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Cementitious Repair Material Data Sheet—Guide

Reported by ACI Committee 364

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Cementitious Repair Material Data Sheet—Guide

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Cementitious Repair Material Data Sheet—Guide

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The purpose of this document is to provide a guide to the protocol for testing and reporting of data for cementitious repair materials. It does not address all the issues associated with material selection. It is the responsibility of the user of this document to determine the suitability of the repair material before use.

Keywords: data sheet protocol; material characteristics; material properties; packaging; repair materials; test methods; user guide.

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CHAPTER 1—INTRODUCTION AND SCOPE

1.1—Introduction

The guidance on testing and reporting verifiable properties of mortar, extended mortar, and concrete is primarily intended for the manufacturer, to make sure the repair material data sheets are prepared in a standard way, with reproducible and comparable information. The manufacturer should use it for developing products based on market needs and technology improvements. The information provided in this guide is useful to the specifier in choosing verifiable properties consistent with the requirements of a particular repair situation. It provides the general user education on the range of material characteristics and properties that may impact a repair and on the nuances of the various tests available for that matter.

1.2—Scope

To facilitate readability of this guide, Chapters 4 through 8 are in two-column format. The first column provides guidance for the protocol for testing and reporting of data for cementitious repair materials to allow objective comparison between alternative products. The second column provides guidance and referenced sources for additional information presented in the first column. It does not address every issue associated with material selection; for further discussion, refer to **ACI 546.3R**. The characteristics and properties described in this document do not necessarily need to be reported, depending on the nature of the material and its intended use. Certain tests may not be appropriate for some materials. Materials containing lightweight aggregate or heavyweight aggregate are beyond the scope of this document, as typically specialized tests are required for these materials.

The test methods used for the determination of the reported data should be selected from those listed in Table 1.2 and further explained within the document. The table covers most of the characteristics and properties generally of interest for cementitious materials, although it does not preclude others to be reported. Test data should be reported in the order and sections as listed, with the test method(s) used explicitly mentioned adjacent to it. Variations in the standardized test methods or substitute test methods prevent direct comparison between alternative materials by the specifier. Any additional test methods, non-standardized methods, or deviations from the test methods in this document should be reported and documented in sufficient detail to allow the specifier to evaluate the likely impact on test results and to allow other laboratories to repeat the testing within acceptable repeatability and reproducibility.

Additional information describing the significance and use of the test methods described herein may be found in **ACI 546.3R** and **ICRI 320.2R**. In comparison with these documents, **ACI 364.3R/ICRI 320.3R** serves a very different purpose—that is, guidance on uniformized testing and reporting Material Data Sheet information. While **ACI 546.3R** lists standardized tests only, **ACI 364.3R/ICRI 320.3R** provides guidance on testing and

Table 1.2—Summary of the material characteristics and properties to be reported and referenced test methods

Section	Characteristic/property	Referenced test method(s)*
Packaged dry material		
4.1	Total sulfur trioxide (SO ₃)	ASTM C114
4.2	Total alkali content	ASTM C114
4.3	Chloride content	ASTM C1152/C1152M, ASTM C1218/C1218M
4.4	pH	ACI 364.17T
4.5	Characteristics of aggregate	ASTM C33/C33M, ASTM C88/C88M, ASTM C117, ASTM C1778
Fresh state material		
5.1	Consistency	ASTM C143/C143M, ASTM C1437, ASTM C1611/C1611M
5.2	Material unit weight	ASTM C138/C138M, ASTM C185
5.3	Time of setting	ASTM C191, ASTM C266, ASTM C403/C403M
5.4	Air content	ASTM C231/C231M
5.5	Yield	ASTM C138/C138M, ASTM C185
Hardened state material		
6.2	Density, absorption, and voids	ASTM C642
6.3	Air content	ASTM C457/C457M
6.4	Compressive strength	ASTM C39/C39M, ASTM C109/C109M
6.5	Splitting tensile strength	ASTM C496/C496M
6.6	Flexural strength	ASTM C78/C78M, ASTM C348
6.7	Direct tensile strength	CRD-C 164
6.8	Short-term tensile bond	ASTM C1583/C1583M, ICRI 210.3R
6.9	Modulus of elasticity	ASTM C469/C469M
6.10	Compressive creep	ASTM C512/C512M
6.11	Coefficient of thermal expansion	CRD-C 39
6.12	Length change	ASTM C157/C157M
6.13	Restrained expansion	ASTM C806, ASTM C878/C878M
6.14	Cracking resistance	ASTM C1581/C1581M
6.15	Resistance to freezing and thawing	ASTM C666/C666M
6.16	Scaling resistance	ASTM C672/C672M (withdrawn), ICRI No. 320.2R
6.17	Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration	ASTM C1202
6.18	Chloride ponding	AASHTO T 259
6.19	Bulk electrical resistivity or conductivity	ASTM C1876
6.20	Sulfate resistance	ASTM C1012/C1012M
6.21	Chemical resistance	ASTM D1308

