



TECHNICAL **GUIDELINES**

Prepared by the International Concrete Repair Institute

August 2012

Guideline for Inorganic Repair Material Data Sheet Protocol

Guideline No. 320.3R-2012

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International Concrete Repair Institute

10600 West Higgins Road, Suite 607, Rosemont, IL 60018

Phone: 847-827-0830 Fax: 847-827-0832

E-mail: info@icri.org

Web: www.icri.org

About ICRI Guidelines

The International Concrete Repair Institute (ICRI) was founded to improve the durability of concrete repair and enhance its value for structure owners. The identification, development, and promotion of the most promising methods and materials are primary vehicles for accelerating advances in repair technology. Working through a variety of forums, ICRI members have the opportunity to address these issues and directly contribute to improving the practice of concrete repair.

A principal component of this effort is to make carefully selected information on important repair subjects readily accessible to decision-makers. During the past several decades, much has been reported in the literature on concrete repair methods and materials as they have been developed and refined. Nevertheless, it has been difficult to find critically reviewed information on the state of the art condensed into easy-to-use formats.

To that end, ICRI guidelines are prepared by sanctioned task groups and approved by the ICRI Technical Activities Committee. Each guideline is designed to address a specific area of practice recognized as essential to the achievement of durable repairs. All ICRI guideline documents are subject to continual review by the membership and may be revised as approved by the Technical Activities Committee.

Synopsis

The purpose of this document is to provide a standardized protocol for testing and reporting of data for inorganic repair materials. It does not address all of the issues associated with material selection. It is the responsibility of the user of this document to determine the suitability of the repair material prior to use. Commentary and supplemental information in this document is italicized. The test methods for the determination of the reported data must be reported from the methods listed in this document and the method used listed adjacent to the reported data. Test data must be reported in the order and sections as listed in this document. Terminology, except as defined within this document, should refer to the current version of the ICRI Concrete Repair Terminology. Further information describing the significance and use of the test methods described herein may be found in ICRI 320.2, ACI 364.3, and ACI 546.3.

Keywords

data sheet protocol; material properties; material specifications; repair material; test methods

Technical Activities Committee

Kevin A. Michols, Chair
James E. McDonald, Secretary
Voting Members:
Frank Apicella
Don Caple
Jorge Costa
Andrew S. Fulkerson
H. Peter Golter
Gabriel A. Jimenez
Peter R. Kolf
David Rodler
Lee Sizemore
Stephan Trepanier
David Whitmore
Patrick Winkler

Producers of this Guideline

This document was prepared by a task group consisting of individuals representing the repair industry. Task Group members who contributed to the creation of this document are:

Stephen Baxter
Andrew Fulkerson
Fred Goodwin
Pierre Hebert
James McDonald
Mark Nelson
Thomas Quinn
Robert Terpening
Torrey Thompson
Stephan Trepanier

Members of **ICRI Committee 320, Concrete Repair Materials and Methods**, finalized and approved this document:

Fred Goodwin, Chair*	Kiley P. Marcoe
Frank Verano, Secretary	James E. McDonald*
Dick Bonin	Kevin A. Michols
Richard Braun	Paul Millette
Joe Daley	Michael A. Paipal
Mark A. DeStefano	Greg Peak
Luis Diaz DeLeon	Clyde Porter Jr.
Andrew S. Fulkerson*	Scott Rand
Steven Geiger	Jeffery G. Smith
Narendra Gosain	Robert Swan
Pierre Hebert*	Aamer Syed
James Hicks	Dan Wald
Joshua Hollis	Patrick "Doc" Watson
David G. Karins	
Peter R. Kolf	*Task Group Member

