



Designation: C 1404/C 1404M – 98

## Standard Test Method for Bond Strength of Adhesive Systems Used With Concrete as Measured by Direct Tension<sup>1</sup>

This standard is issued under the fixed designation C 1404/C 1404M; 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 reappraisal. A superscript epsilon (ε) indicates an editorial change since the last revision or reappraisal.

### 1. Scope

1.1 This test method covers the laboratory determination of the bond strength of adhesive systems used to adhere freshly mixed mortar to hardened portland-cement concrete.

1.2 The values stated, in either SI units or other units shall be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore each system must be used independently of the other, without combining values in any way.

1.3 *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:

- A 333/A 333M Specification for Seamless and Welded Steel Pipe for Low-Temperature Service<sup>2</sup>
- C 33 Specification for Concrete Aggregates<sup>3</sup>
- C 39 Test Method for Compressive Strength of Cylindrical Concrete Specimens<sup>3</sup>
- C 42 Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete<sup>3</sup>
- C 109 Test Method for Compressive Strength of Hydraulic Cement Mortars using 2-in. [50 mm] Cube Specimens<sup>4</sup>
- C 150 Specification for Portland Cement<sup>3</sup>
- C 171 Specification for Sheet Materials for Curing Concrete<sup>3</sup>
- C 192 Practice for Making and Curing Concrete Specimens in the Laboratory<sup>3</sup>
- C 305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency<sup>4</sup>
- C 494 Specification for Chemical Admixtures for Concrete<sup>3</sup>

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee C-9 on Concrete and Concrete Aggregates, and is the direct responsibility of Subcommittee C09.25 on Organic Materials for Bonding, Patching, and Decking.

Current edition approved Sept. 10, 1998. Published April 1999.

<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.01.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 04.02.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 04.01.

C 881 Specification for Epoxy-Resin-Base Bonding Systems for Concrete<sup>3</sup>

C 670 Practice for Preparing Precision Statements for Test Methods for Construction Materials<sup>3</sup>

### 3. Summary of Test Method

3.1 Each specimen consists of a base and overlay, bonded together with the adhesive being tested. The base is half of a 3-in. [75-mm] by 6-in. [150-mm] hardened-concrete cylinder mounted inside of a steel-pipe nipple. The overlay consists of freshly mixed mortar placed in a steel-pipe nipple positioned on top of the base.

3.2 The prepared surface of the base is coated with the adhesive, onto which freshly mixed mortar is applied. After curing, the assembly is pulled in tension to measure the bond strength of the adhesive. The tensile strength is calculated, and the location of failure is determined visually.

### 4. Significance and Use

4.1 The bonding properties of adhesives are important for concrete repair applications. This test method provides a means to measure the adhesive characteristics of materials used to bond freshly mixed mortar to hardened concrete.

4.2 In addition to providing information on bond strength, the location of failure is determined visually and is thus instructive regarding the weakest element in the composite tested.

4.3 The bond strength that is measured is limited by the tensile strength of the base concrete and mortar. While an attempt has been made to choose materials that are strong enough to force a bond failure, there may be cases where failure occurs in concrete or mortar. In these situations, the actual bond strength exceeds the measured result.

### 5. Apparatus

5.1 *Testing Machine*—The testing machine shall be of the hydraulic or screw-type and capable of measuring tensile loads up to 5000 lbf [22 kN] in increments of 45 lbf [200 N] at rates described in 9.3.

5.2 *Steel-Pipe Nipples*—The steel-pipe nipples shall conform to Specification A 333/A 333M, be nominally 3 in. [75 mm] in diameter by 3 in. [75 mm] long Schedule 40, threaded;

**ASTM C 1404/C 1404M**

two per specimen. The inside surface of the steel-pipe nipples shall be clean and free of oil or other contaminants that could inhibit bond. The inside surface shall be sandblasted to gray metal condition.

5.3 *Steel-Pipe Cap*—Two steel-pipe caps nominally 3 in. [75 mm] in diameter, and threaded to fit the steel-pipe nipple molds. Each cap shall be fitted with a steel rod or eye bolt with at least one universal joint for connection to the testing machine. The assembly shall have a tensile capacity of at least 5000 lbf [22 kN]. See Fig. 1 for details of preparation.

