Designation: A1081/A1081M – 15

Standard Test Method for Evaluating Bond of Seven-Wire Steel Prestressing Strand[1]

This standard is issued under the fixed designation A1081/A1081M; 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 This test method describes procedures for determining the bond of seven-wire steel prestressing strand. The bond determined by this test method is stated as the tensile force required to pull the strand through the cured mortar in a cylindrical steel casing. The result of the test is the tensile force measured on the loaded-end of the strand corresponding to a movement of 0.1 in. [2.5 mm] at the free-end of the strand.

1.2 This test method is applicable either in inch-pound units (as Specification A1081) or SI units (as Specification A1081M).

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

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:*[2]

A416/A416M Specification for Low-Relaxation, Seven-Wire Steel Strand for Prestressed Concrete

C33/C33M Specification for Concrete Aggregates

C109/C109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)

C150/C150M Specification for Portland Cement

C192/C192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C1437 Test Method for Flow of Hydraulic Cement Mortar

3. Terminology

3.1 *Definitions:*

3.1.1 *bond*—the adhesion of strand to concrete or mortar.

3.1.2 *bond breaker*—a product wrapped around strand to prevent strand-to-concrete bond over the installed length. Extruded polystyrene foam pipe insulation is commonly used for this purpose.

3.1.3 *manufactured length*—a length of strand that is manufactured in one continuous length.

3.1.4 *mortar*—a mixture of cement, fine aggregate (that is, sand) and water.

3.1.5 *strand*—all references to strand in this test method shall be interpreted to be Specification A416/A416M seven-wire prestressing steel strand with nominal diameters of 0.500 in. [12.70 mm] or 0.600 in. [15.24 mm].

3.1.6 *test specimen*—an assembly consisting of one steel casing, one sample of strand and mortar.

4. Summary of Test Method

4.1 Six samples of seven-wire steel prestressing strand with nominal diameters of 0.500 in. [12.7 mm] or 0.600 in. [15.24 mm] are selected from a single continuous length. Each of the six strand samples are individually cast in a steel cylinder casing with a specified cement mortar. The strand is exposed on both ends of the cylinder with a designated loaded-end and free-end. Once the mortar reaches a specified compressive strength, the cylinder with the embedded steel strand is loaded into a tensile testing machine. The designated loaded-end of the steel strand is gripped by the tensile testing machine and pulled away from the cylinder at a specified displacement rate. The tensile force on the loaded-end of the strand is measured along with the corresponding displacement of the free-end. The result of the test is the tensile force measured at the loaded-end of the strand corresponding to a movement of 0.1 in. [2.5 mm] at the free-end of the strand. The results of each sample test in the set of six are reported individually and as an average.

[1] This test method is 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. Significance and Use

5.1 Prestressing steel strand is used in pre-tensioned and post-tensioned concrete construction.

5.2 In pre-tensioned concrete applications, the prestressing steel strand is expected to transfer prestressing forces to the structural member via the adhesion (that is, bond) of the exposed wire strand surfaces to the surrounding cementitous material.

5.3 Manufacturing processes, subsequent handling, and storage conditions can influence the strand bond.

5.4 Prestressing steel strand is used in construction applications with a variety of concrete mixtures. Developing tests and threshold values for the performance of the strand in each of these unique mixtures is impractical.

6. Apparatus

6.1 A dial gauge or position transducer with a minimum precision of 0.001 in. [0.025 mm].

6.2 A tensile testing machine with the following functionality:

6.2.1 Controlled loading rate based on cross-head displacement.

6.2.2 Gripping device without torsional restraint. The lack of torsion restraint and satisfaction of this requirement shall be verified by demonstrating the ability to twist the actuator or the test specimen by hand or by manual lever (Note 1).

NOTE 1—In testing to develop the test method, hydraulic actuators were employed to apply tension force to the strand. The nature of the hydraulic actuators generally allows the piston to rotate with minimal resistance (since the piston floats on hydraulic fluid). Neither a roller bearing nor a ball bearing is required though one may be necessary if the pull-out force is applied through a mechanism where twist is restrained.

7. Sampling of Strand

7.1 Six samples of prestressing steel strand are needed for this test. Each sample shall be at least 32 in. [800 mm] long.

7.2 Samples shall be collected from the same reel or reelless pack of strand (typically 3.5 tons [3 metric tons]) or the same manufactured length of strand (typically 20–28 tons [18–25 metric tons]).

7.3 The surface condition of the strand samples shall be representative of the strand intended for use in bonded applications. Care shall be taken to prevent the introduction of surface contaminants which may alter the bond performance of the strand. For qualification of a manufacturing process, sample surface shall be in the as-manufactured condition.

8. Mortar Requirements

8.1 *Materials:*

8.1.1 *Sand*—The sand shall conform to Specification C33/C33M requirements for fine aggregate. The sand shall come from natural sources. Manufactured sand shall not be permitted.

