DEPARTMENT OF TRANSPORTATION
DIVISION OF ENGINEERING SERVICES
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METHOD OF TESTS FOR MECHANICAL AND WELDED REINFORCING STEEL SPLICES

CAUTION: Prior to handling test materials, performing equipment setups, and/or conducting this method, testers are required to read "**SAFETY AND HEALTH**" in Section G of this method. It is the responsibility of the user of this method to consult and use departmental safety and health practices and determine the applicability of regulatory limitations before any testing is performed.

A. SCOPE

This method presents the testing procedures for determining mechanical properties of spliced reinforcing steel.

B. DEFINITIONS

Coupler – mechanical device that physically connects two reinforcing bars.

Lot – quantity of spliced reinforcing steel, as defined in 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 D below.

Sample – spliced reinforcing steel bar that has the physical properties required in Section D below.

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.

C. TESTING APPARATUS AND ACCESSORIES

1. Tensile test machine able to apply a tensile force greater than the ultimate tensile strength of the sample. Tensile test machine must be accurate in accordance with ASTM A 370.
2. Slip measurement device consisting of two dial indicators that measure displacement across the splice to the nearest 0.025 mm. See Figure 1. A dial indicator may have an analog dial or be digital. Alternatively, an extensometer accurate to within 0.025 mm.
3. Caliper accurate to 0.025 mm.

D. TEST PROCEDURES FOR PRODUCTION TESTING AND QUALITY ASSURANCE TESTING

PHYSICAL PROPERTIES AND PREPARATION

Before accepting samples, ensure each sample has these physical parameters:

1. Sample length. A minimum sample length is required for the submitted samples. Depending on a lab's specific testing equipment, the lab may shorten, machine, or otherwise alter the submitted samples to meet the configuration of its testing equipment. This alteration is allowable under this Test Method and *Standard Specifications* Section 52.
   For rebar sizes #25 and smaller, sample length must be at least 1.5 m. For rebar sizes #29 and larger, sample length must be at least 2 m.
2. Coupler diameter. For mechanical couplers, length of the coupler must be less than 10 times the nominal bar diameter.
3. Alignment. With the exception of spliced hoops, the alignment across the splice must be straight to within 7 mm in 0.9 m of length.

Record results on the Test Form (Figure 2).

SLIP TEST

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

Slip Test (Option I)

Option I uses two dial indicators that measure displacement across the splice. Steps:

1. Mount the sample in the tensile test machine.
2. Preload the sample to 4 MPa to set the jaws on the bar ends. Attach the slip measurement device so that the dial indicators are 180° apart. Zero them out.
3. Apply an axial stress of 200 MPa. Maintain load until obtaining a steady reading on both dial indicators.
4. Reduce the stress to 20 MPa and measure the two readings. Sum the value of the two readings and divide the resultant sum by two. This is the total slip. Record the total slip on the Test Form (Figure 2).
5. Remove the two dial indicators.

Slip Test (Option II)

The second option for measuring slip (Option II) uses punch marks. Steps:

1. Place one set of punch marks that span the splice. The distance between the punch marks should be approximately equal to the coupler length plus four bar diameters. Place a second set of punch marks 180° apart from the first set.
2. Preload the sample to 4 MPa to set the jaws on the bar ends.
3. Measure distance between the punch marks to the nearest 0.025 mm.
4. Apply an axial stress of 200 MPa. Maintain the load for 60 seconds.
5. Reduce the stress to 20 MPa and measure the distance between each set of punch marks. For each set, calculate the slip (measured length – original length) and average the results. This is the total slip. Record result on the Test Form.

TENSILE TEST

Tensile testing must be done in general accordance with ASTM A 370 Sections 13 and A9.

1. Apply an axial tensile load to the sample sufficient to cause failure.
2. Document the maximum load obtained.
3. Calculate the ultimate tensile strength by dividing the maximum load by the sample's nominal cross-sectional area. ASTM A 706, Table 1, provides the nominal cross-sectional areas for A 706 reinforcing steel. Record the ultimate tensile strength on the Test Form.
4. Check for necking. This can be done visually (Option I) or by measuring strain (Option II). Also, it does not matter which option was used for the slip test when choosing an option to assess necking.