Contents

- 1.0 Introduction**
- 2.0 Definitions**
- 3.0 Repair Material Description**
 - 3.1 Material Type
 - 3.2 Recommended Use
 - 3.3 Benefits
 - 3.4 Limitations
- 4.0 Composition Properties**
 - 4.1 Total Sulfate Trioxide Content
 - 4.2 Total Alkali Content
 - 4.3 Total Chloride Content
 - 4.4 pH
 - 4.5 Characteristics of Aggregate
 - 4.5.1 Fine Aggregate
 - 4.5.2 Coarse Aggregate
- 5.0 Material Properties**
 - 5.1 Curing Regimen
 - 5.2 Unit Weight
 - 5.3 Air Content
 - 5.4 Yield
 - 5.5 Density, Absorption, and Voids
 - 5.6 Setting Time
 - 5.7 Compressive Strength
 - 5.8 Flexural Strength
 - 5.9 Splitting Tensile Strength
 - 5.10 Direct Tensile Strength
 - 5.11 Modulus of Elasticity
 - 5.12 Bond Strength
 - 5.13 Length Change
 - 5.14 Coefficient of Thermal Expansion
 - 5.15 Resistance to Freezing-and-Thawing Cycles
 - 5.16 Scaling Resistance
 - 5.17 Compressive Creep
 - 5.18 Rapid Chloride Ion Permeability
 - 5.19 Chloride Ponding
 - 5.20 Sulfate Resistance
 - 5.21 Chemical Resistance
 - 5.22 Cracking Resistance
- 6.0 Packaging and Storage**
 - 6.1 Packaging
 - 6.2 Other Information

Contents (cont.)

7.0 How to Use the Material

- 7.1 Surface Preparation
- 7.2 Mixing
 - 7.2.1 Aggregate Extension
 - 7.2.2 Mixing Time
 - 7.2.3 Mixing Equipment
 - 7.2.4 Mixing Liquid
 - 7.2.5 Yield
 - 7.2.6 Application
 - 7.2.7 Finishing
 - 7.2.8 Curing
- 7.3 Bonding Agents
- 7.4 Cleanup
- 7.5 Safety

8.0 References

- 8.1 Referenced Standards and Reports
- 8.2 Other Cited References

This document is intended as a voluntary guideline for the owner, design professional, and concrete repair contractor. It is not intended to relieve the professional engineer or designer of any responsibility for the specification of concrete repair methods, materials, or practices. While we believe the information contained herein represents the proper means to achieve quality results, the International Concrete Repair Institute must disclaim any liability or responsibility to those who may choose to rely on all or any part of this guideline.

1.0 Introduction

This document, commonly called “The Data Sheet Protocol,” was an outcome of Vision 2020 and is intended to allow the specifier to choose verifiable properties optimized for their selected requirements of a particular repair situation. The repair material applicator can also obtain useful information about yield, working time, surface preparation, application temperature range, curing, and compatibility, as well as verify the material performance. The material producer can optimize products based on market needs and technology improvements.

2.0 Definitions

Cementitious material—That fraction of the inorganic repair material passing a 90 μ (micron) (No. 170 mesh) per ASTM E11, and mortar to be a material consisting of an inorganic binder with the only aggregate being fine aggregate according to ASTM C33/C33M.

Data Sheet Protocol—A list of significant properties, methods for determining those properties, and reporting that information.

Extended mortar—Concrete produced by the addition of coarse aggregate to a mortar product.

Extended mortar and concrete—Those materials that contain both fine and coarse aggregate per ASTM C33/C33M.

Material properties—An intensive, often quantitative property of a material, usually with a unit that may be used as a metric of value to compare the benefits of one material versus another, such as mechanical, physical, or electrochemical characteristics.

Material specifications—An explicit set of requirements to be satisfied by a material.

Polymer-cement materials—A mortar or concrete whose properties benefit from the addition of polymer when cured per ASTM C1439, commonly known as polymer-modified materials.

Repair material—A material applied to hardened concrete intended to restore the concrete to its desired function.

Test methods—A definitive procedure that produces a test result.

3.0 Repair Material Description

3.1 Material Type

Examples: Repair mortar, extended/extendable repair mortar, concrete, etc.

3.2 Recommended Use

Examples: Horizontal, vertical, overhead, traffic-wearing surface repairs, etc.

3.3 Benefits

Examples: Rapid strength development, shrinkage-compensated, polymer-cement, etc.

3.4 Limitations

Examples: Minimum/maximum placement depth with/without aggregate, application temperature range, moisture exposure, etc.

4.0 Composition Properties

4.1 Total Sulfate Trioxide (SO₃) Content, %, ASTM C114

State the percentage of total SO₃ contained within all cementitious materials stated as a percentage by mass. If sulfate levels are above those contributed from portland cement, the material producer shall provide data and methods used to establish suitability for the recommended uses stated in Section 1.0.