8.1.2 *Cement*—The cement shall conform to Specification C150/C150M requirements for Type III cement.

8.1.3 *Water*—The water shall be potable.

8.2 *Mortar Preparation*—The preparation of the materials and procedure used to mix the mortar shall be performed in conformance with Practice C192/C192M (Note 2) with the following exceptions:

8.2.1 Aggregates, other than sand, shall not be used.

8.2.2 Admixtures shall not be used.

8.3 *Mortar Performance Requirements*—The mortar shall be tested in conformance with Practice C192/C192M with the following exceptions and additional requirements.

8.3.1 *Slump*—No measurements required.

8.3.2 *Air Content*—No measurements required.

8.3.3 *Flow*—Mortar flow shall be measured in accordance with the procedures in Test Method C1437. The flow rate shall be greater than or equal to 100 % but shall not exceed 125 %.

8.3.4 *Strength*—Mortar strength shall be evaluated in conformance with Test Method C109/C109M using 2 in. [50 mm] mortar cubes. Before starting the test and after a minimum of 22 hours curing time, mean mortar cube strength shall not be less than 4 500 psi [31 MPa]. During performance of the strand bond test and within 24 hours ± 2 hours of mortar mixing, mean mortar cube strengths shall be between 4 500 psi [31 MPa] and 5 000 psi [34.5 MPa] (Note 3).

NOTE 2—Practice C192/C192M is described as a standard practice to be used for concrete test specimens. As outlined in 8.1, only fine aggregates (that is, sand) are included in the mixture along with cement and water. Because coarse aggregates are not included, this mixture is defined as "mortar" and not "concrete." Aside from this difference and a few other exceptions noted in Section 8, the practices documented in Practice C192/C192M are to be applied when making the mortar used in this test method.

NOTE 3—The ability to consistently achieve the specified mortar strengths can be a challenge for testing facilities with limited mortar experience and/or limited mixing and curing facilities and multiple trial batches may be required to develop appropriate mixes. If mean mortar strengths are less than the 4 500 psi [31 MPa] when the strand bond test is performed, the strand bond test results will be biased to provide lower bond test values than if the mortar was within the specified range. For the purpose of comparing the bond test results of this test method against a minimum threshold value, a bond test result that exceeds a minimum threshold value with a mean mortar strength less than 4 500 psi [31 MPa] should be accepted as meeting a specified minimum threshold value.

If mortar strengths are greater than the 5 000 psi [34.5 MPa] when the strand bond test is performed, the strand bond test results will be biased to provide higher bond test values than if the mortar was within the specified range. For the purpose of comparing the bond test results of this test method against a minimum threshold value, a bond test result that is below a minimum threshold value with a mean mortar strength greater than 5 000 psi [34.5 MPa] should be considered as failing to meet the specified minimum threshold value.

