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METHOD OF TESTS FOR MECHANICAL AND WELDED REINFORCING STEEL SPLICES

A. SCOPE

This method presents the testing procedures for determining mechanical properties of spliced ASTM A 706 and ASTM A 615 reinforcing steel.

B. REFERENCES

ASTM A 370/A 370M - Mechanical Testing of Steel Products
ASTM A 615/A 615M - Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement
ASTM A 706/A 706M - Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement
Caltrans Standard Specifications - Section 52, "Reinforcement"
Concrete Reinforcing Steel Institute - CRSI Manual of Standard Practice

C. APPARATUS

1. A tensile test machine able to apply a tensile force greater than the ultimate tensile strength of the sample. This machine must be accurate and calibrated in accordance with ASTM A 370.
2. A slip-measuring device consisting of two calibrated dial indicators that measure displacement across the splice to the nearest 0.001 in. A typical test set-up is shown in Figure 1a. The dial indicators may have an analog dial or be digital. Alternatively, extensometers accurate to within 0.001 in. can be used.
3. A calibrated caliper accurate to within 0.001 in.

D. DEFINITIONS

Affected Zone – portion of the reinforcing bar where any properties of the bar, including the physical, metallurgical, or material characteristics, have been changed.

Coupler – mechanical device that physically connects two reinforcing bars.

Lot – quantity of spliced reinforcing steel, as defined in the Caltrans Standard Specifications, Section 52.

Necking – localized reduction in cross-section that may occur in material under tensile stress. For this California Test, a sample has necking if the reduction in cross-section is visible, or if the sample has sufficient ductility as determined by the strain measurement in Section E, Part III.4.

Sample – spliced reinforcing steel bar that has the physical properties required in Section E, Part I.

Sample No. – unique tracking number assigned to the sample(s) or set of samples being tested.

Slip test – procedure for determining inherent axial displacement within the mechanical coupler.

Splice – physical device or mechanism for joining reinforcing steel, as defined in Caltrans Standard Specifications, Section 52. Mechanical non-lap splices and resistance welded splices are the most common types encountered. Per the Standard Specifications, splices can be service or ultimate butt splices.

Fracture - physical separation/breaking of the bar and/or mechanical coupler.

E. TEST PROCEDURES FOR PRODUCTION TESTING AND QUALITY ASSURANCE TESTING

PART I. PHYSICAL PROPERTIES AND PREPARATION

Each sample submitted for testing shall conform to the following requirements:

1. Sample length: For rebar sizes #9 and smaller, sample length must be at least 4 ft. For rebar sizes #10 and larger, sample length must be at least 6½ ft.
2. Test specimen length: The lab may shorten, machine, or otherwise alter the submitted samples' length to meet the configuration of its testing equipment within the following limits:
 - a. Mechanical splices: The minimum length of the test specimen between the grips of the tensile testing machine shall be equal to $8d + 16 \text{ in.} + L_c$, where L_c is the coupler length, and d is the nominal bar diameter. The coupler shall be located at the center of the test specimen.
 - b. Welded splices: The minimum length of the test specimen between the grips of the tensile testing machine shall be 28 in.
3. Coupler length: For ultimate splice mechanical couplers only, the length of the coupler must be less than 10 times the nominal bar diameter.
4. Alignment: With the exception of spliced hoops, the alignment across the splice must be straight to within 0.5 in. along any 3 ft of length of the sample.

PART II. SLIP TEST

The slip test is required for all mechanical splices except mechanical lap splices or splices that are used on hoops. There are two acceptable options for measuring slip.

1. Slip Test (Option I)

Option I requires the use of two dial indicators to measure displacement across the splice. Testing is performed as follows:

- a. Mount the sample in the tensile test machine.
- b. Attach the slip-measuring device so that the dial indicators are 180° apart as shown in Figure 1a. Figure 1a shows a typical test set-up. If this set-up is used, the vertical bars shall be securely attached with the hex socket bolts shown in Figure 1b.
- c. Once the measuring device is securely attached, release any restraining bars to allow free movement of the device. For the testing device shown in Figure 1a, this is done by removing the hex socket bolts from the bottom

end of the vertical bars as shown in Figures 2a and 2b. (Alternate test set-ups that permit accurate slip measurement are allowed.)

