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Standard Test Methods for Testing Multi-Wire Steel Prestressing Strand[1]

This standard is issued under the fixed designation A1061/A1061M; 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 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 are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined.

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

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
E83 Practice for Verification and Classification of Extensometer Systems
E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods
E328 Test Methods for Stress Relaxation for Materials and Structures
E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

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.

[1] 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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[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.

***A Summary of Changes section appears at the end of this standard**

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 Semi-Cylindrical Grooves (Note 2, Fig. 1)*—The grips can be used as is or in conjunction with an abrasive medium (typically, a slurry or coating) applied to prevent slippage to the grooves of the grips, the gripped portion of the test specimen, or both.

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.

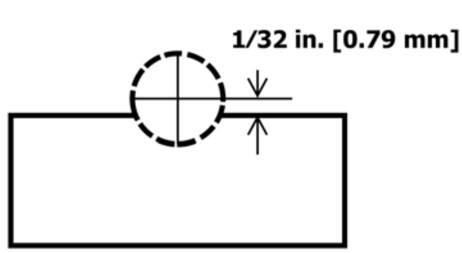

FIG. 1 Note the 1⁄32 in. [0.79 mm] Spacing Between the Flat Face and the Radius of the Grip

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 1⁄32 in. [0.79 mm] above the flat face of the grip (see Fig. 1).

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. Next, attach the extensometer described in 5.2 and adjust it to a reading of 0.1 % of the extensometer gauge length. Resume loading until the extensometer indicates a total extension of 1.0 % of the extensometer gauge length (a change in extension equal to 0.9 % of the extensometer gauge length, relative to the reading of 0.1 % of gauge length, is required to obtain a total extension of 1.0 % of the gauge length). Record the load at 1.0 % extension as the yield strength. The extensometer should remain 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. Data corresponding to at least 70 % of the range between 20 % and 65 % of the minimum breaking strength (inclusive) shall be used for the linear regression used to calculate the elastic modulus. Once the elastic modulus is determined, the force-elongation curve shall be extrapolated 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. Record the yield strength as the load corresponding to 1.0 % extension on the force-elongation curve. The extensometer should remain 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 test 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 ±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 the test result falls below the specified minimum breaking strength, yield strength, or elongation values, the test shall be considered invalid. However, if all values meet or exceed the specified minimums, the results shall be accepted (Note 4). Test results from specimens that fracture within secondary chucking devices shall be considered invalid regardless of whether minimum values are satisfied. 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 fractures occurring within 0.25 in. [6.0 mm] of the grips are affected by stress concentrations due to the gripping system. Consequently, values from these test results should be considered conservative. Conversely, values from tests where fracture occurs within secondary gripping devices may not be conservative. A fracture 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]) 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 fracture occurs. Fractures occurring in the gripping device will also sometimes indicate limited tensile reduction of area and will often indicate a shear-type fracture (a near 45° fracture profile). Observation of necking (or "cupping") at the fracture point is not to be considered as evidence that the gripping device had negligible effect on test results and should not be used as a basis for determining test validity.

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 ± 3.5°F [20 ± 2°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.