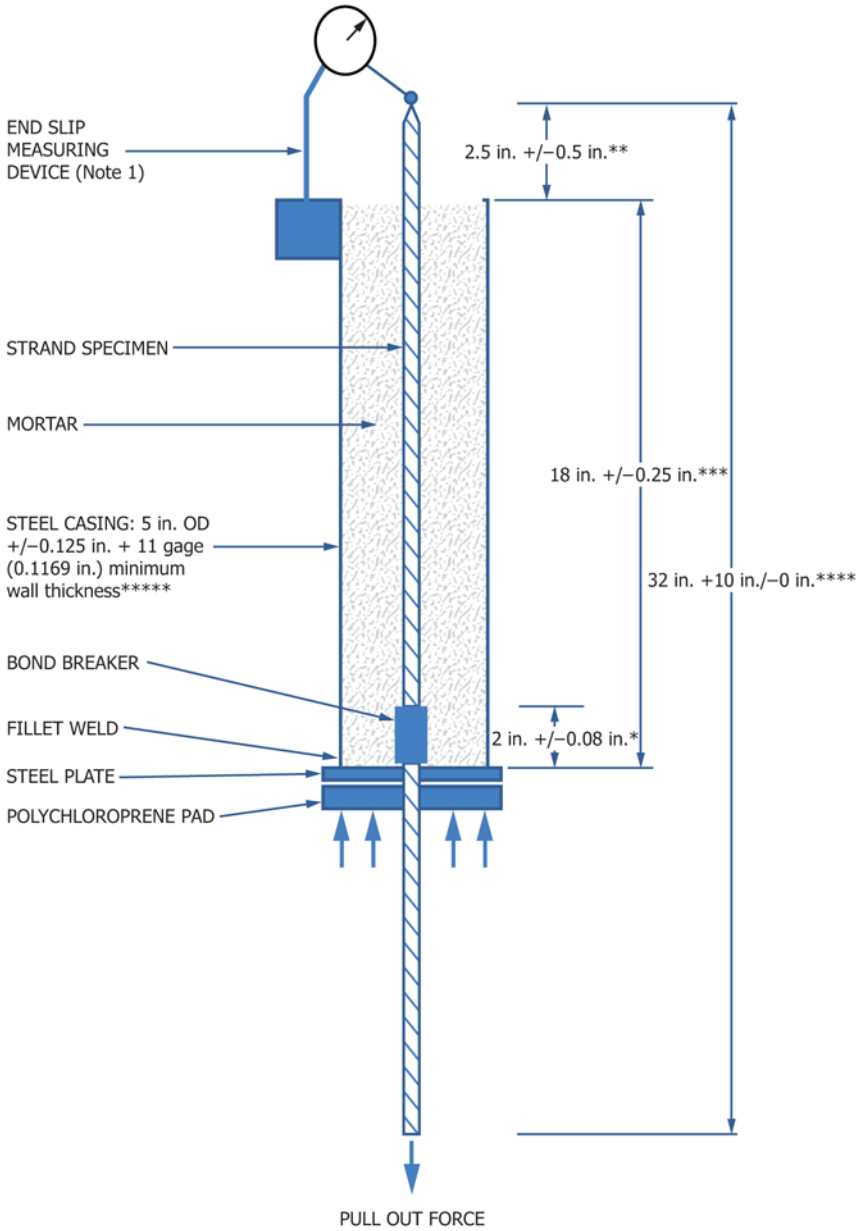
9. Preparation of Test Specimens

9.1 *Materials:*

9.1.1 *Strand Samples*—Strand sample requirements are defined in Section 7.

9.1.2 *Mortar*—Mortar requirements are defined in Section 8.

9.1.3 *Bond Breaker*—A 1 in. ± 0.25 in. [25 mm ± 6 mm] outside diameter × 2 in. ± 0.08 in. [50 mm ± 2 mm] length section of pipe insulation or equivalent material shall be used as a bond breaker. The position of the bond breaker shall be as defined in Fig. 1 (Note 4).



*SI equivalent: 50 mm ± 2.0 mm
**SI equivalent: 64 mm ± 13 mm
*** SI equivalent: 450 mm ± 6.4 mm
**** SI equivalent: 800 mm +250 mm –0 mm
*****SI equivalent: 130 mm ± 3 mm (OD) × 3 mm min (wall thickness)

NOTE 1—The "Electronic End Slip Measurement" apparatus shown here is an example of one type of measurement set-up. Other configurations and devices can be used. A mold release agent may be sprayed onto the canister ID walls before pouring mortar.

FIG. 1 Longitudinal Cross-Section Diagram of Strand Test Specimen in a Mortar-Filled Cylinder

9.1.4 *Steel Casing*—Each individual test specimen of strand shall be cast in a 5 in. [130 mm] outside diameter × 18 in. [450 mm] long cylindrical steel casing as defined in Fig. 1. The thickness of the cylindrical walls of the steel casing shall not be less than 11 gage or 0.119 in. [3.0 mm]. A 6 in. × 6 in. × 0.25 in. [150 mm × 150 mm × 6 mm] square plate with a ⅝ in. [16 mm] hole located at the center of the plate to accommodate the strand shall be welded to the bottom of the casing. A 50 durometer 6 in. × 6 in. × 0.5 in. ± 0.125 in. [150 mm × 150 mm × 12.5 mm ± 3 mm] polychloroprene pad with a ⅝ in. [16 mm] diameter hole or slit sufficient to accommodate the strand shall be located between the plate and bearing. (Note 5) The other dimensions of the steel casing and the strand are indicated on the diagram. The steel casing shall have sufficient rigidity to prevent radial cracking visible to normal or corrected vision in the concrete mortar during testing.

9.2 *Specimen Assembly*—Each individual test specimen shall be made by casting one single strand concentrically in the steel casing with the mortar. The test specimen shall be cast with the longitudinal axis of the strand and the steel casing in the vertical position. Temporary jigs shall be used to keep the strand sample concentrically centered ± ½ in. [13 mm] in the steel casing and to prevent longitudinal movement during mortar installation and consolidation. The temporary jigs can be removed after the mortar has cured and prior to testing.

9.3 *Consolidation*—After the cylinder is approximately 50 % filled with mortar, the test specimens shall be mechanically consolidated by vibration in conformance with Practice C192/C192M. The mortar shall be consolidated to ensure that a normal amount of air voids exist at the interface between the strand and the surrounding concrete mortar (see Note 6). Once the initial addition of mortar is consolidated, the next 40 % of mortar shall be added to the steel casing and again mechanically consolidated by vibration in conformance with Practice C192/C192M. Once the mortar is consolidated the second time, the remaining 10 % of mortar shall be added to the steel casing until a smooth, level mortar surface is achieved at the top of the casing.

