



# Standard Test Methods for Testing Multi-Wire Steel Prestressing Strand<sup>1</sup>

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## 1. Scope

1.1 These test methods describe procedures for testing the mechanical properties of multi-wire steel prestressing strand.

1.2 These test methods are intended for use in evaluating specific strand properties prescribed in specifications for multi-wire steel prestressing strand, but they do not quantify acceptance criteria specified in the applicable specification for the strand being tested.

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. 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.

1.4 *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:*<sup>2</sup>

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

E4 Practices for Force Verification of Testing Machines

E83 Practice for Verification and Classification of Extensometer Systems

E328 Test Methods for Stress Relaxation for Materials and Structures

## 3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

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

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<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

3.1.1 *breaking strength, n*—maximum force at or after which one or more wires fracture.

3.1.2 *free span, n*—the distance between the gripping jaws occupied by the length of strand to be tested in which the strand is not contacted or detrimentally influenced by the gripping system.

3.1.3 *lay length, n*—the axial distance required to make one complete revolution of any wire of a strand.

3.1.4 *strand, n*—a group of two, three or seven steel wires wound together in a helical form with uniform lay length of not less than 12 and not more than 16 times the nominal diameter of the strand.

3.1.5 *yield strength, n*—measured force at 1.0 % extension under load (EUL).

## 4. Significance and Use

4.1 The breaking strength and elongation of the strand are determined by one or more tensile tests in which fracture of the specimen ideally occurs in the free span.

4.2 Mechanical properties of the strand will be negatively affected if proper care is not taken to prevent damage such as severe bending, abrasion, or nicking of the strand during sampling.

4.3 Premature failure of the test specimens may result if there is appreciable notching, cutting, or bending of the specimen by the gripping devices of the testing machine.

4.4 Errors in testing will result if the wires constituting the strand are not loaded uniformly.

4.5 The mechanical properties of the strand will be materially affected by excessive heating during test specimen collection or preparation.

## 5. Apparatus

5.1 Tensile testing machine calibrated in accordance with Practices E4.

5.2 Class B-1 extensometer as described in Practice E83.

5.3 Class D extensometer as described in Practice E83; alternately, a linear dial gauge or ruler with precision of  $\pm 1/16$  in. [1.5 mm].

## 6. Sampling

6.1 Unless otherwise specified in the applicable specification for the strand being tested, test specimens shall be taken from the finished strand prior to packaging. The number of test specimens shall be taken as specified in the applicable specification for the strand being tested.

## 7. Gripping Devices

7.1 Due to inherent physical characteristics of individual tensile testing machines, it is not practical to recommend a universal gripping method that is suitable for all tensile testing machines. Therefore, it is necessary to determine which of the methods of gripping described in 7.1.1 – 7.1.3 is most suitable for the tensile testing machine available. The gripping devices shall be designed such that during testing the load is distributed along the entire length of the grips. The minimum effective gripping length should be equal to or greater than the lay length of the strand.

7.1.1 *Standard V-Grips with Serrated Teeth (Note 1).*

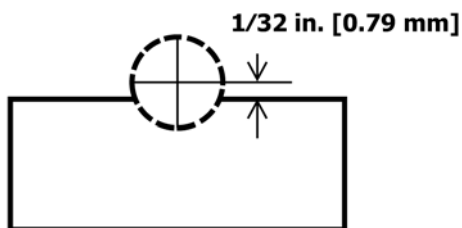
7.1.2 *Standard V-Grips with Serrated Teeth (Note 1), Using Cushioning Material*—In this method, material is placed between the grips and the test specimen to minimize the notching effect of the teeth. Materials that have been used include, but are not limited to lead foil, aluminum foil, carborundum cloth, and brass shims. The type and thickness of material required is dependent on the shape, condition, and coarseness of the teeth.

7.1.3 *Special Grips with Smooth, Semi-Cylindrical Grooves (Note 2, Fig. 1)*—The grips can be used as is or in conjunction with an abrasive slurry applied to the grooves of the grips and the gripped portion of the test specimen to prevent slippage. The slurry consists of abrasive such as Grade 3-F aluminum oxide and a carrier such as water or glycerin.

7.1.4 *Chucking Devices*—Use of chucking devices of the type generally used for applying tension to strands in casting beds or post-tensioning anchorages shall not be used as primary gripping devices for testing purposes. Tests involving chuck devices or post-tensioning anchorages as the primary gripping device shall be considered invalid. It shall be permissible to use chucking devices or post-tensioning anchorages as a secondary gripping system, coupled with one of the methods listed above, to prevent strand slippage.

NOTE 1—The number of teeth should be 10 to 30 per inch [25 mm].

