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Standard Specification for Epoxy-Resin-Base Bonding Systems for Concrete[1]

This standard is issued under the fixed designation C 881; 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.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers two-component, epoxy-resin bonding systems for application to portland-cement concrete, which are able to cure under humid conditions and bond to damp surfaces.

1.2 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 exact equivalents, therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with this specification.

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.* For specific hazards statements, see Section 9.

2. Referenced Documents

2.1 *ASTM Standards:*

C 882 Test Method for Bond Strength of Epoxy-Resin Systems Used with Concrete by Slant Shear[2]

C 884 Test Method for Thermal Compatibility Between Concrete and an Epoxy-Resin Overlay[2]

D 570 Test Method for Water Absorption of Plastics[3]

D 638 Test Method for Tensile Properties of Plastics[3]

D 648 Test Method for Deflection Temperature of Plastics Under Flexural Load[3]

D 695 Test Method for Compressive Properties of Rigid Plastics[3]

D 1259 Test Methods for Nonvolatile Content of Resin Solutions[4]

D 1652 Test Method for Epoxy Content of Epoxy Resins[5]

D 2393 Test Method for Viscosity of Epoxy Resins and Related Compounds[6]

D 2566 Test Method for Linear Shrinkage of Cured Thermosetting Casting Resins During Cure[6]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *binder, n*—the cementitious part of a grout, mortar, or concrete that binds the aggregate or filler into a cohesive mass.

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

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

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

3.1.5 *contact time, n*—specified time between when the epoxy 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.

3.1.6 *curing agent, n*—a substance that causes the conversion of a fluid resin system to a solid cured resin by means of a chemical reaction.

3.1.7 *epoxy equivalent, n*—the weight of resin containing one molecular weight of epoxy groups.

3.1.8 *epoxy resin, n*—a resin that contains or did contain epoxy groups principally responsible for its polymerization.

3.1.9 *filler, n*—a finely divided solid, predominantly passing the No. 200 [75-μm] sieve, that is used to improve certain properties of the bonding system or to reduce cost.

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

3.1.11 *lot or batch, n*—that quantity of manufactured material which has been subjected to the same unit chemical or physical processes intended to make the final product substantially uniform.

3.1.12 *manufacturer, n*—a producer of a basic constituent part of a component.

3.1.13 *reactive diluent, n*—a relatively free flowing liquid used to reduce the viscosity of the liquid resin or resin mixture, and which contains reactive groups that cause it to become an

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[2] *Annual Book of ASTM Standards*, Vol 04.02.

[3] *Annual Book of ASTM Standards*, Vol 08.01.

[4] *Annual Book of ASTM Standards*, Vol 06.01.

[5] *Annual Book of ASTM Standards*, Vol 06.03.

[6] *Annual Book of ASTM Standards*, Vol 08.02.

integral part of the cured resin.

3.1.14 *working (pot) life, n*—the time after mixing during which a bonding system or mixture containing it retains sufficient workability for proper use.

4. Classification

4.1 This specification provides for the classification of epoxy-resin bonding systems by type, grade, class, and color.

4.2 *Types*—Seven types of systems that are distinguished by the requirements of Table 1 are recognized:

4.2.1 *Type I*—For use in non-load bearing application for bonding hardened concrete to hardened concrete and other materials, and as a binder in epoxy mortars or epoxy concretes.

4.2.2 *Type II*—For use in non-load bearing applications for bonding freshly mixed concrete to hardened concrete.

4.2.3 *Type III*—For use in bonding skid-resistant materials to hardened concrete and as a binder in epoxy mortars or epoxy concretes used on traffic bearing surfaces (or surfaces subject to thermal or mechanical movements).

4.2.4 *Type IV*—For use in load bearing applications for bonding hardened concrete to hardened concrete and other materials and as a binder for epoxy mortars and concretes.

4.2.5 *Type V*—For use in load bearing applications for bonding freshly mixed concrete to hardened concrete.

4.2.6 *Type VI*—For bonding and sealing segmental precast elements with internal tendons and for span-by-span erection when temporary post tensioning is applied.