- d. Once the test set-up is complete, pre-stress the sample to 3,000 psi and then zero out the dial indicators.
- e. Apply an axial stress of 30,000 psi. Maintain this stress until a steady reading is obtained on both dial indicators.
- f. Reduce the stress to 3,000 psi and record the two dial indicator readings. Take an average of the two readings. This is the total slip. Record the total slip on the Test Form (Figure 3).
- g. Remove the slip-measuring device.

2. Slip Test (Option II)

Option II requires the use of punch marks to measure displacement across the splice. Testing is performed as follows:

- a. Place one set of punch marks that straddle the splice. The distance between the punch marks should be approximately equal to the coupler length plus four bar diameters. Using a permanent marker, label this side of the bar as "A." Place a second set of punch marks 180° apart from the first set and label that side of the bar as "B."
- b. Pre-stress the sample to 3,000 psi.
- c. Measure the distance between the punch marks to the nearest 0.001 in. and record these initial gage lengths on the Test Report Form (Figure 3).
- d. Apply an axial stress of 30,000 psi. Maintain this stress for 60 seconds.
- e. Reduce the stress to 3,000 psi and measure the final gage length between each set of punch marks. For each set, calculate the slip as follows:
$$\text{Slip (A, B)} = (\text{final gage length} - \text{initial gage length})$$
- f. Average the results. This is the total slip. Record the total slip on the Test Report Form (Figure 3).

PART III. TENSILE TEST

Tensile testing is required for all mechanical and welded splices and must be performed in accordance with ASTM A 370 as follows:

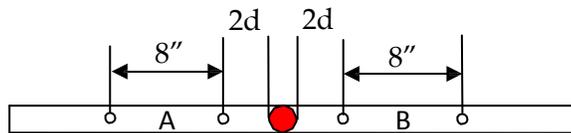
1. Apply an axial tensile load to the sample sufficient to cause fracture. (The ends of hoop samples should be straightened prior to testing in order to fit the sample into the testing grips. This straightening should be in accordance with the Concrete Reinforcing Steel Institute's Manual of Standard Practice MSP 1-90.)
2. Document the ultimate load obtained and the location of the fracture (bar, affected zone, or coupler) on the Test Report Form (Figure 3).
3. Calculate the ultimate tensile strength by dividing the ultimate load by the sample's nominal cross-sectional area. Record the ultimate tensile strength

on the Test Report Form (Figure 3).

4. For ultimate splices, check for necking. This can be done either visually (Option I) or by determining the strain value (Option II).
 - a. Necking (Option I)
 - 1) Examine the fractured area. If there is a visible decrease in the sample's cross-sectional area at the point of fracture, then there is visible necking. Record the results on the Test Report Form (Figure 3).
 - b. Necking (Option II)

Alternatively, assess necking by determining the sample's strain value following the procedure described below:

- 1) Welded Straight Splices:
 - a) For straight samples, place punch marks along the sides of the samples to create a total of two 8-inch gage lengths, one on each side of the weld. Leave a gap of at least two bar diameters between the weld splice and the 8-inch gage marks. Label these gage lengths as "A" and "B." (See figure below)



- b) Measure and record the initial length (L_o) of the two 8-inch gage lengths "A" and "B" to the nearest 0.001 in.
- c) Tensile test the sample following the procedure in Section E, Part III.
- d) Measure and record, to the nearest 0.001 in., the final gage length (L_f) on the side that did not fracture.
- e) Calculate the percent strain as follows:

$$\% \text{ strain} = [(L_f - L_o) / L_o] \times 100$$

where:

L_o = Initial gage length

L_f = final gage length

- f) Record the calculated percent strain on the Test Report Form (Figure 3).