4.2 Total Alkali Content, %, ASTM C114

State the total sodium equivalent alkalis contained within all cementitious materials as a percentage by weight.

The typical means by which the alkali content has been controlled with concrete mixtures in the United States has been to establish a maximum limit only on the portland cement. Cement with an alkali content of less than 0.6%, expressed as equivalent Na₂O, is referred to as low-alkali cement. This provision has generally proven to be satisfactory for concrete. The disadvantage of establishing an alkali limit based

on the alkali of the portland cement alone for repair materials is that many proprietary repair materials contain blends of different cements, additives, admixtures, and other constituents that contain alkali. It is the sum of the alkalis from all sources that is pertinent to the potential reaction with a reactive aggregate.

Past research conducted in Germany and Canada led to the conclusion that when the alkali in a mixture is kept below a maximum of 3.0 kg/m³ (5.0 lb/yd³), there will be no alkali-aggregate reaction (Gress 1997).

4.3 Total Chloride Content, %

State the total water-soluble chlorides per ASTM C1218/C1218M and acid-soluble chloride content per ASTM C1152/C1152M as a percentage by weight of the material. The considerations of chloride-ion content discussed in ACI 222R require a cautionary statement on the packaging if an oxidizable metal such as iron, steel, zinc, or aluminum is allowed to be embedded in proximity of a chloride containing concrete repair material.

4.4 pH

Report the pH of the fresh and hardened repair material.

Crush a hardened sample of the inorganic repair material to pass a No. 170 (90 μ) mesh sieve, stir 0.35 oz (10 g) of the crushed material into 3.2 oz (90 g) distilled or deionized water for 1 minute and, after settling, use pH paper or a suitable pH meter per the recommendations of the supplier of the pH equipment. The determination of pH provides an indication whether sufficient hydroxide ion is present to provide passivation of reinforcing steel.

4.5 Characteristics of Aggregate, ASTM C33/C33M

For prepackaged products, use the +170 mesh fraction obtained by wet-sieving according to ASTM C117 for the tests specified in the section titled “Methods of Sampling and Testing” of ASTM C33/C33M. Provide the following information:

4.5.1 Fine Aggregate

- General characteristics
- Grading
- Deleterious substances
- Soundness per ASTM C88
- Reactivity per ASTM C1260

4.5.2 Coarse Aggregate

- General characteristics
- Grading
- Deleterious substances
- Soundness (per ASTM C88)
- Reactivity (per ASTM C1260)

ASTM C1260 provides a means of detecting the potential of an aggregate intended for use in concrete for undergoing alkali-silica reaction, resulting in potentially deleterious internal expansion within 16 days in mortar bars. It is especially useful for aggregates that react slowly or produce expansion late in the reaction. However, the potential reactivity determined by ASTM C1260 does not evaluate all possible factors influencing alkali-aggregate reactions, such as combinations of aggregates with cementitious materials, nor are the test conditions representative of those encountered by concrete in service. Because the specimens are exposed to an NaOH solution, the alkali content of the cement is not a significant factor in affecting expansions. When excessive expansions are observed from the results of ASTM C1260, it is recommended that supplementary information be developed to confirm that the expansion is actually due to alkali-silica reaction. Sources of such supplementary information include: 1) petrographic examination of the aggregate to determine if known reactive constituents are present (ASTM C295/C295M); 2) examination of the specimens after tests (ASTM C856) to identify the products of alkali reaction; and 3) where available, field service records can be used in the assessment of performance. When it has been concluded from the results of tests performed using this test method and supplementary information that a given aggregate should be considered potentially deleteriously reactive, the use of mitigative measures should be evaluated.

5.0 Material Properties

The material property and test methods are to be performed at 1, 7, and 28 days of age, unless otherwise noted.

5.1 Curing Regimen

- Normal-setting nonpolymer-cement materials—
Cure in moist cabinet or room per ASTM C511.

Remove specimens from mold at $23.5 \pm 1/2$ hours from the time of initial contact of liquid and powder during mixing and make initial comparator reading immediately.