4.2.7 *Type VII*—For use as a nonstress carrying sealer for segmental precast elements when temporary post tensioning is not applied as in span-by-span erection.

NOTE 1— Epoxy resin systems will adhere to a wide variety of materials, including wood, metals, masonry, and most plastics. Polyethylene, TFE-fluorocarbon, cellophane, and greased or waxed surfaces are

TABLE 1 Physical Requirements of Bonding Systems

Property	Type						
	I	II	III	IV	V	VI	VII
Viscosity, P [Pa·s]:							
Grade 1, max	20[2.0]	20[2.0]	20[2.0]	20[2.0]	20[2.0]	...	...
Grade 2, min	20[2.0]	20[2.0]	20[2.0]	20[2.0]	20[2.0]	...	...
max	100[10]	100[10]	100[10]	100[10]	100[10]	...	...
Consistency, in [mm]:							
Grade 3, Types I, II, III, IV, V, VI, VII, max	¼[6.0]	¼[6.0]	¼[6.0]	¼[6.0]	¼[6.0]	¼[6.0]	¼[6.0]
Gel time, minutes, min	30	30	30	30	30	30	30
Bond strength, min, psi [MPa]:							
2 days (moist cure)	1000[7.0]	...	...	1000[7.0]	...	1000[7.0]	...
14 days (moist cure)	1500[10.0]	1500[10.0]	1500[10.0]	1500[10.0]	1500[10.0]	...	1000[7.0]
Absorption, 24 h max, %	1	1	1	1	1	...	...
Heat Deflection Temperature, min, °F [°C]:							
7 days	...	...	...	120[50]	120[50]	...	...
14 days	...	...	...	...	...	120[50]	120[50]
Thermal compatibility	...	...	passes test	...	...	...	...
Linear coefficient of shrinkage on cure, max	0.005	0.005	...	0.005	0.005	...	...
Compressive Yield Strength, min, psi [MPa]:							
24 h	...	...	...	...	...	2000[14.0]	...
36 h	...	...	...	...	...	...	1000[7.0]
48 h	...	...	...	...	...	6000[40.0]	...
72 h	...	...	...	...	...	...	2000[14.0]
7 days	8000[55.0]	5000[35.0]	...	10 000[70.0]	8000[55.0]	...	...
Compressive Modulus, psi [MPa]							
Min	150 000[1000]	90 000[600]	...	200 000[1400]	150 000[1000]	...	...
Max	...	...	130 000[896]	...	...	...	...
Tensile Strength, 7 days min, psi [MPa]	5000[35.0]	2000[14.0]	...	7000[50.0]	6000[40.0]	...	...
Elongation at Break, %, min	1	1	30	1	1	...	...
Contact strength, psi [MPa] min							
2 days	...	...	...	...	...	1000[7.0]	...
14 days	...	...	...	...	...	...	1000[7.0]

among the few materials to which these systems will not adhere.

4.3 *Grades*—Three grades of systems are defined according to their flow characteristics and are distinguished by the viscosity and consistency requirements of Table 1.

4.3.1 *Grade 1*—Low viscosity.

4.3.2 *Grade 2*—Medium viscosity.

4.3.3 *Grade 3*—Non-sagging consistency.

4.4 *Classes*—Classes A, B, and C are defined for Types I through V, and Classes D, E, and F are defined for Types VI and VII, in accordance with the range of temperatures for which they are suitable (Note 2).

4.4.1 *Class A*—For use below 40°F [4.0°C] the lowest allowable temperature to be defined by the manufacturer of the product.

4.4.2 *Class B*—For use between 40 and 60°F [4.0 and 15.0°C].

4.4.3 *Class C*—For use above 60°F [15.0°C] the highest allowable temperature to be defined by the manufacturer of the product.

4.4.4 *Class D*—For use between 40 and 65°F [4.0 and 18.0°C].

4.4.5 *Class E*—For use between 60 and 80°F [15.0 and 30.0°C].

4.4.6 *Class F*—For use between 75 and 90°F [25.0 and 30.0°C].

