



# Standard Test Method for Bond Strength of Epoxy-Resin Systems Used With Concrete By Slant Shear<sup>1</sup>

This standard is issued under the fixed designation C882/C882M; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope\*

1.1 This test method covers the determination of the bond strength of epoxy-resin-base bonding systems for use with portland-cement concrete. This test method covers bonding hardened concrete to hardened or freshly-mixed concrete.

1.2 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.

1.3 *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.* A specific hazard statement is given in Section 8. (**Warning**—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to exposed skin and tissue upon prolonged exposure.<sup>2</sup>)

## 2. Referenced Documents

### 2.1 ASTM Standards:<sup>3</sup>

- C39/C39M Test Method for Compressive Strength of Cylindrical Concrete Specimens
- C109/C109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)
- C125 Terminology Relating to Concrete and Concrete Aggregates
- C150 Specification for Portland Cement

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

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<sup>2</sup> See Section on Safety Precautions, Manual of Aggregate and Concrete Testing, *Annual Book of ASTM Standards*, Vol. 04.02.

<sup>3</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.

- C192/C192M Practice for Making and Curing Concrete Test Specimens in the Laboratory
- C470/C470M Specification for Molds for Forming Concrete Test Cylinders Vertically
- C511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes
- C617 Practice for Capping Cylindrical Concrete Specimens
- C881/C881M Specification for Epoxy-Resin-Base Bonding Systems for Concrete

## 3. Terminology

### 3.1 Definitions:

3.1.1 For definitions of terms used in this specification, refer to Terminology C125.

### 3.2 Definitions of Terms Specific to This Standard:

3.2.1 *bonding system, n*—the product resulting from the combination of all the components supplied for use as a bonding material.

3.2.2 *component, n*—a constituent that is intended to be combined with one or more other constituents to form a bonding system.

3.2.3 *contact strength, n*—bond strength measured by slant shear after a specified contact and cure time.

3.2.4 *contact time, n*—specified time between when the bonding system is applied and when the two segments are bonded together and still achieve a specified bond strength after a specified curing time and temperature.

3.2.5 *formulator, n*—the agency responsible for preparing the separate components and for recommending the proportions to be used in preparing the final bonding system.

## 4. Summary of Test Method

4.1 The bond strength is determined by using the epoxy system to bond together two equal sections of a 75 by 150-mm [3 by 6-in.] portland-cement mortar cylinder, each section of which has a diagonally cast bonding area at a 30° angle from vertical. After suitable curing of the bonding agent, the test is performed by determining the compressive strength of the composite cylinder.

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

## 5. Significance and Use

5.1 The strength developed by a bonding system that joins two regions of concrete is its most important property.

## 6. Apparatus

6.1 *Apparatus to Mix Portland-Cement Mortar*—This apparatus shall be as described in Test Method [C109/C109M](#), except for the sections on specimen molds, tamper, and testing machine.

6.2 *Specimen Molds*—The molds shall meet the requirements of Specification [C470/C470M](#) and be  $75 \pm 2$  mm [ $3 \pm \frac{1}{16}$  in.] in inside diameter and  $150 \pm 2$  mm [ $6 \pm \frac{1}{16}$  in.] in height.

6.3 *Dummy Section*—A dummy section ([Fig. 1](#)) shall be machined of a hard material that is not attacked by portland-cement mortar. It shall fit the mold and be equal to half the volume of the cylinder, but at an angle of  $30^\circ$  from the vertical. Additional dummy sections can be made by casting an epoxy-resin mortar against the machined dummy section contained in a specimen mold. Due precautions, such as waxing, shall be taken to prevent the bonding of the epoxy-resin mortar to the machined dummy section or the mold.

6.4 *Tamping Rod*—A 10-mm [ $\frac{3}{8}$ -in.] diameter tamping rod, as described in Practice [C192/C192M](#).