2) Welded Hoops:

- a) For hoops, first determine the outside diameter of the hoop from submittal documents. Record this information on the Test Report Form (Figure 3). Next calculate the bar center to bar center hoop diameter (D) as follows:

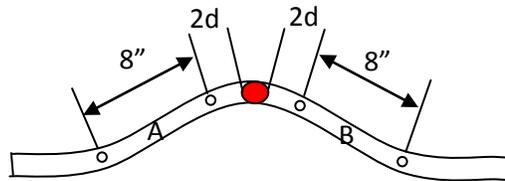
$$D = D_{od} - \text{bar nominal diameter}$$

where:

D = diameter of the hoop

D_{od} = hoop outside diameter

- b) Place punch marks along the sides of the samples (not along the concave or convex sides of the bar) to create a total of two 8-inch gage lengths, one on each side of the weld. Label these gage lengths as "A" and "B." Leave a gap of at least two bar diameters between the weld splice and the 8-inch gage marks. See figure below:



- c) Measure and record the initial length (L_o) of the two 8-inch gage lengths "A" and "B" to the nearest 0.001 in.
- d) Straighten the ends of the hoop samples to fit the sample into the testing grips. This straightening should be performed gradually, using bending rollers in accordance with the Concrete Reinforcing Steel Institute's Manual of Standard Practice MSP 1-90.
- e) Tensile test the sample following the procedure in Section E, Part III.
- f) Measure and record, to the nearest 0.001 in., the final gage length (L_f) on the side that did not fracture.
- g) Calculate the corrected final gage length (L_n) as follows:

$$L_n = L_f \times \text{correction factor}$$

where:

L_n = Corrected final gage length

L_f = final gage length

$$\text{correction factor} = \frac{L_{cd}}{D \left[\text{ArcSin} \left(\frac{L_{cd}}{D} \right) \right]}$$

where:

L_{cd} = Length of chord (8-inch nominal)

D = diameter of the hoop (rebar center to rebar center in inches)

ArcSin should be expressed in radians.

- h) Calculate the percent strain as follows:

$$\% \text{ strain} = [(L_n - L_o) / L_o] \times 100$$

where:

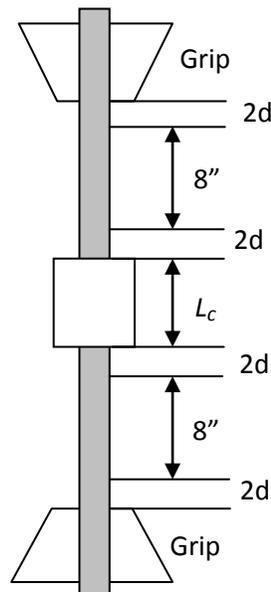
L_n = Corrected final gage length

L_o = Initial gage length

- i) Record the calculated percent strain on the Test Report Form (Figure 3).

3) Mechanical Splices:

- a) Place punch marks, to create 8-inch gage lengths on each side of the coupler. Leave a gap of at least two bar diameters between the 8-inch gage marks and the ends of the coupler/grips as shown in the figure below.



- b) Mark each of the 8-inch nominal gage lengths sequentially as "A" and "B."
- c) Individually, measure and record the initial (L_o) 8-inch gage lengths "A" and "B," to the nearest 0.001 in.
- d) Tensile test each sample following the procedure in Section E, Part III.
- e) Measure and record, to the nearest 0.001 in., the final gage length (L_f) on the side that did not fracture.
- f) Calculate the percent strain as follows:

$$\% \text{ strain} = [(L_f - L_o) / L_o] \times 100$$

where:

L_o = Initial gage length

L_f = final gage length

- g) Record the measured percent strain on the Test Report Form (Figure 3).

F. SUPPLEMENTARY TESTS FOR INCLUSION ON THE AUTHORIZED MATERIAL LIST

1. Cyclical Testing

- a. Cyclically load the sample from 5% to 90% of the specified yield strength (σ_y) of the sample for 100 cycles. Use a haversine waveform at 0.5 cycles per second (cps) for #10, #11, #14, and #18 bars, and a haversine waveform at 0.7 cps for smaller bars. Record whether or not the sample fractures.
- b. If sample does not fracture during the cyclical test, increase the axial tensile load until the sample fractures.
- c. If applicable, record the ultimate load, ultimate tensile strength, location of failure, and any necking on the Test Report Form (Figure 3).