NOTE 2—The temperature in question is usually that of the surface of the hardened concrete to which the bonding system is to be applied. This temperature may be considerably different from that of the air. Where unusual curing rates are desired it is possible to use a class of bonding agent at a temperature other than that for which it is normally intended. For example, a Class A system will cure rapidly at room temperature.

4.5 *Color*—Epoxy resin systems are normally unpigmented, but they can be colored or darkened. If a specific color is desired, it should be so stated by the purchaser.

5. Ordering Information

5.1 The purchaser shall specify the type, grade, class, and color of bonding system desired and the size of units in which the components shall be furnished. Special requirements regarding filling of either the components or the final bonding system should be stated. The product furnished under this specification is intended to be resistant to moisture and therefore should be suitable for either indoor or outdoor exposure.

5.2 The purchaser may specify a minimum gel time of 5 min for Types I and IV when automatic proportioning, mixing, and dispensing equipment are used.

6. Materials and Manufacture

6.1 The systems covered by this specification shall be furnished in two components for combining immediately prior to use in accordance with written instructions of the formulator. Component A shall contain an epoxy resin with or without a reactive diluent. Component B shall contain one or more curing agents, which on mixing with Component A shall cause the mixture to harden. A suitable inert filler may be uniformly incorporated in one or both components. The filler shall be either nonsettling or readily dispersible in any component in which it is incorporated. All systems shall cure under humid conditions, and bond to damp surfaces.

7. Chemical Composition

7.1 The epoxy resin constituent of Component A shall have an epoxy equivalent of 155 to 275.

8. Physical Properties

8.1 A mixture of Components A and B in the proportions recommended by the formulator shall conform to the properties prescribed in Table 1.

9. Safety Hazards

9.1 **Caution:** 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 washed thoroughly with soap and water. Solvents shall *not* be used, because they carry the irritant into the skin. Cured epoxy resins are innocuous.

10. Sampling

10.1 Take a representative sample of each of the two components from a well-blended lot prior to packaging or by withdrawing samples from no fewer than 5 % of the containers comprising the lot or shipment. Unless the samples of the same component taken from containers show visual evidence of variability, they may be combined into a single composite sample. In place of the foregoing, packaged materials may be sampled by a random selection of containers of each component from each lot, provided such a procedure is acceptable to the purchaser.

11. Test Methods

11.1 *Consistency*—Test Method to Determine The Consistency of an Epoxy Resin System.

11.1.1 *Scope*—This test provides a method for determining the consistency of Grade 3 epoxy resin systems.

11.1.2 *Significance and Use*—This test method is used to determine compliance with the requirements of the specification.

11.1.3 *Apparatus*:

11.1.3.1 *Paper cup*—Approximately 3 oz. [approximately 0.100L] unwaxed paper cup.

11.1.3.2 *Mixing blade*—Ordinary wooden tongue depressor or stick of similar size.

11.1.3.3 *Glass panel.*

11.1.4 *Conditioning*—Condition the individual components and any equipment with which they will come in contact to the following temperatures: Class A, 32 ± 2°F [0 ± 1°C]; Class B, 50 ± 2°F [10 ± 1°C]; Class C, 73 ± 2°F [23 ± 1°C], Class D, 65° ± 2°F [18° ± 1°C]; Class E, 80° ± 2°F [27°± 1°C]; Class F, 90° ± 2°F [32° ± 1°C] or to the temperature at which the material will be used (Note 2).

11.1.5 *Procedure*—Prepare approximately 30 cm^3 of the bonding system. Weigh the necessary amounts of the components to an accuracy of 1 % into a single 3-oz [approximately 100-cm^3] unwaxed paper cup. Mix immediately with a wooden tongue depressor or stick of similar size. Note the time at

which mixing begins. Mix for 3 min, taking care to scrape the side and bottom of the cup periodically. Immediately apply about 2 cm^3 of the mixture to a glass panel. Form a semicylindrical bead of the bonding system by drawing the applicator blade through the sample in a straight line with the panel horizontal. Immediately raise the panel to a position inclined at no greater than 10° from vertical and with the bead horizontal. Maintain the panel and sample at their original temperature until the bonding system has cured, as determined by an inability to indent it appreciably with a pencil point or fingernail. Determine the consistency by measuring the flow of the lower edge of the bead from its original position at three points along its length.