6.5 *Apparatus for Mixing Epoxy-Resin Bonding System*—A glass, plastic, or metal container of approximately 0.1 L [3 oz.] capacity shall be used to hand-mix the bonding system. A tongue depressor or wooden stick of similar dimensions shall be used as a paddle.

6.6 *Testing Machine*—The testing machine shall be as described in Test Method [C39/C39M](#).

6.7 *Moist Room*—The moist room shall conform to the requirements of Specification [C511](#).

6.8 *Temperature-Conditioning Chambers*—Rooms or chambers in which the temperature is maintained appropriate to the

class of the resin system being tested, in accordance with Specification [C881/C881M](#).

## 7. Materials

7.1 *Portland Cement Mortar Specimens* Laboratory conditions, materials, proportions, and procedures for mixing the portland-cement mortar shall be in accordance with Test Method [C109/C109M](#). A Type III cement (Specification [C150](#)) shall be used.

7.1.1 Lightly oil the dummy section and the cylinder mold. Position the dummy section in the mold with the slant side up. Place the portland-cement mortar in the mold in two layers of approximately equal volume. Rod each layer with 25 strokes of the tamping rod. Distribute the strokes uniformly over the section and rod deeply enough to penetrate into any underlying layer. Rod the bottom layer as deeply as possible. Strike off the surface of the top layer with the trowel, and cover the specimen and mold with a glass or metal plate. Cure the mortar half-cylinder in accordance with Practice [C192/C192M](#) for at least 28 days. Then dry the half-cylinder in laboratory air for at least 7 days. As an alternative, a complete 75 by 150 mm [3 by 6-in.] cylinder shall be cast, cured for at least 28 days, and saw-cut at an angle of  $30^\circ$ .

7.1.2 A 75 by 150-mm [3 by 6-in.] cylinder of the mortar shall have a compressive strength, when tested in accordance with [11.3](#), of at least 31 MPa [4500 psi] at 28-days age (see [Note 1](#)).

NOTE 1—Calculations for bond strength are determined based on the elliptical bonding surface of the cut cylinder. For an angle of  $30^\circ$  from the vertical this corresponds to exactly twice the surface area of the base of the assembled cylinder. Use of mortar with the minimum compressive strength listed in Section [7.1.2](#) will only provide a qualitative pass/fail result for bond strengths exceeding approximately 13 MPa [1900 psi]. If quantitative results are desired it is recommended the mortar compressive strength of the mortar exceed the anticipated bond strength by a factor of 2.5 or more.

7.2 *Bonding System*—The bonding systems covered by this test method shall be furnished in two or more components for combining immediately prior to use in accordance with the written instructions of the manufacturer.

7.3 *Polyethylene Film*—Film thickness of 100  $\mu$ m [4 mil] cut into 150  $\times$  500 mm [6  $\times$  30 in.] sections.

7.4 *Masking Tape*.

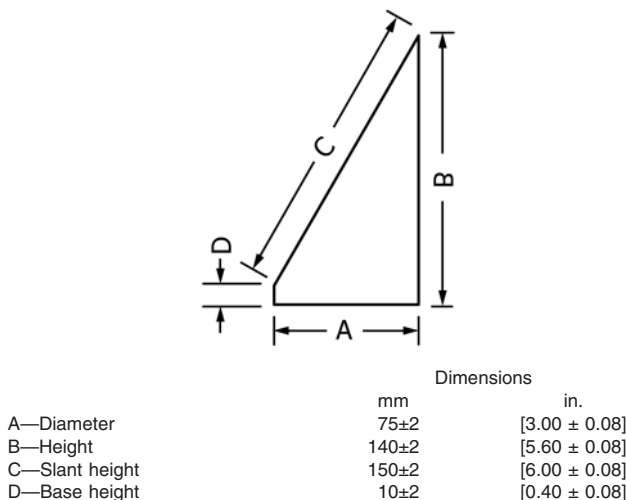
7.5 *Paraffin Wax*.

