return the key to an FSEL staff member.

6. SUPPORTING DOCUMENTS

None.

7. 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.

7.1. ASTM A370-15: Standard Test Methods and Definition for Mechanical Testing of Steel Products. West Conshohocken: ASTM International, 2015.

7.2. ASTM A615-16: Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement. West Conshohocken: ASTM International, 2016.

7.3. MTS Technical Drawing 700-000-290 – “GL Extend 634.15-4X Long Post Install” Rev A.

7.4. MTS Technical Drawing 495732-01 – “Extensometer, Sm. Elastic Band Attachment Sys.” Rev A.

7.5. MTS Technical Drawing 700-001-693 – “Extensometer Model 643.25-2X Installation” Rev A.

7.6. MTS Technical Drawing 446065-01 – “Extensometer Spring & Elastic Band Attachment” Rev B.

8. RECORD OF REVISIONS

Revision	Date	Affected Pages	Description
0	2016-10-21	All	Initial Issue
1	2016-11-04	1 & 3	Corrected type-graphical error in gage length
2	2017-01-26	All	Revised procedure to align with steel coupon testing procedure.