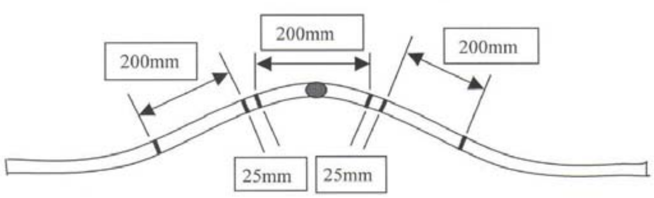
Necking (Option I)

Examine the fractured area. If there is a visible decrease in the sample's cross-sectional area at the point of fracture, there is visible necking. Record result on the Test Form.

Necking (Option II)

Alternatively, assess necking by measuring the sample's strain. Follow this procedure for measuring strain:

a. For straight samples, place punch marks along the sample to create three gauge lengths with a nominal length of 200 mm. For hoops, place punch marks along the sides of the hoop rebar samples (not the concave or convex sides of the bar) to create a total of three gauge lengths, each 200 mm in length. For both straight samples and hoops, leave a gap of at least 25 mm between any two 200 mm gauge lengths to separate the gauge marks. Splices, if any, shall be centered in the middle 200 mm gauge length. See figure below:



b. Do not confuse these punch marks with the punch marks that may have been placed for the slip test.
c. Straight samples are tested as received. For hoops, straighten the ends of hoop samples to fit sample into the testing grips. This straightening should be outside of the gauge marks, in accordance with the Concrete Reinforcing Steel Institute's *Manual of Standard Practice MSP-1-90*.
d. Mark each one of the 200 mm nominal gauge lengths sequentially as A, B, C. B designates the middle segment and it contains the splice, if any.
e. Individually, measure and record the initial three 200 mm gauge lengths A, B, and C to the nearest 0.025 mm.
f. Tensile test each sample following the instructions in "Tensile Test" above.
g. Measure the two gauge lengths not encompassing the location of failure. For hoop samples, correct the final gauge length values for curvature by multiplying the final readings by this factor:

corrected gauge (L_n) =
*measured gauge * factor*

$$factor = \frac{L_c}{D * ArcSin\left(\frac{L_c}{D}\right)}$$

where:

L_c = length of chord (200 mm nominal)
D = diameter of the hoop (rebar center to rebar center in mm)
L_n = corrected gauge length (in mm)
ArcSin is in radians

h. Calculate the percent strain for each one of the gauge lengths measured in step g. For straight samples:

$$\% \; strain = (L_f - L_o)/L_o * 100$$

where:

L_f = final gauge length
L_o = original gauge length

For hoop samples:

$$\% \; strain = (L_n - L_o)/L_o * 100$$

where:

L_n = corrected gauge length
L_o = original gauge length

i. If the largest measured strain is $\geq$ 6% for #36 and larger bars, or $\geq$ 9% for #32 and smaller bars, then the sample is considered to have necking. If the largest measured strain is < 6% for #36 and larger bars, or < 9% for #32 and smaller bars, then the sample is considered to have no necking.

j. Record the largest measured strain on the Test Form.

CYCLICAL TESTING

This section applies only to mechanical splices on straight reinforcing steel:

1. Cyclically load the sample from 5% σ_y to 90% σ_y for 100 cycles. Use a haversine waveform at 0.5 cps for #36, #43, and #57 bars, and a haversine waveform at 0.7 cps for smaller bars.
2. If sample has not failed, increase axial tensile load to cause failure.
3. On the Test Form, record whether or not the sample passed the cyclical testing and, if applicable, the ultimate tensile strength, location of failure, and any necking.

FATIGUE TESTING

This section applies only to mechanical splices on straight reinforcing steel:

1. Fatigue load the sample from + 173 MPa to - 173 MPa for 10,000 cycles. Use a sine waveform at 0.083 cps for #36, #43, and #57 bars, and a sine waveform at 0.35 cps for smaller bars.
2. If sample has not failed, increase axial tensile load to cause failure in the sample.
3. Record whether or not the sample passed the fatigue testing and, if applicable, the ultimate tensile strength, location of failure, and any necking.

CONTROL BARS

Control bars must comply with the requirements in Caltrans *Standard Specifications* Section 52.