- Normal-setting polymer-cement materials—ASTM C1439. Immediately cover molded specimens with polyethylene film (>3.9 mil [0.1 mm] thickness) and store at $73 \pm 3^\circ\text{F}$ ($23 \pm 2^\circ\text{C}$) and $50 \pm 4\%$ relative humidity (RH). Remove specimens from mold at $23\text{-}1/2 \pm 1/2$ hours from the time of initial contact of liquid and powder during mixing and make initial comparator reading immediately.
- Rapid-hardening nonpolymer-cement materials—Cure in moist cabinet or room per ASTM C511. Remove specimens from mold at $2 \pm 1/4$ hours after final set and take initial comparator reading immediately.

Rapid-hardening materials are defined as those materials complying with the compressive strength requirements described in Table 1 of ASTM C928/C928M or materials whose primary binder is compliant with ASTM C1600/C1600M.

- Rapid-hardening polymer-cement materials—ASTM C1439, except remove specimens from mold at $2 \pm 1/4$ hours after final set and take initial comparator reading immediately. Store specimens under the standard conditions for air storage of $73.4 \pm 3^\circ\text{F}$ ($23 \pm 2^\circ\text{C}$) and $50 \pm 4\%$ RH and water storage $73.4 \pm 1^\circ\text{F}$ ($23.0 \pm 0.5^\circ\text{C}$.)

Rapid-hardening materials are those materials complying with the compressive strength requirements described in Table 1 of ASTM C928/C928M or materials whose primary binder is compliant with ASTM C1600/C1600M.

Comparison of curing regimens using compressive strength testing can be used to determine the benefit of polymer modification for the purposes of this document if such guidance is not provided by the material manufacturer or specifier.

5.2 Unit Weight

- Mortar—ASTM C185 calculated from “mass per 400 mL of mortar” using the calculations for yield from ASTM C138/C138M.
- Extended mortar and concrete—ASTM C138/C138M.

5.3 Air Content

- Mortar—ASTM C231/C231M.
- Extended mortar and concrete—ASTM C231/C231M.

5.4 Yield

- Mortar—ASTM C185.
- Extended mortar and concrete—ASTM C138/C138M.

5.5 Density, Absorption, and Voids—ASTM C642

Use the same air-stored specimens from the length change test as described in the “Property and Test Method” section.

5.6 Setting Time

- At minimum application temperature—ASTM C403/C403M.
- At maximum application temperature—ASTM C403/C403M.

5.7 Compressive Strength

- Mortar—ASTM C109/C109M: 2 in. (51 mm) cubes.
- Extended mortar and concrete—ASTM C39/C39M: 3 x 6 in. (76 x 152 mm) cylinders.

Report the method of capping of the cylinders and the dimensions of the cylinders used, in addition to the other requirements of the report section of ASTM C39/C39M.

- Cure specimens according to the curing regimen section using one of the four regimens, depending on the setting time and polymer modification of the material.

5.8 Flexural Strength

- Mortar—ASTM C348.
- Extended mortar and concrete—ASTM C78/C78M.
- Cure specimens according to the curing regimen section using one of the four regimens, depending on the setting time and polymer modification of the material.

5.9 Splitting Tensile Strength—ASTM C496/C496M

- Mortar—2 x 4 in. (51 x 102 mm) cylindrical specimen.
- Extended mortar and concrete—3 x 6 in. (76 x 152 mm) cylindrical specimen unless otherwise indicated.

If coarse aggregate larger than 3/8 in. (9.5 mm) is used, then refer to ASTM C39/C39M for appropriate specimen size.

- Cure specimens according to the curing regimen section using one of the four regimens, depending on the setting time and polymer modification of the material.

5.10 Direct Tensile Strength—CRD C 164

- Mortar—2 x 4 in. (51 x 102 mm) cylindrical specimen.
- Extended mortar and concrete—3 x 6 in. (76 x 152 mm) cylindrical specimen.
- Cure specimens according to the curing regimen section using one of the four regimens, depending on the setting time and polymer modification of the material.

Unless the repair material is rapid-hardening, there may be erratic results for 1-day tensile adhesion values. For those materials that are not appropriate for 1-day tensile adhesion determination, report 2-day tensile adhesion results.