NOTE 2—The radius of curvature of the grooves should be approximately the same as the radius of the strand being tested. To prevent the two grips from closing tightly when the test specimen is in place, each groove should be located  $\frac{1}{32}$  in. [0.79 mm] above the flat face of the grip (see Fig. 1).



**FIG. 1** Note the  $\frac{1}{32}$  in. [0.79 mm] Spacing Between the Flat Face and the Radius of the Grip

## 8. Speed of Testing

8.1 The speed of testing shall not be greater than that at which load and strain readings can be made accurately. Refer to speed of testing in Test Methods A370 on Testing Apparatus and Operations.

## 9. Test Procedures

9.1 *Yield Strength*—As listed in 5.2, a Class B-1 extensometer (Note 3) shall be used as described in Practice E83 with a gauge length equal to or greater than the lay length of the strand. Typically, an extensometer with a 24 in. [600 mm] gauge length is used. The force-elongation data collected while loading, when plotted, shall produce a smooth curve free of irregular step-wise movements or other evidence of non-uniform force-elongation loading of the test specimen. One of the two following methods shall be used to correct for gripper seating losses and other sources of elongation error normally present during the initial loading of the test specimen.

9.1.1 *Preload Method*—After loading the specimen in the test frame, apply and hold an initial load of 10 % of the required minimum breaking strength to the specimen. Next, attach the extensometer described in 5.2 and adjust it to a reading of 0.1 % of gauge length. Continue loading until the extensometer indicates a total extension of 1.0 % of the extensometer gauge length (including the 0.1 % extension during pre-loading.) Record the load at 1.0 % extension as the yield strength. The extensometer remains attached to the strand until at least 1.05 % EUL is reached to ensure the yield strength is accurately measured and recorded; typically, the extensometer is then removed from the specimen to avoid possible extensometer damage due to strand rupture.

9.1.2 *Elastic Modulus Extrapolation Method*—Use a computerized data acquisition system with a software-based test procedure to calculate the elastic modulus of the specimen as load is applied. The calculation of the elastic modulus shall use either the actual cross-sectional area of the specimen or the nominal cross-sectional area as defined in the applicable specification for the size and grade of strand being tested. The elastic modulus shall be calculated using a sum-of-least-squares linear regression in the linear-elastic portion of the curve. To prevent errors potentially introduced during the initial loading phase, the linear regression shall not utilize data points measured until a minimum of 20 % of the minimum breaking strength is reached. Also, to safely avoid the non-linear elastic portion of the force-elongation curve as the yielding process starts, the linear regression shall not use data points collected after 65 % of the minimum breaking strength is reached. Between 20 % and 65 % of the minimum breaking strength, the linear regression shall collect data over at least 70 % of this range to ensure sufficient data is included to generate the elastic modulus value. Once the elastic modulus is measured, the software shall extrapolate the force-elongation curve using the measured slope of the elastic modulus to identify the intersection with the elongation axis zero force point. This is the origin from which the 1.0 % EUL shall be determined. The extensometer remains attached to the strand until at least 1.05 % EUL is reached to ensure the yield strength

is accurately measured and recorded; typically, the extensometer is then removed from the specimen after the yield strength has been determined to avoid possible extensometer damage due to strand rupture.

**9.2 Elongation**—As listed in 5.3, a Class D extensometer (Note 3) as described in Practice E83, a linear dial gauge, or ruler with precision of  $\pm 1/16$  in. [2.0 mm] shall be used. The gauge length shall not be less than 24 in. [600 mm] (Note 3). Total elongation value is determined when one or more wires fail during the test. It is not necessary to determine the total percent elongation at maximum force if the specified minimum elongation has been reached. One of the two methods described below shall be used.

**9.2.1 Pre-Load Method**—Apply an initial load of 10 % of the required minimum breaking strength to the test specimen. Attach the extensometer and adjust it to a zero reading. Increase the load until the extensometer indicates an elongation value equal to or greater than the minimum specified in the applicable specification.

**9.2.2 Elongation After Measuring Yield Strength Method**—Total elongation at fracture may be determined by measuring the movement between gripping jaws using a linear dial gauge, a ruler, or a Class D extensometer. After the yield strength is measured, loading is stopped and the load is maintained; the distance between the gripping jaws is measured to establish the current gauge length of the loaded specimen. The extensometer used to measure the yield strength may be removed. Loading is then continued until failure of one or more wires, or until an elongation value equal to or greater than the minimum specified in the applicable specification is measured. If a wire failure occurs, loading (movement) is immediately stopped and the distance between the jaws is again measured or the incremental movement of the test frame's moving crosshead is recorded. The total percent elongation is then calculated as a percentage of the change in the jaw-to-jaw distance which is then added to the percent elongation value obtained by the extensometer during the yield strength portion of the test.