9.4 *Curing*—Once all six test specimens and mortar cubes have been cast, curing of the mortar shall occur in conformance with Practice C192/C192M. The concrete mortar shall be cured in a controlled environment with the following conditions:

9.4.1 *Curing Temperature*—Curing temperatures shall be 73.4°F ± 3°F [23°C ± 2°C].

9.4.2 *Curing Relative Humidity*—Average hourly relative humidity during curing shall be maintained above 90 %.

9.4.3 *Vibration*—The test specimens shall be cured in an environment free of vibrations.

NOTE 4—Variances in the length of the bond breaker can cause significant variance in the results of this test method. Careful attention to the dimensions, installation and position of the bond breaker during and after the addition of the mortar is essential.

NOTE 5—The polychloroprene pad helps control the force loading rate and can provide a better surface to allow for minor centering corrections as load is applied to the cylinder.

NOTE 6—Excessive air voids can cause erroneous test results because air voids reduce the available bonding surface between the concrete mortar and the strand.

10. Test Set-up

10.1 *Test Frame*—The test specimens shall be placed into the test frame with the capabilities as defined in Section 6. The load shall be measured as applied to the loaded-end.

10.2 *Free-End Slip Measurement*—A position transducer or dial gauge shall be installed capable of measuring the movement of the free-end of the strand relative to the hardened mortar or the steel casing. Fig. 1 shows an example of one type of measurement apparatus. The measuring device shall measure free-end strand movement as observed by movement of the center wire only.

10.3 *Strand Gripping*—The strand shall be gripped by a chucking device capable of uniformly pulling all six outer wires of the strand. The free length between the bottom plate of the steel casing housing the specimen and the gripping device shall be a minimum of 8 in. [200 mm]. The strand gripping device (or test cylinder) shall not be restrained from torsional movement (Note 1).

11. Test Procedure

11.1 *Test Conditions*—The specimens shall be removed from the controlled curing chamber and tested when both of the following 2 parameters are satisfied:

11.1.1 *Time*—24 hours ± 2 hours of casting the specimens (Note 7).

11.1.2 *Mortar Strength*—Within the strength range specified in 8.3.4.

11.2 *Mortar Strength*—Mortar strengths shall be tested at the beginning of the test and at the end of the test.

11.3 *Displacement Rate*—Load (that is, pull-out force) shall be applied to the strand by displacement of the gripping device. The displacement rate shall be 0.1 in./min ± 0.005 in./min [2.5 mm/min ± 0.13 mm/min]. As load is applied to the strand, some seating of the gripping device or other test frame deflection is possible. These seating actions should be visibly smooth and not subject to sudden releases of energy. A maximum force loading rate of 8 500 lbf/min [38 kN/min] is recommended based on data collected during test development (Note 8).

11.4 *Test Result*—The load (that is, pull-out force) rounded to the nearest 10 lbf [50 N] shall be recorded at the moment the free-end of the strand has moved down into the mortar a cumulative total of 0.10 in. [2.5 mm] by the application of force on the loaded-end.

11.5 *Acceptance of Test Result*—If the hardened mortar exhibits cracking visible to normal or corrected vision in two or more of the six test specimens, the entire batch of six specimens shall be discarded and new specimens prepared.

NOTE 7—Current research is investigating the importance of this time constraint. In the future, it is possible this time constraint may be extended to allow more time to complete the testing.

NOTE 8—The loading rate of the specimen is specified as a rate of loaded-end displacement. During the development of this test method, strand loading rates in terms of force were also monitored and recorded concurrently with the displacement loading rates. The maximum force loading rate is recommended since frame stiffness may influence reported test values.

12. Report

12.1 Identification of the strand tested (that is, reel or reelless pack number).

12.2 Date of original strand manufacture.

12.3 Dates of test.

12.4 Size of strand.

12.5 Grade of strand.

12.6 Six individual test results.

12.7 Average test results.

12.8 Individual mortar cube compressive strengths.

12.9 Average of beginning and ending mortar strengths.

13. Precision and Bias

13.1 The single operator coefficient of variation has been found to be 9.0 %. It was also determined by Practice C670 that two properly conducted tests (each consisting of the average of six individual pullout values) by the same operator on the same material are not expected to differ by more than 12.1 %. The range (difference between highest and lowest) of the six individual pullout values used in calculating the average is not expected to exceed 24.9 %, as determined by Practice C670. The multi-laboratory coefficient of variation was calculated as 14.5 %. The results of two properly conducted tests in different laboratories on the same material are not expected to differ by more than 40.2 %, as determined following Practice C670.

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

14. Keywords

14.1 bond test; prestressing steel strand; seven-wire strand

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A1081/A1081M – 13) that may impact the use of this standard. (Approved Nov. 1, 2015.)

(1) Revised 13.1.