5.11 Modulus of Elasticity—ASTM C469/C469M

- Mortar, extended mortar and concrete—3 x 6 in. (76 x 152 mm) cylindrical specimen, or as appropriate depending on aggregate size for cylindrical specimens per ASTM C31/C31M.
- Cure specimens according to the curing regimen section using one of the four regimens, depending on the setting time and polymer modification of the material.

5.12 Bond Strength—ICRI 210.3 or ASTM C1583/C1583M

- Use a concrete substrate of 4000 to 5000 psi (27.6 to 34.7 MPa) compressive strength and prepared in accordance with project requirements and equipment manufacturer recommendations for the substrate of the repair material application. Apply the repair material to the manufacturer's recommended thickness (if a range of thicknesses, use the midpoint of the range) using the manufacturer's recommendations for material mixing, surface treatment (such as prewetting, priming, use of a scrub coat, etc.), placement, and curing.

This method is also recommended for evaluation of minimum in-place bond. Comparative data between materials reported should use identical substrates and preparation techniques with the compressive strength of the concrete substrate and the ICRI concrete surface profile (CSP) per ICRI Technical Guideline 310.2 reported.

- Report which test method (ICRI 210.3 or ASTM C1583/C1583M) is used.
- Report the CSP for the prepared surface (ICRI 310.2).
- Cure specimens according to the curing regimen section using one of the four regimens, depending on the setting time and polymer modification of the material. Any additions, requirements, or supplemental materials (such as bonding aids) of the material manufacturer shall be used and reported when performing the testing in this document.
- Report the failure mode for each specimen (that is, cohesive or adhesive through material, at the bond line, or within the substrate). If mixed failure modes are found, report the percent adherence to each interface.
- Report the average bond strength, the age of each specimen since casting, the curing regimen used, the number of specimens tested, and the standard deviation for the specimen set.

Testing at 1-day age may be omitted for normal setting (non-rapid-hardening) materials if so reported.

5.13 Length Change—ASTM C157/C157M (modified as described in the following)

- Standard specimen size is 3 x 3 x 11-1/4 in. (76 x 76 x 275 mm) for mortar, extended mortar, and concrete.

Use of the same specimen size for mortar, extended mortar, and concrete produces the same surface-to-volume ratio, allowing direct comparison of length change values between materials. The specified length change measurement intervals and extrapolation to ultimate length change provides information on drying rates between materials.

- Specimens shall be exposed to both drying at 50% RH and water immersion. Cure specimens according to the curing regimen section using one of the four regimens, depending on the setting time and polymer modification of the material.

- Subsequent comparator readings are to be taken at ages of 3 days, 7 days, 14 days, 1 month, and 2 months; measurements shall continue until 90% of ultimate drying shrinkage is reached. Ultimate drying shrinkage and moisture expansion is to be determined as described in ASTM C596.

5.14 Coefficient of Thermal Expansion— CRD C 39-81 (modified as described in the following)

- Use the same air-stored specimens from the length change test, as described previously.
- 3 x 3 x 11-1/4 in. (76 x 76 x 275 mm) for mortar, concrete, and extended mortar.
- Cycle specimens from 140 to 40°F (60 to 5°C) at 50% RH and greater than 95% RH.

5.15 Resistance to Freezing-and-Thawing Cycles—ASTM C666/ C666M, Procedure A (in addition to the procedure described in the following)

- One set of composite beams comprised of a 3 x 1 x 16 in. (76 x 25 x 406 mm) overlay of repair mortar applied per the manufacturer's recommendations on the top surface of a freezeing-and-thawing-resistant concrete substrate measuring 3 x 3 x 16 in. (76 x 76 x 406 mm) that has been prepared in accordance with the "How to Use the Material" section of this document, or if no profile or surface preparation instructions are provided, is prepared to CSP 3 (ICRI 310.2) for the substrate of the repair material application.
- One set of homogenous beams comprised of the type described in ASTM C666/C666M.
- Cure specimens according to the curing regimen section using the appropriate regimen, depending on the setting time and polymer modification of the material. Continue to cure the specimen in a moist cabinet or room per ASTM C511 until an elapsed time of 28 days from date of casting of the composite specimen has elapsed.
- Start testing after 28 days of curing by determining the initial mass and surface condition of the

specimen. For the forced resonance measurement method, place the vibration device centered on the side surface of the repair mortar layer and the sensor device centered on the top surface of the concrete at the opposite end of the specimen. For the impact resonance method of measurement, strike the specimen in an area centered on the side surface of the repair mortar layer and measure the specimen response by placing the accelerometer centered on the side surface of the concrete at the opposite end of the specimen. This is to measure not only the repair material resistance to freezing and thawing but also any possible deterioration of the bonding between the repair material and substrate concrete.