**9.3 Breaking Strength**—Continue loading the strand until either the minimum specified breaking strength is achieved or until failure of one or more wires occurs. Record the actual breaking strength of the strand (3.1.1).

**9.3.1 Fracture Location**—If a fracture occurs within a distance of 0.25 in. [6.0 mm] from the grips and falls below the specified minimum breaking strength, yield strength, or elongation values, the test shall be considered as invalid. However, if all values meet or exceed the specified minimums, the results shall be accepted (Note 4). Material for which specimens break outside the gripping jaws and do not meet the minimum specified values are subject to additional tests according to the applicable specification.

**9.3.2 Wire Slip**—Gripping systems shall securely grip all outer wires and, in the case of 7-wire strand, the center wire throughout the test. If any wire(s) show(s) evidence of slipping out of the grips and the specimen fails to meet the required minimums, the test shall be invalid (Note 5).

NOTE 3—The yield-strength extensometer and the elongation extensometer may be the same instrument or two separate instruments. It is advisable to use two separate instruments since the more sensitive

yield-strength extensometer, which could be damaged when the strand fractures, may be removed following the determination of yield strength. The elongation extensometer may be constructed with less sensitive parts or be constructed in such a way that minimal damage would result if fracture occurs while the extensometer is attached to the test specimen.

NOTE 4—Wire or strand fracture occurring within 0.25 in. [6.0 mm] of the grips is affected by stress concentrations due to the gripping system. Consequently, values from these test results should be considered conservative. A break influenced by the grips will typically occur at the exit of the gripping device and will typically have visible scraping or notching from the gripping device very close to (within 0.25 in. [6.0 mm]) of the fracture point on at least one piece of the broken wire or strand. Most often, the visible marking will be on the portion of the specimen remaining in the gripping device after a failure occurs. Failures in the gripping device will also sometimes indicate limited tensile reduction of area and will often indicate a shear-type failure (a near 45° fracture profile).

NOTE 5—Wire or strand grip slipping may be indicated by abrupt axial movements of the wire or strand in the test frame. Test curves with wire or strand slippage may show vertical lines at one or more portions of the curve where loading conditions appear to show step-wise behavior often evidenced by a sudden decrease in actual load.

**9.4 Relaxation Properties**—In addition to the general test procedures described in Test Methods E328, Test Method A, the specific conditions for testing steel prestressing strand listed below shall be followed:

**9.4.1** The temperature of the test specimen shall be maintained at  $68 \pm 3.5^\circ\text{F}$  [ $20 \pm 2^\circ\text{C}$ ].

**9.4.2** The test specimen shall not be subjected to loading above 20 % of the minimum breaking strength prior to the relaxation test (see Note 6).

**9.4.3** The initial load shall be applied uniformly over a period of not less than 3 min and not more than 5 min. The gauge length shall be maintained constant.

**9.4.4** Load-relaxation readings shall commence 1 min after application of the total load.

**9.4.5** Over-stressing of the test specimen during application of the load shall not be permitted.

**9.4.6** The duration of the test shall be 1000 h or a shorter period of at least 200 h, provided it can be shown by records that an extrapolation of the shorter period test results to 1000 h will provide similar relaxation values as the full 1000 h test.

**9.4.7** The gauge length of the test specimen shall be at least 40 times the nominal strand diameter. It is recommended that the gauge length of the test specimen be at least 60 times the nominal strand diameter.

NOTE 6—For relaxation testing, a small preload of up to 16 % of minimum breaking strength is commonly used to straighten the strand test specimen prior to initial loading to test stress level. This is not included in the force application time in 9.4.3.

## 10. Report

**10.1** A report shall be prepared with the following information included as a minimum:

**10.1.1** Strand size and grade,

**10.1.2** Manufacturer of strand,

**10.1.3** Date of test,

**10.1.4** Test Number, and

**10.1.5** Mechanical properties determined in accordance with applicable specification.



## **11. Precision and Bias**

11.1 No statement is made on the precision and bias of these test methods since the test results indicate only whether there is conformance to given criteria and no generally accepted method for determining precision of these test methods is currently available. General guidelines provided herein for the specimens, instrumentation, and procedures make the results intractable to calculation of meaningful values by statistical analysis for precision at this time.

11.2 *Bias*—Since there is no accepted reference material suitable for determining the bias in this test method, no statement on bias is made.

## **12. Keywords**

12.1 multi-wire steel prestressing strand; strand-gripping devices; strand mechanical properties

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