5.4 *Base Assembly*—Concrete cylinder and steel pipe nipple, prepared according to Section 7; one for each specimen.

5.5 *O-rings*—Rubber, 2-7/8 in. [73 mm] inside diameter × 3-1/4 in. [83 mm] outside diameter; 3/16 in. [5 mm] thick; one for each specimen.

5.6 *Concrete Mixer*—As described in Practice C 192.

5.7 *Mixer, Bowl, and Paddle*—A mechanical mortar mixer, as described in Practice C 305.

5.8 *Small Tools*—Tools and items such as a straightedge, scoops, rubber gloves, and metal mixing bowls.

5.9 *Tamping Rod*—The tamping rod shall be a round steel rod, 3/8 in. [10 mm] in diameter, conforming to Practice C 192.

5.10 *Saw*, as described in Test Method C 42, with diamond saw blade and plain water as the only cutting fluid.

5.11 *Cylinder Molds*—The cylinder molds shall be 3-in. [75-mm] diameter by 6-in. [150-mm] long, as described in Practice C 192.

**6. Materials**

6.1 *Cement*—The cement shall be portland cement meeting the requirements of Specification C 150.

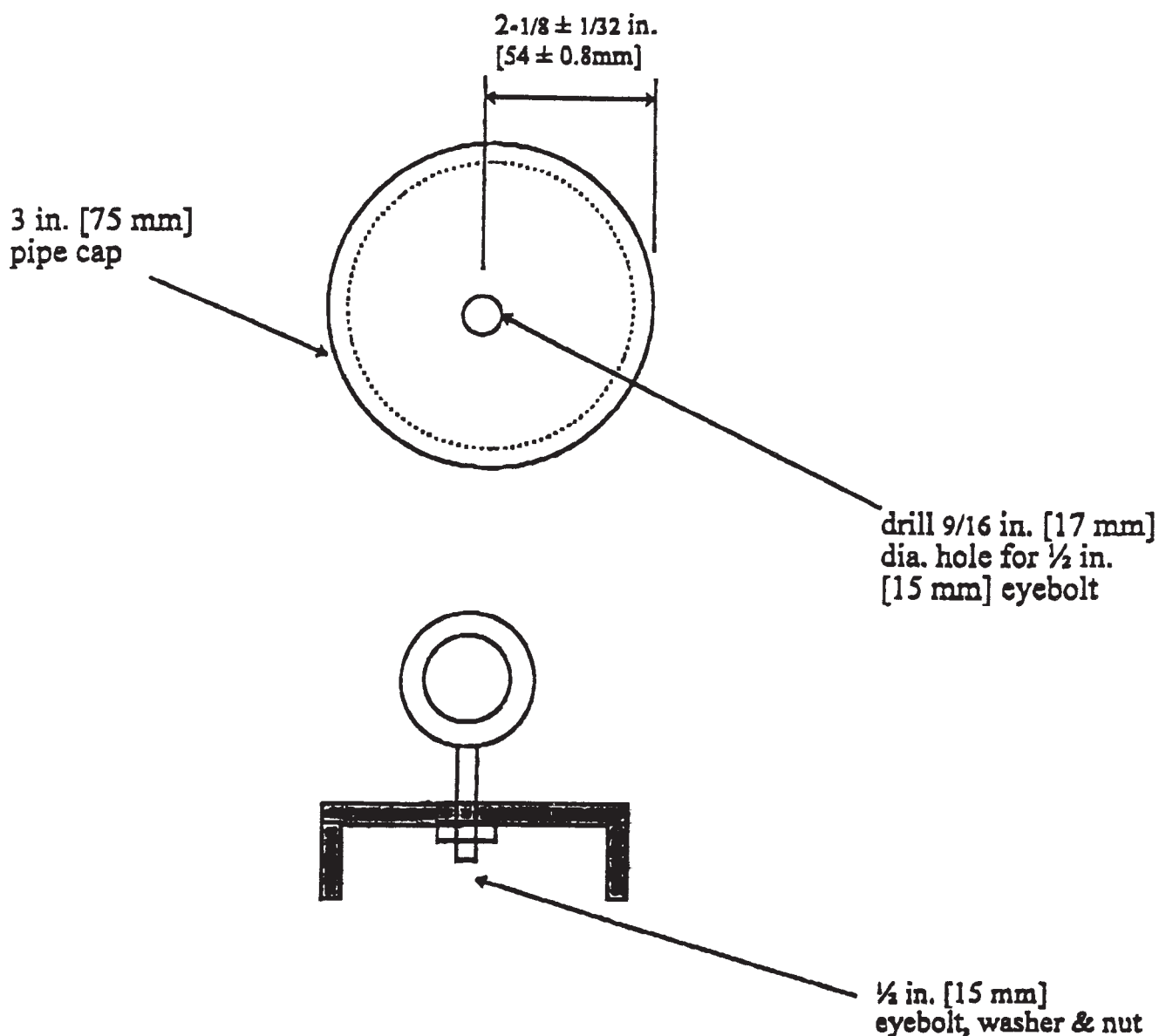


FIG. 1 Pipe Cap Detail

6.2 *Aggregate*—The aggregate shall conform to Specification C 33; the coarse aggregate shall conform to Size No. 7.

6.3 *Mortar*—Prepare and test the mortar in accordance with Test Method C 109, and each specimen tested shall have a compressive strength of at least 4500 psi [31 MPa] at seven days age.

6.4 *Concrete*—The concrete shall be non air-entrained, prepared and cured in accordance with Practice C 192, tested according to Test Method C 39, and each specimen tested shall have a compressive strength of at least 6000 psi [41 MPa] at 28 days. Water-reducing admixtures, meeting Specification C 494, may be used.

6.5 For the purpose of qualifying the reference mortar and concrete, compressive strengths of all specimens tested shall exceed the minimum stated.

6.6 *Abrasive Paper*—Sandpaper, emery cloth, or other abrasive paper of grit No. 100.

6.7 *Tape*—Plastic tape, minimum 2 in. [50 mm] wide.