2. Fatigue Testing

- a. Fatigue load the sample from + 25,000 psi to - 25,000 psi for 10,000 cycles. Use a sine waveform at 0.083 cps for #10, #11, #14, and #18 bars, and a sine waveform at 0.35 cps for smaller bars. Record whether or not the sample fractures.
- b. If the sample does not fracture during the fatigue test, increase axial tensile load until the sample fractures.
- c. If applicable, record the ultimate load, ultimate tensile strength, location of failure, and any necking on the Test Report Form (Figure 3).

G. REPORT

The Test Report Form shown in Figure 3 is the recommended form to report test results. Modification of this form is allowed as long as all the information listed in this figure is reported in the modified form.

H. HAZARDS

The test samples are heavy and may contain sharp edges or burrs. Sample fracture may involve brittle fractures and ejection of sample fragments. Use appropriate safety measures.

I. HEALTH AND SAFETY

It is the responsibility of the user of this test method to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. Prior to handling, testing or disposing of any materials, testers must be knowledgeable about safe laboratory practices, hazards and exposure, chemical procurement and storage, and personal protective apparel and equipment.

Caltrans Laboratory Safety Manual is available at:

http://www.dot.ca.gov/hq/esc/ctms/pdf/lab_safety_manual.pdf

**End of Text
(California Test 670 contains 13 pages)**



FIGURE 1a. Measuring device with dial indicators used for measuring slip.



FIGURE 1b. Close up of hex socket bolts used to hold the vertical bars during the set up of the measuring device.



FIGURE 2a. Close up of the removal of the hex socket bolts before testing.



FIGURE 2b. Measuring device ready for testing with bottom hex socket bolts removed.

TEST REPORT OF MECHANICAL SPLICES/WELDED BARS (Page 1 of 2)

Date Sampled: _____ Date Received: _____ Material: _____
 TL-101 No.: _____ Lot No.: _____ Sample No.: _____
 Contract No.: _____ Bar Size: _____ Manufacturer: _____
 Service /Ultimate?: _____ Splice Type: _____ Hoop Diameter: _____
 Date Tested: _____ Lab Technician: _____ Testing Machine: _____
 Sampler/Inspector: _____ Report Results To: _____

	Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4
Acceptable sample length?				
Coupler within 10 times the bar diameter?				
Sample properly aligned?				
<u>Slip Test Option I:</u>				
Caliper 1 reading:				
Caliper 2 reading:				
Total slip (in.)				
<u>Slip Test Option II:</u>				
Initial gage length, Side A:				
Final gage length, Side A:				
<i>Calculated slip, Side A:</i>				
Initial gage length, Side B:				
Final gage length, Side B:				
<i>Calculated slip, Side B:</i>				
Total Slip (Avg. Side A + B)				
<u>TENSILE TEST:</u>				
Bar nominal area (sq. in.)				
Ultimate load (lbs)				
Ultimate tensile strength (psi)				
<u>Necking Option I:</u>				
Visible Necking?				
Location of fracture?				
<u>Necking Option II:</u>				
<u>A. Straight Sample:</u>				
<u>Side A:</u>				
Initial gage length (Side A)				
Final gage length (Side A)				
% Strain (Side A)				

FIGURE 3. Test Report Form

TEST REPORT OF MECHANICAL SPLICES/WELDED BARS (Page 2 of 2)

	Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4
<u>Side B:</u>				
Initial gage length (Side B)				
Final gage length (Side B)				
% Strain (Side B)				
<u>B. Hoops:</u>				
Outside hoop diameter				
Bar nominal diameter				
Hoop diameter (D) - (bar center to bar center)				
<u>Side A:</u>				
Initial gage length (Lo), Side A:				
Final gage length (Lf), Side A:				
Correction factor				
Corrected final gage length (Ln), Side A				
% Strain (Side A)				
<u>Side B:</u>				
Initial gage length (Lo), Side B:				
Final gage length (Lf), Side B:				
Correction factor				
Corrected final gage length (Ln), Side B				
% Strain (Side B)				
<u>CYCLICAL TESTING:</u>				
Specimen fractured?		n/a	n/a	n/a
<u>FATIGUE TESTING:</u>				
Specimen fractured?	n/a		n/a	n/a

Samples pass.

Samples fail, because: _____

 Approved by Quality / Lab Manager

FIGURE 3. Test Report Form



FIGURE 4. Digital calipers used to measure initial gage length to the nearest 0.001”.