



Standard Test Methods for Testing Mechanical Splices for Steel Reinforcing Bars¹

This standard is issued under the fixed designation A1034/A1034M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 These test methods cover the testing of mechanical splices for reinforcing bars. The various tests herein described can be specified in total or individually.

1.2 The test methods herein described are applicable to any type of mechanical splice manufactured to join steel reinforcing bars of any grade (specified minimum yield strength), uncoated or coated.

1.3 This standard describes only the methods for testing mechanical splices for steel reinforcing bars, but does not quantify the parameters for testing nor acceptance criteria, which must be specified.

NOTE 1—Various code-writing bodies specify various parameters, such as test loads, number of cycles and test temperature, for testing.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:²

- A370 Test Methods and Definitions for Mechanical Testing of Steel Products
- E4 Practices for Force Verification of Testing Machines
- E8 Test Methods for Tension Testing of Metallic Materials
- E9 Test Methods of Compression Testing of Metallic Materials at Room Temperature
- E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
- E83 Practice for Verification and Classification of Extensometer Systems
- E466 Practice for Conducting Force Controlled Constant Amplitude Axial Fatigue Tests of Metallic Materials
- E467 Practice for Verification of Constant Amplitude Dynamic Forces in an Axial Fatigue Testing System

¹ These test methods are under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and are the direct responsibility of Subcommittee A01.05 on Steel Reinforcement.

Current edition approved Dec. 1, 2015. Published December 2015. Originally approved in 2004. Last previous edition approved in 2010 as A1034/A1034M – 10a. DOI: 10.1520/A1034_A1034M-10AR15.

² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 *bar-splice assembly*—an assembled specimen consisting of two reinforcing bars connected with a mechanical splice.

3.1.2 *clip gage*—an electrical device used to measure small displacements in test specimens whose voltage output is convertible into strain.

3.1.3 *coupler*—threaded device for joining reinforcing bars for the purpose of providing transfer of either axial compression or axial tension or both from one bar to the other.

3.1.4 *coupling sleeve*—non-threaded device for joining reinforcing bars for the purpose of providing transfer of either axial compression or axial tension or both from one bar to the other.

3.1.5 *data acquisition system*—a computer based data logging system to record the output of electrical transducers reporting load, strain or displacement.

3.1.6 *differential elongation*—the difference between the total movement measured on the splice specimen from zero load to a predetermined test load and the total movement measured on an unspliced bar specimen under the same predetermined load.

3.1.7 *linear variable differential transformer (LVDT)*—an electrical device used to measure displacements, whose voltage output is convertible into strain.

3.1.8 *mechanical splice*—the complete assembly of a coupler or a coupling sleeve and possibly additional intervening material or other components to accomplish the splicing of two reinforcing bars.

3.1.9 *slip*—the difference in extensometer readings over the gage length across the splice, measured at an initial nominal

zero load and, after having loaded the bar-splice assembly to a test load and unloaded it again, at the same nominal zero load.

3.1.10 *splice components*—all components that make up a mechanical splice for reinforcing bars, including coupler, coupling sleeve, locknuts, bolts, grout, epoxy, ferrous filler metal and/or other components.

4. Summary of Test Method

4.1 Various test methods are used to determine the performance of a mechanical splice under loading.

4.1.1 *Monotonic Tension Test*—This test measures the performance of the bar-splice assembly under an increasing tension load. The specimen is placed in the testing machine and pulled to failure.

NOTE 2—Testing of specimens in tension to failure should be approached with caution. Some types of mechanical splices may shatter while failing in tension.

4.1.2 *Monotonic Compression Test*—This test is used to ascertain the performance of the bar-splice assembly under an increasing compressive load. The specimen is placed in the testing machine and is loaded in compression until failure or a specified load is applied.

NOTE 3—Typical maximum compressive load imposed in this test is 125 % of the specified yield strength of the reinforcing bar. Testing of specimens in compression should be approached with caution. The buckling load predicted by Euler Column formula may be less than the compression load specified.

4.1.3 *Cyclic Load Test*—This test is used to ascertain how the bar-splice assembly performs when the specimen is subjected to alternating tension and compression cycles. The specimen is placed in the testing machine and is loaded in tension, then in compression until the specified number of cycles is reached. Each cycle may exceed the yield strain of the bar and is intended to simulate the demands of earthquake loading on the specimen.