11.1.6 *Report*—Report the average value to the nearest ⅛in. [1 mm].

11.1.7 *Precision and Bias*:

11.1.7.1 *Precision*—The precision of the procedure in this test method for consistency is being determined.

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

11.2 *Gel Time*:

11.2.1 Test Method to Determine the Gel Time of an Epoxy Resin System.

11.2.2 *Scope*—This test method determines the time after mixing when an epoxy resin system gels.

11.2.3 *Significance and Use*—This test method is used to determine compliance with the requirements of the specification.

11.2.4 *Apparatus*:

11.2.4.1 *Paper cup*—8 oz. [approximately 250 cm^3] unwaxed paper cup

11.2.4.2 *Mixing blade*—Ordinary wooden tongue depressor or stick of similar size.

11.2.5 *Conditioning*—Condition the individual components and any equipment with which they will come in contact to the temperatures set forth in 11.1, depending on the class of system in question, or to the temperature at which the material will be used, providing that temperature is within the ranges established in 4.4 for Types I, II, III, and V. For Type VI and VII use the highest temperature of the specified class (Note 2). Prepare 60 g of the bonding system for Types I through V and 1 gal [4.0 L] for Types VI and VII using the procedures set forth in 11.1.

11.2.6 *Procedure*—Transfer as much as possible of the sample into an 8-oz [approximately 250-cm^3] unwaxed paper cup and set it on a wooden surface in a location maintained at the original conditioning temperature and not subject to abnormal room air movement. Determine the time at which a soft, gelatinous mass forms in the center of the sample by probing every 2 min with a wooden tongue depressor or similar device, starting 8 min after the beginning of mixing.

11.2.7 *Report*—The gel time is the interval between the beginning of mixing and the formation of the gelatinous mass.

11.2.8 *Precision and Bias*:

11.2.8.1 *Precision*—The precision of the procedure in this test method for gel time is being determined.

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

11.3 *Filler Content*:

11.3.1 Test Method to Determine the Filler Content of Epoxy Resin Systems.

11.3.2 *Scope*—This test method is a quantitative test to determine the filler content of epoxy resin systems.

11.3.3 *Significance and Use*—the filler content of an epoxy resin system must be known in order to determine the epoxy equivalent.

11.3.4 *Apparatus*:

11.3.4.1 150 mL beaker.

11.3.4.2 Medium porosity, fritted disk filtering crucible.

11.3.4.3 *Mixing blade*—Ordinary wooden tongue depressor or stick of similar size.

11.3.5 *Reagents*:

11.3.5.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society where such specifications are available.[7] Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

11.3.5.2 Methyl ethyl ketone (MEK).

11.3.5.3 Benzene.

11.3.6 *Procedure*—Weigh, to the nearest 0.1 mg, approximately 10 g of the epoxy resin component into a 150-mL beaker. Add 50 mL of methyl ethyl ketone (MEK) to the beaker, and stir the contents until all the soluble matter is dissolved. If the sample is black, owing to the presence of bituminous material, the solvent used shall be a mixture of 1+1 MEK and benzene, by volume. Dry a medium-porosity, fritted-disk filtering crucible to constant weight at 230 ± 9°F [110 ± 5°C]. Wet the filter with MEK, then filter the contents of the beaker through the filtering crucible with the aid of a vacuum. Transfer the contents of the beaker entirely to the crucible, and wash the beaker and the residue on the filter with MEK. The total volume of solvent used to transfer and wash the residue should be about 200 mL. Dry the filter and residue to constant weight at 230 ± 9°F [110 ± 5°C].

11.3.7 *Report*—Calculate the percentage of filler in the component, and report the value to the nearest 0.1 %.

11.3.8 *Precision and Bias*

11.3.8.1 *Precision*—The precision of the procedure in this test method for filler content is being determined.