6.8 *Epoxy*—Type V, Grade 1 epoxy resin, Specification C 881, shall have low enough viscosity to flow into the annular space between the concrete base cylinder and steel-pipe nipple.

NOTE 1—A hot-air blower to heat the pipe nipple has been found useful to increase flow of the epoxy adhesive between the pipe and the concrete cylinder.

6.9 *Sealant*—Capable of sealing the rubber to the concrete to prevent the flow of the epoxy adhesive; an example is RTV silicone rubber.

6.10 *Polyethylene Film*—Meeting Specification C 171 and having a minimum thickness of 4 mil [0.1 mm].

## 7. Base Assembly Preparation

7.1 Prepare concrete as described in 6.4 and place in the cylinder molds, 3-in. [75-mm] diameter by 6-in [150-mm] long.

7.2 Cure in accordance with Practice C 192 except that moist curing shall be continuous for 28 days. After this time, and until the cylinders are cut, they shall be stored at 73.4 ± 3.0°F [23 ± 2°C] and 50 ± 10 % R.H.

7.3 Not more than seven days after completing the curing cycle, cut the cast cylinders so that two cylinders, 3 in. [75 mm] diameter by nominally 3 in. [75 mm] long, are produced. Take care that the edges are not chipped during the cutting operation. Discard any half-cylinders with chips or defects estimated to be greater than 5 % of the cross-sectional area. Store the acceptable half-cylinders with the cut surface down, on a clean, dry surface, at 73.4 ± 3.0°F [23 ± 2°C] and 50 ± 10 % R.H. until used.

7.4 Place a half-cylinder, cut end down, on a clean, non-porous surface and position the O-ring so that it rests snugly against the clean surface. Seal the O-ring to the side of the concrete half-cylinder with sealant. Before the sealant cures, place a 3 in. [75 mm] long steel pipe nipple onto the cylinder so that it rests against the O-ring and the sealant. After the sealant cures, pour epoxy into the annular space between the nipple and cylinder until the space is full. See Fig. 2 for details.