- Record durability factor for the homogenous repair material specimens and the composite specimens, mass loss, and surface condition of the specimen using the rating's weight loss of ASTM C672/C672M and ICRI 320.2. Record the length change for the homogenous specimen.

5.16 Scaling Resistance— ASTM C672/C672M

- Cure specimens according to the curing regimen section using the appropriate regimen, depending on the setting time and polymer modification of the material. Continue to cure the specimen in a moist cabinet or room per ASTM C511 until an elapsed time of 28 days from date of casting of the composite specimen. Test after 28 days of curing.

5.17 Compressive Creep— ASTM C512/C512M

- Cure specimens according to the curing regimen section using one of the four regimens, depending on the setting time and polymer modification of the material.
- Specimens shall be cured according to the curing regimen section for both sets of specimens. Two sets of specimens shall be used, one with initial loading beginning at 7 days and the other with initial loading beginning at 28 days.
- Report the initial elastic strain, as well as the specific creep, compressive creep strain, compressive creep rate, and compressive creep coefficient values at 1, 7, 28 days, and 1 year of age.

- If initial loading begins at ages other than specified, a separate set of replicate specimens shall be used for each initial loading age and reported separately.

The requirement for separate specimens to be used for loading at other ages is to initiate creep measurements at different ages when initial loading occurs—that is, if creep is determined on 3-day-old specimens, then the specimens are cured for 3 days, then initially loaded; if creep is determined on 28-day-old specimens, then another set of specimens is cured for 28 days, then initially loaded.

5.18 Rapid Chloride Ion Permeability— ASTM C1202

- Start test after 28 days of curing.
- Rapid chloride permeability testing shall be correlated with ASTM C1543 chloride ponding, as described in the following.

Rapid chloride permeability testing per ASTM C1202 is actually a measurement of electrical conductivity of the material under standardized conditions that can be correlated to chloride diffusion if chloride ponding has been performed on the same material. Use of certain admixtures, fibers, and other ingredients can affect this correlation. Therefore, correlation of ASTM C1202 with chloride ponding results per ASTM C1543 for a given material provides a more realistic means of estimating chloride ingress using the rapid method.

5.19 Chloride Ponding— ASTM C1543

- Cure specimens according to the curing regimen section using the appropriate regimen, depending on the setting time and polymer modification of the material. Continue to cure the specimen in a moist cabinet or room per ASTM C511 until an elapsed time of 14 days from date of casting, then dried for 14 days as specified in ASTM C1543 and then abraded to a minimum of CSP 3, as defined by ICRI 310.2 before beginning the test.

5.20 Sulfate Resistance— ASTM C1012/C1012M

- Cure specimens according to the curing regimen section using one of the four regimens,

depending on the setting time and polymer modification of the material.

For concrete materials, the aggregate shall be removed by screening of the material prior to mixing using the method described in Compositional Information. The coarse aggregate shall be removed from separate samples and the resulting mortar tested according to ASTM C1012/C1012M, as described in the aggregate characteristics section.

5.21 Chemical Resistance—ASTM D1308 Spot Test, Covered

- Use same-size specimens as used for length change.

Unless otherwise stated, the chemical exposure testing shall be conducted on 28-day-old hardened specimens cured as described in the curing regimen section using exposure times of 15 minutes, 1 hour, and 16 hours.

5.22 Cracking Resistance—Ring Test ASTM C1581/C1581M

- Description of the ring test.