4.1.4 *High-Cycle Fatigue Test*—This test is conducted with alternating tension load cycles or alternating tension to compress load cycles, with the load staying below the yield strength of the reinforcing bar. This test is conducted until failure or a specified number of cycles are reached and simulates the demands on mechanical splices placed in bridges or other structures subjected to frequent elastic load cycles.

4.1.5 *Slip Test*—This test is used to ascertain the plastic movement (slip) between reinforcing bars within the bar-splice assembly, when loaded in tension.

4.1.6 *Low-Temperature Test*—This test is run using the test methods described in 4.1.1 through 4.1.5, to ascertain the behavior of the bar-splice assembly under low temperatures.

4.1.7 *Combination Tests*—Features of one or more of the test methods described in 4.1.1 through 4.1.6 can be combined.

5. Significance and Use

5.1 Significance:

5.1.1 The bar-splice assembly test specimen shall closely represent the mechanical splice used in practice. The behavior of the bar-splice assembly embedded in concrete, however, may differ from its behavior during testing where it is not embedded in concrete.

5.2 Usefulness:

5.2.1 Testing of mechanical splices for reinforcing bars shall establish the behavior of the bar-splice assembly under the loading conditions described herein for the various test methods to determine the acceptability of the mechanical splice for use in reinforced concrete structural members under specific design criteria.

5.3 Interpretation of Test Results:

5.3.1 Similar or better performance of mechanical splices installed in structural members shall be expected only if materials and methods of assembly are similar to the materials and methods used in the tests.

6. Apparatus

6.1 Equipment:

6.1.1 A suitable testing machine or load frame shall be used. The test apparatus shall have sufficient capacity to prevent yielding of its components and shall ensure that the applied tension loads or compression loads or both remain parallel to the axis of the test specimen during testing. The equipment shall be capable of applying cyclic loads within the time periods specified herein for the individual tests.

6.2 Load Measurements:

6.2.1 The load in the specimen shall be measured by load cell or other external load measuring method. The load cell shall be capable of providing electronic output of load measurements and sending to a data acquisition system for later data reduction. If a data acquisition system is used, it shall be capable of recording at least one measurement per second. Strain gages or other instrumentation that may be damaged or lose accuracy when the bar yields shall not be used to measure force.

6.2.2 It shall be permissible to mark bars and couplers or coupling sleeves with punch marks, or other legible scribe or stylus markings for measuring elongation at post yield rupture.

6.2.3 The loading systems shall be calibrated in accordance with Practices E4.

6.3 Elongation Measurements:

6.3.1 The displacements of the reinforcing bar ends within the coupler or coupling sleeve, as well as elastic and plastic deformations in the reinforcing bar and coupler or coupling sleeve materials, shall be measured, if required, using a mechanical extensometer or an LVDT, clip gage or other electronic means. The equipment need only be capable of measuring the sum of all displacements and elongations. The elongation measuring devices shall be at least of Class C, in accordance with Practice E83.

6.3.2 The motion of the testing machine grips or cross head shall not be used for determining specimen elongation.

6.4 Compression Test Measurements:

6.4.1 Unless otherwise specified, it shall not be required to monitor strain in monotonic compression tests.

NOTE 4—Only the compressive strength of the test specimen is of interest for evaluating a mechanical splice in compression and not the strain.

7. Materials

7.1 Steel Reinforcing Bars:

7.1.1 The minimum yield strength (grade) of the reinforcing bars shall be specified. The pattern and the dimensional aspects of the reinforcing bar deformations shall be representative of the bars used in practice.

7.2 Splice Components:

7.2.1 The couplers or coupling sleeves and any other components needed for the proper functioning of the mechanical splice shall correspond to the size and specified minimum yield strength (grade) of the reinforcing bars tested.

7.3 Mechanical properties of the splice components used in the test shall be documented prior to testing of the bar-splice assembly. Certified mill test reports shall be considered adequate proof of these properties. Properties to be documented for these components shall include the yield and tensile strength, as well as the ultimate elongation. For components made by forging or casting, a chemical analysis and hardness tests shall be considered to be sufficient.