## 8. Preparation and Curing of Composite Specimens

8.1 After the epoxy has cured, invert the base assembly so that the cut surface of the concrete is up. Rub this surface with

the abrasive paper to remove any extraneous material that could inhibit bond. Wipe this prepared surface with a damp cloth to remove any dust or powder that may have accumulated.

8.2 Place a 3 in. [75 mm] long nipple on this assembly and secure it to the bottom nipple with tape around the outside of both nipples.

8.3 Apply the adhesive being tested to the prepared surface of the concrete base using the manufacturer's recommendations for thickness and procedure, including moisture condition of substrate.

8.4 Mix mortar as described in Test Method C 109. Fill the nipple in two equal layers, and rod the mortar with 25 strokes per layer. Strike off the surface with a trowel and cover with polyethylene film.

8.5 Prepare a minimum of three specimens per test age.

8.6 Moist cure the specimens according to Practice C 192.

## 9. Procedure

9.1 Remove the tape from the specimens.

9.2 Screw the pipe caps (Fig. 1) onto the ends of the specimen (Fig. 2) and connect to the testing machine (see Fig. 3).

9.3 Set the testing machine so the specimen can be loaded into tension, at least 5000 lbf [22 kN] maximum load capability. For screw type, set cross-head speed at 0.04 in/min [1.0 mm/min]; for hydraulic type, load at 5 ± 2 psi/s [35 ± 15 kPa/s].

9.4 Load the specimen at constant rate until failure.

## 10. Calculation

10.1 Calculate the tensile strength to the nearest 10 psi [0.1 MPa] as follows:

$$T = P/A \quad (1)$$

where:

$T$  = tensile strength at failure, psi [MPa],

$P$  = maximum applied load, lbf [N], and

$A$  = cross sectional area of concrete base.

10.2 Estimate the location of failure in percent of cross sectional area for each element of the specimen, that is, in concrete base, at bond line, in mortar overlay. The sum of the three values must equal 100.