This method allows the determination of materials' sensitivity to cracking caused by restrained volume changes. Material in the mold should be consolidated as recommended by the manufacturer. The material rings are to be kept in their molds and covered with plastic for the first 24 hours after they are cast. After the completion of the recommended curing period, the specimen should then be kept for a minimum of 60 days under the standard laboratory conditions: $73.4 \pm 3^{\circ}\text{F}$ ($24.0 \pm 2^{\circ}\text{C}$) and $50 \pm 4\%$ RH. The rings should be monitored using the prescribed strain gauges and visually inspected daily for evidence of cracking. On the day that cracking is observed, the width should be recorded with precision of 0.001 in. (0.04 mm). Each of the cracks that formed should be measured periodically for width at quarter points and in the middle along the crack and the average width recorded. Report per ASTM C1581/C1581M.

If specimens are cured by another procedure other than as described in the preceding

paragraph, such curing procedures should be described in sufficient detail to allow the duplication of results by others wishing to verify the data.

6.0 Packaging and Storage

6.1 Packaging

All packages shall show at least the following information in clearly legible form:

- Brand name;
- Usable working time for high and low temperatures within which the product will meet the stated performance parameters;
- Date of manufacture;
- Recommended use expiration date;
- Storage conditions, including minimum and maximum temperature, humidity, and other conditions;
- Conditioning requirements of the material prior to use;
- Lot identification number;
- Net weight in each container;
 - The contents of any container shall not vary by more than 2% from the weight stated in the markings.
 - The average weight of filled containers in a lot shall be not less than the weight stated in the markings.
- If the product is formulated for use in vertical or overhead applications, it shall be so stated on the package.

6.2 Other Information

Other information shall be marked on either the package and/or on the product data sheet.

7.0 How to Use the Material

7.1 Surface Preparation

- Specify the CSP number or range (ICRI 310.2) and prepare the surface in accordance with ICRI 310.2.
- Report the moisture condition for the surface.

7.2 Mixing

7.2.1 Aggregate Extension

If the product is permitted to be aggregate-extended, report:

- The mass quantity to add per unit of material;
- The grading size number per ASTM C33/C33M;
- The recommended aggregate moisture content; and
- Any other requirements of the aggregate to be used shall be listed.

7.2.2 Mixing Time

Specify the recommended length of mixing time or sequence of mixing and resting times in minutes.

7.2.3 Mixing Equipment

Specify the recommended mixing equipment per ICRI 320.5.

7.2.4 Mixing Liquid

Specify the amount of mixing water or other designated liquid to be used, or maximum recommended consistency or range.

7.2.5 Yield

Report the yield at maximum mixing liquid content, or maximum consistency. The yield claimed shall not be greater than that measured in Section 5.4 and shall be reported in ft³ (L) or yield in ft²/in. (m²/mm) for the designated package size.

7.2.6 Application

Placing instructions: Specify the minimum and maximum application thickness.

7.2.7 Finishing

Specify the finishing instructions.

7.2.8 Curing

Specify the curing instructions:

- List the acceptable methods and materials for curing of the applied material.
- Indicate the return-to-service time guidelines at maximum and minimum curing temperatures.

7.3 Bonding Agents

When a bonding agent is recommended, the type, kind, and allowable interval of the adhesive

recommended to bond fresh repair material to the concrete or mortar being repaired shall be listed.

7.4 Cleanup

Provide recommendations for cleanup and disposal of material in accordance with local regulations and requirements.

7.5 Safety

Refer to the manufacturer's Material Safety Data Sheet (MSDS). This document 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 document to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to use. Useful guidance can also be found in ICRI 120.1.

8.0 References

8.1 Referenced Standards and Reports

The standards and reports listed as follows were the latest editions at the time this document was prepared. Because these documents are revised frequently, the reader is advised to contact the proper sponsoring group if it is desired to refer to the latest version.