## 8. Hazards

8.1 **Warning**—Epoxy resins contain irritants, especially to the skin, eyes, and respiratory system. Persons handling these materials shall use appropriate protective clothing, including rubber or plastic gloves. If an epoxy resin should contact the skin, it shall be removed immediately with a dry cloth or paper towel, and the area of contact shall be washed thoroughly with soap and water. Solvents shall *not* be used, because they carry the irritant into the skin. Cured epoxy resins are innocuous.

## 9. Sampling

9.1 Take samples in accordance with Specification [C881/C881M](#).



**FIG. 1 Dummy Section**



## 10. Test Specimens

10.1 Three composite test specimens are required for all Types of resin systems.

### 10.2 Conditioning:

10.2.1 *Types I, III, IV, VI, and VII Systems*—Condition the resin system components, the mortar sections, and all equipment that will contact the resin to the temperatures specified in Specification **C881/C881M**.

10.2.1.1 Prepare the test specimens and make provision for maintaining them at the appropriate temperature during the entire cure time. Prepare the surface to be bonded by sand-blasting and dry brushing to remove all loose surface material.

10.2.1.2 Use mortar sections and assemblies that have been soaked in water for 24 h. Place the face of the mortar sections to be bonded on an absorbent material for 10 min prior to applying the adhesive. For assembled test specimens, remove all water by shaking. Allow to air dry for 15 min.

10.2.2 *Type II and Type V Systems*—Since Type II and Type V resins are appropriate for use only at temperatures that permit strength gain of the freshly prepared concrete, only the conditioning temperature for a Class C resin,  $23 \pm 1^\circ\text{C}$  [ $73 \pm 2^\circ\text{F}$ ], need be provided.

### 10.3 Specimen Preparation:

10.3.1 *Type I, III, IV, VI, and VII, Grade 2 or 3 Systems*—Two mortar sections will be needed for each test specimen. Wrap 100  $\mu\text{m}$  [4 mil] of polyethylene film 150 by 500 mm [6 by 20 in.] around one section of each pair, even with the base and secure with masking tape. Thoroughly mix the components of the bonding system in the proportions recommended by the formulator. A mixing time of 3 min should suffice. Support the film-wrapped mortar section so that the prepared bonding surface is horizontal.

10.3.1.1 To test Grade 2 systems, apply a 0.5 mm [0.02 in.] layer of the bonding systems to the prepared elliptical surface of the film wrapped mortar section. Using Grade 3 systems, apply a 0.5 mm [0.02 in.] layer of bonding system on the prepared elliptical surface of the mortar section not film wrapped. For the determination of contact strength (Specification **C881/C881M**) of Type VI and VII systems, apply a 2.0-mm [ $\frac{1}{16}$ -in.] layer to the prepared elliptical surface of both mortar sections.

10.3.1.2 Insert mortar sections not film wrapped into the cylinder formed by film surrounding other mortar sections and squeeze out the excess resin through a hole, or holes, punched in the film at the bondline, while keeping the joint horizontal. Secure the assembly with sufficient additional masking tape placed around the film. Be sure the joint is entirely filled. Keep the bonded joint horizontal for 48 h, then remove all the masking tape.

10.3.2 *Type I, III, and IV, Grade 1 Systems*—Two mortar sections will be needed for each test specimen. Prepare the elliptical bonding surface as described in 10.2. Place the two halves of the specimen together, forming a gap approximately 0.5 mm [0.02 in.]. Wrap masking tape around the periphery of the specimen close to each end. Place additional tape along the joint. Coat the tape over the joint with hot paraffin to help contain the epoxy when it is poured into the slit. Support the

specimen so that the taped joint is vertical. Cut a slit in the tape to expose approximately 20 mm [ $\frac{3}{4}$  in.] of the upper portion of the joint. Slowly pour the resin bonding system into the exposed joint until it is completely filled. Keep the joint vertical for 48 h, then remove all masking tape.