## 11. Report

11.1 Report the following information:

11.1.1 Identification of specimen,

11.1.2 Identification of type of cement used to make the test mortar,

11.1.3 Identification of bonding agent tested,

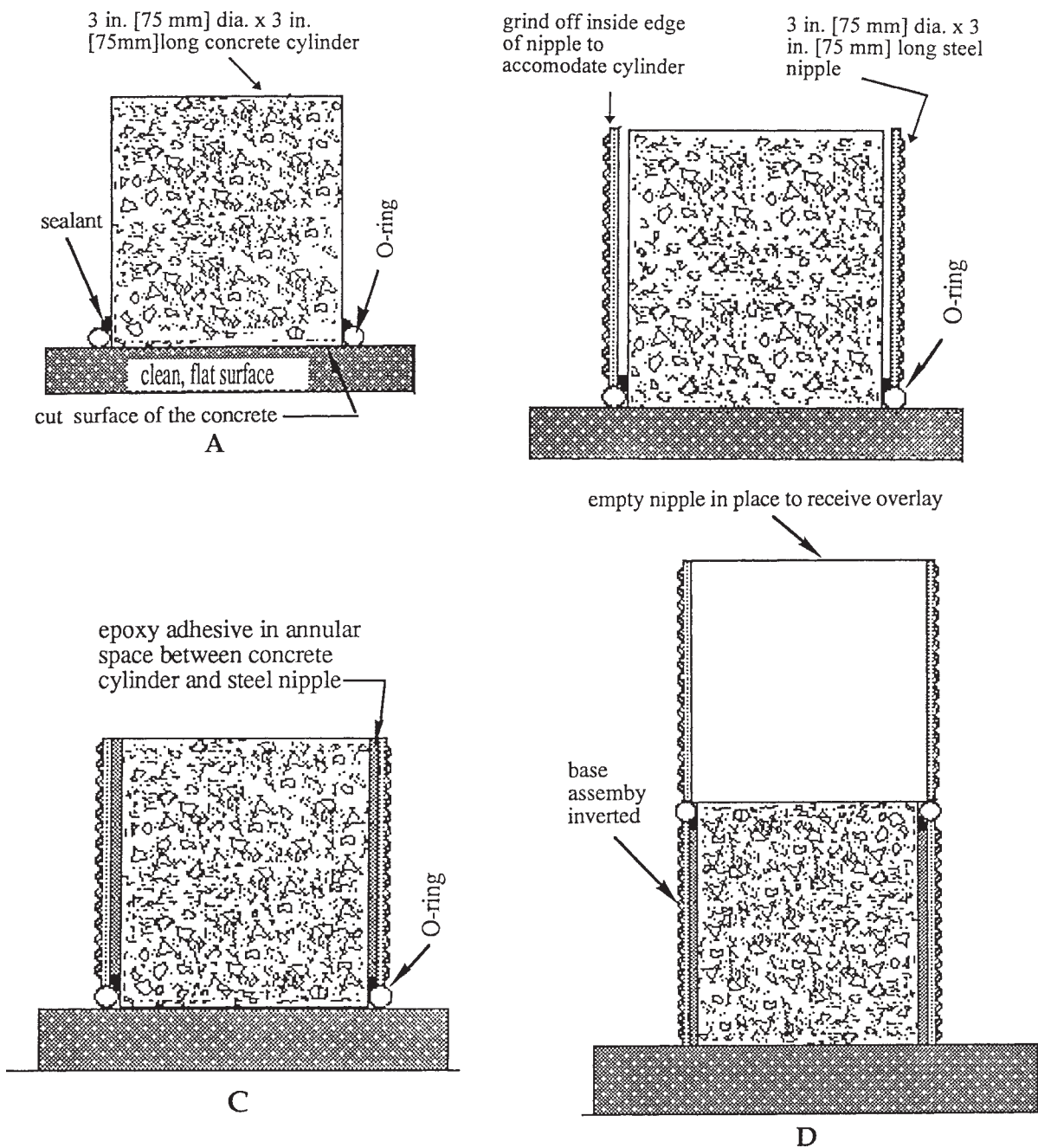
11.1.4 Moisture condition of substrate,

11.1.5 Length of cure of overlay for each set of specimens,

11.1.6 Number of specimens, Mean and Coefficient of Variation of  $T$  for each set, and

11.1.7 Results of test in the following manner:

**ASTM C 1404/C 1404M**



NOTE 1—(A) Place the concrete cylinder on a clean, flat surface; seal the O-ring to the cylinder with the sealant; (B) Place a pipe nipple over the concrete cylinder; (C) Pour epoxy adhesive into the space between the cylinder and nipple; (D) after the epoxy adhesive cures, invert the base assembly and place the second pipe nipple on top.