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

11.4 *Epoxy Equivalent*—Determine the epoxy equivalent of Component A in accordance with Test Method D 1652. Calculate the epoxy equivalent after correcting for any filler and volatile contents of the component as follows:

$$x = y(1 - f - v) \quad (1)$$

[7] *Reagent Chemicals, American Chemical Society Specifications*, American Chemical Society, Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see *Analar Standards for Laboratory Chemicals*, BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopeia and National Formulary*, U.S. Pharmacopeial Convention, Inc. (USPC), Rockville, MD.

where:

x = corrected weight per epoxy equivalent of the component,

y = weight per epoxy equivalent of the total component as determined by Test Method D 1652,

f = weight fraction of filler in the component, and

v = weight fraction of volatile matter in the component.

11.5 *Viscosity*—Determine the viscosity of the freshly mixed resin system by means of Test Method D 2393, except that the determination shall be made at the temperature given in 11.1 for the class of material in question.

11.6 *Absorption*—Determine the absorption by means of Test Method D 570. The test specimens shall have the shape and dimensions specified for molded plastics, shall be cured for 14 days at a temperature of 73 ± 2°F [23 ± 1°C], shall be tested in accordance with the procedure for 24-h immersion and shall be reconditioned, if necessary, as directed in Test Method D 570.

11.7 *Bond Strength*—Determine the bond strength in accordance with Test Method C 882.

11.8 *Thermal Compatibility*—Determine the thermal compatibility in accordance with Test Method C 884.

11.9 *Heat Deflection Temperature*—Determine the heat deflection temperature in accordance with Test Method D 648, except condition, mix, cure, and start testing the resin components at 73 ± 2°F [23 ± 1°C].

11.10 *Linear Coefficient of Shrinkage*— Determine the linear coefficient of shrinkage in accordance with Test Method D 2566, except condition, mix, cure, and test the resin components at 73 ± 2°F [23 ± 1°C].

11.11 *Compressive Yield Strength and Modulus*—Determine the compressive yield strength and modulus in accordance with Test Method D 695, except condition, mix, and cure the resin components at the lowest application temperature of the specified class. Test at 73 ± 2°F [23 ± 1°C] without delay. Use of a 1 × 1 × 2-in. [25.4 × 25.4 × 50.8-mm] specimen is also acceptable.

11.12 *Tensile Strength and Elongation at Break*—Determine the tensile strength and elongation at break in accordance with Test Method D 638, except condition, mix, and cure at the lowest application temperature of the specified class. Test at 73 ± 2°F [23 ± 1°C] without delay.

11.13 *Contact Strength*—Determine the contact strength in accordance with Test Method C 882 except condition the material and the specimens at the highest application temperature of the specified class and apply the bonding system at a thickness of 1/16 in. [2 mm] on the slanted surface of each half cylinder. Maintain at the highest application temperature and assemble the two half cylinders after 1 h for Type VI and 8 h for Type VII. Cure at the assembly temperature and test at 73 ± 2°F [23± 1°C]. Contact strength is expressed in terms of pounds per square inch obtained after a specified time of cure.

12. Rejection and Rehearing

12.1 The purchaser has the right to reject material that fails to conform to the requirements of this specification. Rejection shall be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier has the right to a rehearing.

12.2 If all requirements of this specification are met, except those pertaining to bond strength, the bond tests shall be repeated. If the sample again fails to meet the bond strength requirements, the entire lot shall be rejected.

12.3 *Retest*—Lots of material that have been rejected may be reworked by the producer to correct the defects and resubmitted for test provided specific approval of the purchaser has been obtained for such resubmission. Before resubmission of the material, full particulars concerning the action taken to correct the defects in the original material shall be made available to the purchaser.

13. Packaging and Package Marking

13.1 *Packaging*—The two components furnished under this specification shall be supplied in separate containers that are nonreactive with the contents. They are usually supplied in amounts such that the recommended proportions of the final mixture can be obtained by combining one container of Component A with one container of Component B.

13.2 *Marking*—Containers shall be identified as "Component A—Contains Epoxy Resin" and "Component B—Contains Curing Agent" and shall show the type, grade, class, and color. Each container shall be marked with the name of the formulator, the lot number, the date of packaging, the quantity contained therein, and the recommended mixing ratio, by both weight and volume.

14. Keywords

14.1 bonding; bonding systems; contact strength; contact time; epoxy resin