American Concrete Institute

- 222R, "Protection of Metals in Concrete Against Corrosion"
- 364.3, "Guide for Cementitious Repair Material Data Sheet"
- 546.3, "Guide for the Selection of Materials for the Repair of Concrete"

ASTM International

- C31/C31M, "Standard Practice for Making and Curing Concrete Test Specimens in the Field"
- C33/C33M, "Standard Specification for Concrete Aggregates"
- C39/C39M, "Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens," Vol. 4.02
- C78/C78M, "Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)"

- C88, "Standard Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate"
- C109/C109M, "Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)"
- C114, "Standard Test Methods for Chemical Analysis of Hydraulic Cement"
- C117, "Standard Test Method for Materials Finer than 75- μ (No. 200) Sieve in Mineral Aggregates by Washing"
- C138/C138M, "Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete"
- C157/C157M, "Standard Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete"
- C185, "Standard Test Method for Air Content of Hydraulic Cement Mortar"
- C231/C231M, "Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method"
- C295/C295M, "Standard Guide for Petrographic Examination of Aggregates for Concrete"
- C348, "Standard Test Method for Flexural Strength of Hydraulic-Cement Mortars"
- C403/C403M, "Standard Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance"
- C469/C469M, "Standard Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression"
- C496/C496M, "Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens"
- C511, "Standard Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes"
- C512/C512M, "Standard Test Method for Creep of Concrete in Compression"
- C596, "Standard Test Method for Drying Shrinkage of Mortar Containing Hydraulic Cement"
- C642, "Standard Test Method for Density, Absorption, and Voids in Hardened Concrete"
- C666/C666M, "Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing"
- C672/C672M, "Standard Test Method for Scaling Resistance of Concrete Surfaces Exposed to Deicing Chemicals"

- C856, “Standard Practice for Petrographic Examination of Hardened Concrete”
- C928/C928M, “Standard Specification for Packaged, Dry, Rapid-Hardening Cementitious Materials for Concrete Repairs”
- C1012/C1012M, “Standard Test Method for Length Change of Hydraulic-Cement Mortars Exposed to a Sulfate Solution”
- C1107, “Standard Specification for Packaged Dry, Hydraulic-Cement Grout (Nonshrink)”
- C1152/C1152M, “Standard Test Method for Acid-Soluble Chloride in Mortar and Concrete”
- C1202, “Standard Test Method for Electrical Indication of Concrete’s Ability to Resist Chloride Ion Penetration”
- C1218/C1218M, “Standard Test Method for Water-Soluble Chloride in Mortar and Concrete”
- C1260, “Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)”
- C1439, “Standard Test Methods for Evaluating Polymer Modifiers in Mortar and Concrete”
- C1543, “Standard Test Method for Determining the Penetration of Chloride Ion into Concrete by Ponding”
- C1581/C1581M, “Standard Test Method for Determining Age at Cracking and Induced Tensile Stress Characteristics of Mortar and Concrete under Restrained Shrinkage”
- C1583/C1583M, “Standard Test Method for Tensile Strength of Concrete Surfaces and the Bond Strength or Tensile Strength of Concrete Repair and Overlay Materials by Direct Tension (Pull off Method)”
- C1600/C1600M, “Standard Specification for Rapid Hardening Hydraulic Cement”
- D1308, “Standard Test Method for Effect of Household Chemicals on Clear and Pigmented Organic Finishes”
- E11, “Standard Specification for Woven Wire Test Sieve Cloth and Test Sieves”
- 320.2R, “Guide for Selecting and Specifying Materials for Repair of Concrete Surfaces”
- 320.5, “Pictorial Atlas of Concrete Repair Material Mixing Equipment”

These publications may be obtained from these organizations:

American Concrete Institute
38800 Country Club Drive
Farmington Hills, MI 48331
www.concrete.org

ASTM International
100 Barr Harbor Drive
West Conshohocken, PA 19428
www.astm.org

International Concrete Repair Institute
10600 West Higgins Road, Suite 607
Rosemont, IL 60018
www.icri.org

8.2 Other Cited References

CRD C 164, “Standard Test Method for Direct Tensile Strength of Cylindrical Concrete or Mortar Specimens,” *Handbook for Concrete and Cement*, U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS, http://www.wes.army.mil/SL/MTC/handbook/crd_c164.pdf. (last accessed October 6, 2011)

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Material Safety Data Sheet (MSDS), 1983, *Federal Register*, V. 48, No. 228, Occupational Safety and Health Administration, U.S. Department of Labor, Washington, DC.

International Concrete Repair Institute

- 120.1, “Guidelines and Recommendations for Safety in the Concrete Repair Industry”
- 210.3, “Guide for Using In-Situ Tensile Pull-Off Tests to Evaluate Bond of Concrete Surface Materials”
- 310.2, “Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings, and Polymer Overlays”