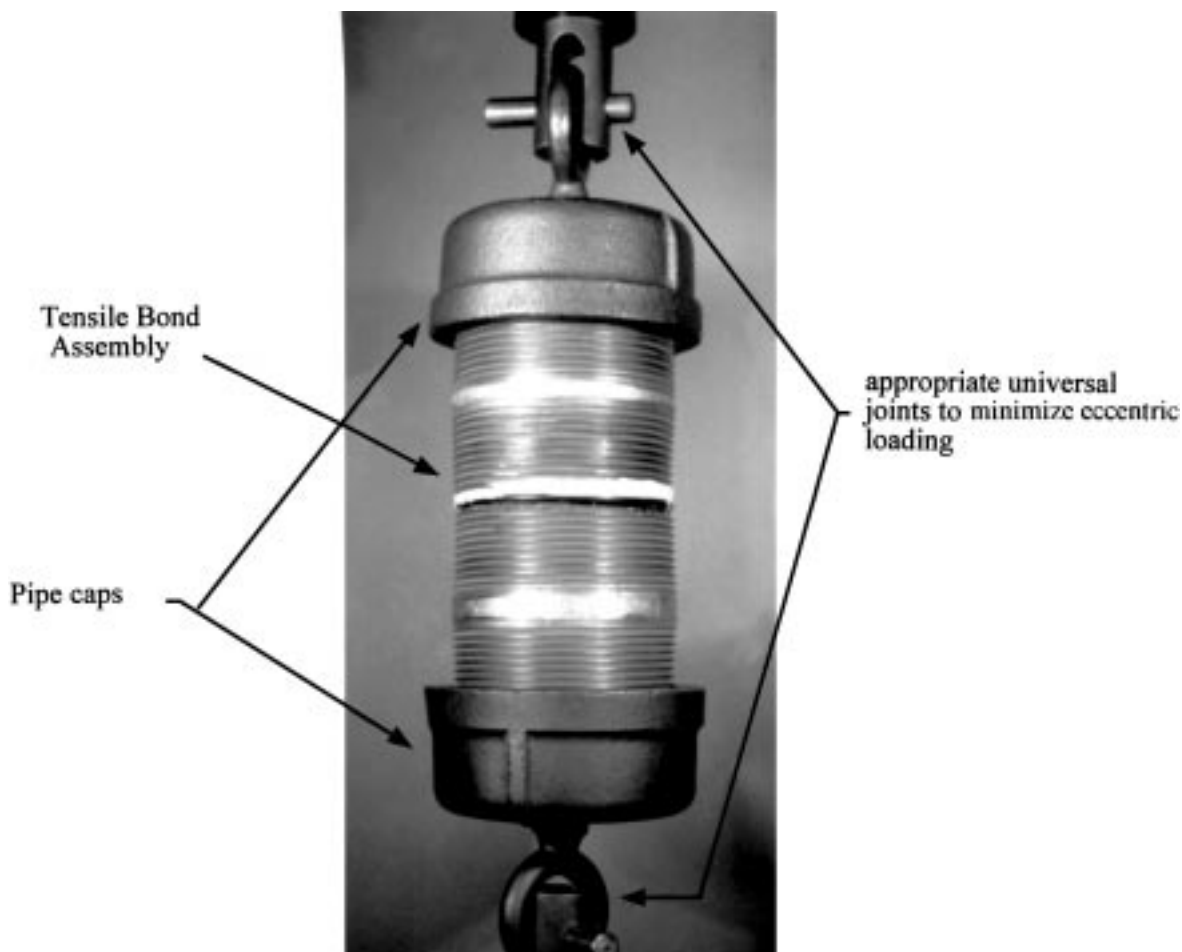
NOTE 2—Tape is wrapped around the outside of this final assembly to keep the pieces aligned as well as protect the threads from being covered with the overlay.

**FIG. 2 Specimen Preparation**

Specimen No.	T, Tensile Strength at Failure, psi [MPa]	Location of Failure, % Area		
		In Mortar Overlay	At Bond Line	In Concrete Base

**12. Precision and Bias**

12.1 *Single Operator Precision*—The single operator within laboratory and multilaboratory standard deviations, as shown below, have been found to be the same:



**FIG. 3 Tensile Bond Assembly in Testing Machine**

44 psi [0.30 MPa] for 3-day cure  
52 psi [0.36 MPa] for 7-day cure  
41 psi [0.28 MPa] for 28-day cure

Therefore, the results of two properly conducted tests from the same operator or from two different laboratories on similar batches should not differ from each other by more than shown below:

124 psi [0.84 MPa] for 3-day cure  
145 psi [1.01 MPa] for 7-day cure  
114 psi [0.78 MPa] for 28-day cure

NOTE 2—These numbers represent the (d2s) limit as described in Practice C 670. Data are from test of specimens that had strengths in the range of 246 to 522 psi [1.7 to 3.6 MPa].

12.2 *Bias*—The test method has no bias because the values determined can be defined only in terms of the test method.

### 13. Keywords

13.1 adhesives; bond strength; bonding agents; concrete-bonding; overlays; tensile bond

*The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.*

*This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 100 Barr Harbor Drive, West Conshohocken, PA 19428.*

*This standard is copyrighted by ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, United States. Individual reprints (single or multiple copies) of this standard may be obtained by contacting ASTM at the above address or at 610-832-9585 (phone), 610-832-9555 (fax), or service@astm.org (e-mail); or through the ASTM website (http://www.astm.org).*