10.3.3 *Type II and V Systems*—One hardened mortar section will be needed for each test specimen. Prepare the mortar surface as described in 10.2, but do not tape around the edge. Mix the components of the bonding system as described in 10.3. Brush the bonding system on the prepared surface. Place the primed mortar section in the cylinder mold that has previously been lined with a 100- $\mu\text{m}$  [4-mil] polyethylene sheet. Support the mold so that the bonding surface of the mortar section is horizontal. Place a layer of freshly mixed portland-cement mortar over the primed surface to a depth of approximately 15 mm [ $\frac{1}{2}$  in.]. Rod the layer with the tamping rod gently, so as to disturb the layer of resin as little as possible. Place the mold in its normal vertical position, and place additional mortar into the mold in two layers of approximately equal volume. Rod each layer with 25 strokes of the tamping rod. Distribute the strokes over the cross section, and make them deep enough to penetrate into the underlying layer. Strike off the surface of the top layer with the trowel, and cover the mold with a glass or metal plate.

### 10.4 Curing:

10.4.1 *Type I, III, IV, VI, and VII Systems*—Maintain all specimens at the preparation temperature in a moist room for the specified period of time.

10.4.2 *Type II and V Systems*—Demold the test specimens and cure in accordance with the curing section of Practice **C192/C192M**.

## 11. Procedure

11.1 Remove the specimens from the cure environment after the specified time.

11.2 *Capping*—Cap the specimens immediately after removal from curing in accordance with Practice **C617**.

11.3 *Strength Testing*—Test the specimens at  $23 \pm 1^\circ\text{C}$  [ $73 \pm 2^\circ\text{F}$ ] in compression after capping in accordance with Test Method **C39/C39M**.

## 12. Calculation

12.1 Calculate the bond strength of the resin bonding system by dividing the load carried by the specimen at failure by the area of the bonded surface (**Note 2**). Reduce the area of the bonded surface by that of any voids found in the bond on inspection after test. Only voids larger than 3 mm [ $\frac{1}{8}$  in.] should be counted in reducing the area. Report the results to the nearest 0.1 MPa [10 psi].

NOTE 2—The area of the elliptical bonding surface of the test cylinders specified in this test method is  $9116\text{ mm}^2$  [ $14.13\text{ in.}^2$ ]. The actual area should be based on measuring the lengths of the two axes for the areas of an ellipse [ $0.7854\text{ a b}$ ]

## 13. Report

13.1 Report the following information:

13.1.1 Identification number,



- 13.1.2 Bond strength,
- 13.1.3 Bonding area,
- 13.1.4 Number and total area of voids in the bond,
- 13.1.5 Type and position of the fracture (in the bonding material, in the mortar, or in the interface between them), and
- 13.1.6 Defects in either the specimen or the cap.

#### 14. Precision and Bias

14.1 *Precision*—The standard deviation was found to be 365 psi for the 14 day bond strength average of 1790 psi. Therefore,

results of two properly conducted tests from two laboratories on similar batches should not differ from each other by more than 1022 psi.

14.2 *Bias*—This test method has no bias since the values determined can only be defined in terms of this test method.

#### 15. Keywords

15.1 adhesives; bonding agents; bond strength; shear bond

### SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to these test methods since the last issue, C882/C882M – 13, that may impact the use of these test methods. (Approved December 1, 2013.)

(1) Revised **Table 1**.

(2) Revised **7.1.1**.

Committee C09 has identified the location of selected changes to these test methods since the last issue, C882/C882M – 12, that may impact the use of these test methods. (Approved June 15, 2013.)

- (1) Revised 2.1 by adding Specification C 470/C 470M as a reference document.
- (2) Revised 6.2 to use Specification C 470/C 470M molds.
- (3) Revised 6.4 to use Practice C 192/C 192M tamping rod.
- (4) Renumbered 7.2 and 7.3 to be subparagraphs of 7.1.
- (5) Revised 7.1.1 to be in agreement with methods of consolidation in Practice C 192/C 192M and added clarification.

- (6) Added Note 1 below 7.1.2 to provide additional information to operators regarding compressive strength requirements of the mortar.
- (7) Added sections 7.2 to 7.5.

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