8. Sampling and Test Specimens

8.1 Sampling:

8.1.1 The samples for one series of tests of the reinforcing bars, as well as the mechanical splice components, shall be selected from the same respective heat of steel.

NOTE 5—Using samples from the same respective heat permits an improved statistical evaluation of the test results.

8.1.2 Testing of mechanical splices from different heats of steel shall be permitted, unless otherwise specified.

8.1.3 The reinforcing bar segments within a test specimen shall be nominally of equal length and shall be clean and free of surface imperfections that would cause the sample to fail to conform to either the specified tensile or the specified bending requirements.

8.1.4 The heat numbers, mill certificates and essential dimensions of all splice components used in the test shall be documented.

8.2 Specimen Length:

8.2.1 The length of the reinforcing bar segment for tension and cyclic load tests shall be chosen such that there is sufficient space in between the cross beams of the testing machine and either side of the coupler or coupling sleeve to allow the attachment of the elongation measuring device at a distance equal to one to three bar diameters from the coupler or coupling sleeve on each side, plus sufficient clearance and gripping length.

8.2.2 The length of compression test specimens shall be such that the distance between the ends of the coupler or coupling sleeve and the grips does not exceed one bar diameter.

8.3 Specimen Preparation:

8.3.1 The test specimens shall be prepared following the splice manufacturer's recommendations for the type of steel, minimum yield strength (grade) and size of the reinforcing bar, for which the mechanical splice is being tested.

NOTE 6—Construction project conditions that may affect the performance of certain types of mechanical splices include the position of the

splice during assembly (vertical, diagonal or horizontal position), temperature, humidity, degree of rusting on the reinforcing bar, and bar end preparation.

8.3.2 The mechanical splice shall be installed on the bar ends in accordance with the splice manufacturer's recommendations and safety instructions. The amount of torque or other means for installing the splice shall be measured and recorded.

8.3.3 Mechanical splices where grout or other cementitious or epoxy material is used to secure the reinforcing bars within the splice shall be prepared in conformance with the splice manufacturer's requirements. Curing of the grout material shall be conducted in conformance with the splice manufacturer's requirements.

9. Conditioning

9.1 When low-temperature testing is required, the splice specimens shall be cold soaked for a minimum of 24 h prior to testing at a temperature equal to or less than the temperature specified for this test.

NOTE 7—Some Building Codes require such testing on mechanical splices.

10. Test Procedures

10.1 Test Set-up:

10.1.1 The test specimen shall be placed into the testing machine such that tension and/or compression loads can be applied axially and without any eccentricity. The ends of the specimen shall be held in the test machine such that tension loads or compression loads or both can be applied to the specimen without movement of the specimen within the grips of the test apparatus.

10.1.2 Suitable means for avoiding buckling of the test specimen under compression loads shall be employed.

10.1.3 At least two elongation measuring devices (extensometers), that continuously monitor elongation, equally spaced around the test specimen, shall be attached to the reinforcing bars next to the coupler or coupling sleeve such that the resulting total gage length equals the length of the coupler or coupling sleeve plus two to six bar diameters. A suitable test set-up is shown in Fig. 1.

10.1.4 If required for the test, additional extensometers shall be placed on the coupler or coupling sleeve or the reinforcing bar segments at one or both ends of the mechanical splice or both.

10.1.5 Gages for measuring compressive strain in monotonic compression tests shall not be required.

10.1.6 Testing of specimens, which use components that need time to cure, shall not commence before these components have reached sufficient strength.

10.2 Baseline Tension Test:

10.2.1 A tension test shall be conducted on a reinforcing bar of the same size and heat of steel as those used in the bar-splice assembly specimens. The stress-strain behavior of the reinforcing bar shall be recorded in accordance with the provisions of Test Methods A370, including the yield and tensile strength of the bar. If specified, the strain shall be measured at the determined or specified yield strength. If the reinforcing bar tested does not have a well-defined yield point, the yield