1. Apply an axial tensile load to the sample sufficient to cause failure.
2. Note the maximum load obtained and record on the Test Form.
3. Calculate the ultimate tensile strength by dividing the maximum load by the sample's nominal cross-sectional area. Record on the Test Form.

E. REPORT

The Test Form shall report the following information, as necessary for the user:

1. Date sampled
2. Date received
3. Date tested
4. Sample no.
5. Lot no.
6. Contract no.
7. Person results reported to
8. Material
9. Bar size
10. Manufacturer
11. Splice type
12. Sampler or inspector
13. Results.

F. HAZARDS

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

G. SAFETY AND HEALTH

Prior to handling, testing or disposing of any waste materials, testers are required to read the *Caltrans Laboratory Safety Manual*. Users of this method do so at their own risk.

REFERENCES:

ASTM Designations A 370 and A 706; Caltrans Standard Specifications Section 52; Concrete Reinforcing Steel Institute's Manual of Standard Practice MSP-1-90.

End of Text
(California Test 670 contains 7 pages)

Figure 1. Example of dial indicators used for measuring slip.

Figure 2. Test Form

Date sampled:	______________	Sample No.	______________
Date received:	______________	TL-101 No.	______________
Date tested:	______________	Contract No.	______________
Sampler/inspector:	______________	Lot No.	______________
Report to:	______________	Material:	______________
Lab technician:	______________	Bar size:	______________
Contract No.	______________	Manufacturer:	______________
Service or Ultimate?	______________	Splice type:	______________

	Sample No. 1	**Control No. 1**	**Sample No. 2**	**Control No. 2**	**Sample No. 3**	**Control No. 3**	**Sample No. 4**	**Control No. 4**
Sample long enough?								
Coupler not longer than 10 times the bar diameter?		n/a		n/a		n/a		n/a
Sample straight enough?								
Total slip (μm)		n/a		n/a		n/a		n/a
Passed cyclical?		n/a	n/a	n/a	n/a	n/a	n/a	n/a
Passed fatigue?	n/a	n/a		n/a	n/a	n/a	n/a	n/a
Ultimate tensile strength (MPa):								
95% of tensile strength (MPa):	n/a		n/a		n/a		n/a	
Strain (%)								
Necking?								

[] Samples pass.

[] Samples fail, because ____

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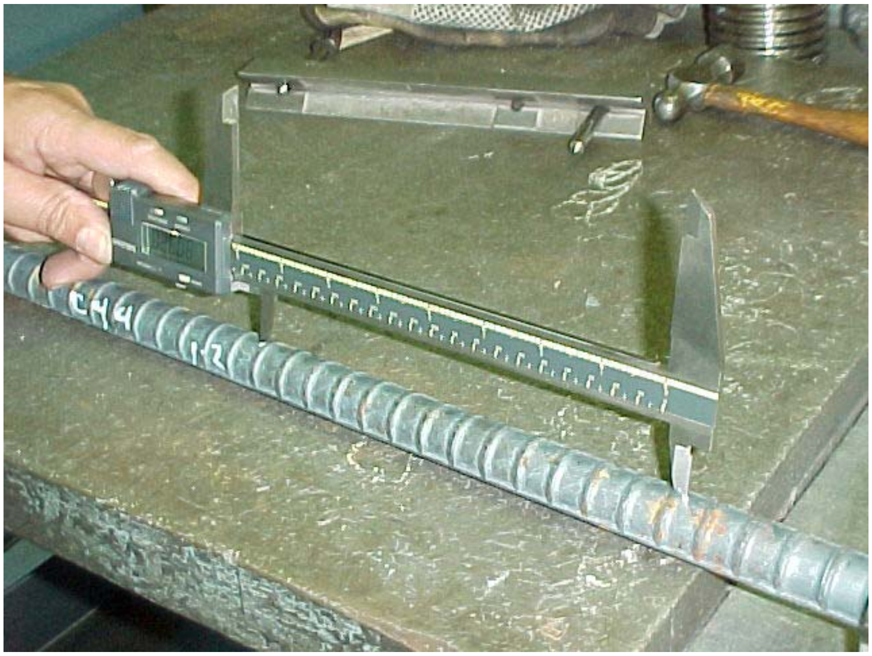

Figure 3. Digital calipers used to measure initial gauge length to the nearest 0.025 mm.