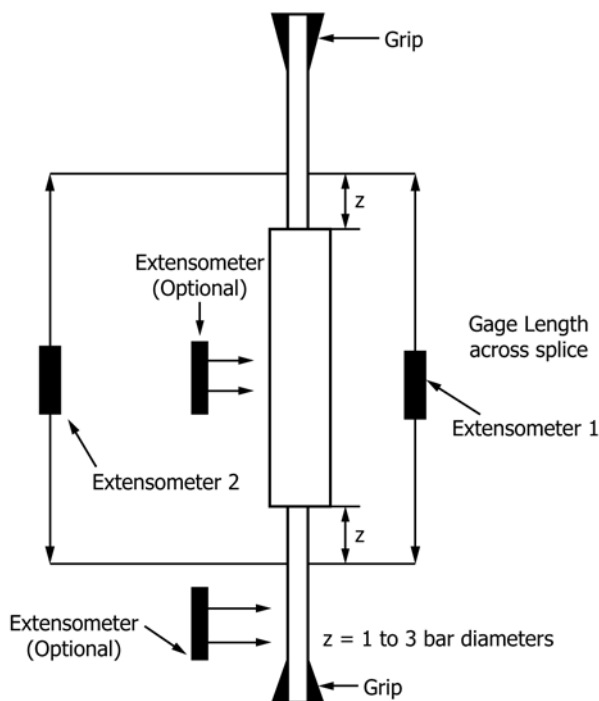


FIG. 1 Specimen Set-up and Gage Length

strength shall be determined in accordance with the instructions of Test Methods A370, Annex 9.

10.3 Monotonic Tension Tests:

10.3.1 Monotonic tension tests shall be conducted in accordance with the provisions of Test Methods A370. Up to the yield point, loads shall be applied at a rate between 70 MPa/min (10 ksi/min) and 700 MPa/min (100 ksi/min).

10.3.2 The elongation of the test specimen shall be measured and recorded continuously.

10.3.3 Tests shall proceed until the load in the test specimen reaches the yield strength of the bar. After yield, the test can be paused to remove any instrumentation that could be damaged. The test shall then continue to failure. Post yield loading rates shall be in accordance with the provisions of Test Methods E8, section 7.6, unless otherwise specified.

NOTE 8—Rugged instruments that can remain mounted to the specimen up to and through failure are commercially available. Care needs to be exercised to ensure the safety of the personnel witnessing the test.

10.4 Monotonic Compression Tests:

10.4.1 Monotonic compression tests shall be conducted in accordance with the provisions of Test Methods A370 and E9. For strain rate controlled tests, the load shall be applied in accordance with Section 8.7 of Test Methods E9. For machines with loading rate control or with cross head speed control, the specimen shall be loaded at a minimum strain rate equal to 0.005/min in the elastic range.

NOTE 9—Care needs to be exercised to ensure the safety of the personnel witnessing the test.

10.4.2 Testing shall proceed until the compressive load in the specimen reaches that specified.

10.5 Cyclic Load Test:

10.5.1 The test specimen shall be loaded following the provisions of 10.3.1 and 10.3.2 until the strain specified has been reached.

10.5.2 The crosshead loading direction shall be reversed until the specimen has reached the compressive loads specified. The loading rate shall conform to 10.4.1. After reaching yield, the test specimen shall be loaded at the strain rates and the strain ranges specified.

NOTE 10—As with the compression testing, care needs to be exercised to ensure the safety of the personnel witnessing the test.

10.5.3 The specimen shall then be reloaded in tension to the specified tensile strain and then loaded in compression again. This procedure shall be repeated until the specified number of cycles at this maximum tensile strain is completed.

10.5.4 This procedure shall be repeated for each strain group increment until all of the tension-compression cycles for all strain group increments specified have been completed.

NOTE 11—Various code bodies or regulatory agencies have developed standards for cyclic testing. These standards may differ in the exact nature of the testing and in the acceptance criteria.

10.5.5 Following the last cycle, the specimen shall be loaded to failure in tension.

10.6 High-Cycle Fatigue Test:

10.6.1 The test specimen shall be loaded to the upper tensile stress specified following the provisions of 10.3.1.

10.6.2 The tensile force then shall be decreased to the lower tensile or compressive force specified.

10.6.3 For cyclic fatigue tests of 10 000 cycles or less, in the absence of a specified wave form and frequency, a sinusoidal wave form shall be used with a frequency of 0.5 Hz for No. 36 (No. 11) and larger diameter bars and 0.7 Hz for smaller bars. The varying stress amplitude, as determined by a suitable dynamic verification (see Practice E467), should be maintained at all times within 2 % of the desired test value.

10.6.4 This procedure shall be repeated until the number of cycles specified has been reached.

10.6.5 Following cyclic loading, the specimen shall be tested in tension to failure.

10.6.6 For cyclic fatigue tests with greater than 10 000 cycles, in absence of a specified wave form and frequency, the test shall be conducted in accordance with the guide lines of Practice E466.

10.7 Slip Test:

10.7.1 The bar-splice assembly shall be loaded in tension to a nominal zero load, not exceeding 4 MPa (600 psi). A zero extensometer reading over the gage length across the splice shall be taken at that point and recorded.

10.7.2 The bar-splice assembly shall then be loaded in tension to a predetermined load. The loading rate shall conform to 10.3.1.

10.7.3 The specimen shall then be unloaded to the same near zero load and the extensometer measured and recorded.

10.7.4 The difference between the extensometer readings recorded at the near zero load under 10.7.3 and under 10.7.1 shall be recorded as slip within the bar-splice assembly.

10.8 *Differential Elongation Test:*

10.8.1 Differential elongation tests shall be carried out without any preloading of the test specimens.

10.8.2 The bar-splice assembly shall be loaded in tension to a predetermined load. The loading rate shall conform to 10.3.1. The elongation of the specimen shall be measured over the gage length shown in Fig. 1 and recorded at this point.

10.8.3 A reinforcing bar of the same size and heat shall be loaded in tension to the same predetermined load, following the loading rate as in 10.3.1. The elongation of the specimen shall be measured over the same gage length as in the test performed under 10.8.2 and recorded at this point.

10.8.4 The difference between the elongation measured under 10.8.2 and the elongation measured under 10.8.3 shall be recorded as differential elongation.

10.9 *Low-Temperature Test:*

10.9.1 When low-temperature testing is required, the temperature at the critical zone shall be maintained at the test temperature until the test has been completed.

11. Report

11.1 A report shall be prepared with the data obtained from the tests. Certification of the report shall be provided in accordance with the specified requirements.

11.2 The report shall contain summaries for each test including the following data:

11.2.1 Date of test and report.

11.2.2 Type, size and grade of steel of each component of the specimen tested. Mill certificates shall be included.

11.2.3 Manufacturer and lot identification of reinforcing steel bar, coupler or coupling sleeve and any additional components.

11.2.4 Type of testing machine and displacement measuring devices used. A copy of the testing machine calibration certificate shall also be included when specified.

11.2.5 Description of the test specimen assembly and any deviations from the fabrication of the test specimen and the specifications for the test procedure.

11.2.6 Performance data in the form of graphs and summaries of maximum load and elongation values, including gage lengths, shall be reported using Practice E29. Further, loading rates, unit strains and test temperature shall be reported. Graphical data shall include plots of load versus elongation across the splice. If additional extensometers have been placed on the reinforcing bar, coupler or coupling sleeve, then load versus elongation plots also shall be provided for these additional data.

11.3 Electronic data shall be furnished, as requested, in ASCII or other acceptable format.

11.4 The testing laboratory shall retain copies of the report and data for a minimum of five years.

11.5 Test Report or similar documents printed from or used in electronic form from an electronic data interchange (EDI) transmission shall be regarded as having the same validity as a counterpart printed in the certifier's facility. The content of the EDI transmitted document must conform to any existing EDI agreement. Notwithstanding the absence of a signature, the organization submitting the EDI transmission is responsible for the content of the report.

NOTE 12—The industry definition as invoked here is: EDI is the computer-to-computer exchange of business information in a standard format such as ANSI ASC X12.

12. Precision and Bias

12.1 No statement is made on the precision or bias of this test method, since the test results indicate only whether there is conformance to given criteria and since no generally accepted method for determining precision and use of the results of this test for mechanical splices embedded in concrete is currently available.

13. Keywords

13.1 bar splicing; mechanical splices; reinforced concrete; reinforcing bars; reinforcing bar testing

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