*Some of the referenced test methods are modified in this document, as stated in the corresponding section.

reporting Material Data Sheet information and, where applicable, describes and explains modifications (such as used for drying shrinkage or freezing and thawing of composite specimens). Contrary to [ACI 546.3R](#), no values are suggested in the ACI 364.3R/ICRI 320.3R document, as its intent is essentially to provide a basis for testing to allow comparison between materials and to verify compliance with values reported by the supplier or other laboratories.

CHAPTER 2—DEFINITIONS

Please refer to the latest version of ACI Concrete Terminology (CT) for a comprehensive list of definitions as published by the American Concrete Institute (ACI). Definitions specific to concrete repair can be found in the ICRI Concrete Repair Terminology (CRT) database as published by the International Concrete Repair Institute (ICRI). Definitions provided herein complement these resources.

CSP—concrete surface profile number based upon a visual roughness scale ranging from 1 to 10 or [ICRI 319.2R](#), with 1 representing the smoothest profile and 10 the roughest.

extended mortar—concrete produced by the addition of coarse aggregate to a mortar product (CRT).

material data sheet protocol—list of significant properties of a material, methods for determining those properties, and guidance for reporting the information referred to herein as Material Data Sheet. Other terms used for the Material Data Sheet include Technical Data Sheets, Product Data Sheets, Product Data Guides, and various other terms to describe the publication of technical product information and application guidance.

material property—objective, often quantitative, characteristic 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—explicit set of requirements to be satisfied by a material (CRT).

polymer-cement material—a mortar or concrete whose properties benefit from the addition of polymer when cured per **ASTM C1439**, commonly known as polymer-modified materials (CRT). A mixture comprising hydraulic cement and aggregate combined at the time of mixing with organic monomers or polymers that are dispersed in water (CT).

repair material—material applied to existing concrete and intended to restore the concrete member to its desired function (CRT).

test method—a detailed procedure used to evaluate the property characteristics and/or performance capabilities of a material (CRT).

CHAPTER 3—REPAIR MATERIAL DESCRIPTION

The following information should be reported in the Material Data Sheet, including the test methods for the determination of the reported data, with the method used listed adjacent to the reported data.

(a) **Material type:** The information relating to the generic nature of the material. For example, repair mortar, extended/extendable repair mortar, and concrete.

(b) **Recommended use:** The information to describe where and how the product should be used, any auxiliary or ancillary products, and suitable service conditions. For example, horizontal, vertical, overhead, traffic wearing surface repairs, and cosmetic.

(c) **Claimed benefits:** Any benefits or special properties claimed for the product. For example, rapid strength development, shrinkage compensated, and extended working time.

(d) **Stated limitations:** Any stipulations or limitations placed on the storage, mixing, use, application methods, substrate preparation, placement, curing, or exposure conditions. For example, minimum/maximum placement depth with/without aggregate, allowable application temperature range, allowable moisture exposure, and thermal coefficient of expansion compared to substrate concrete.

CHAPTER 4—PACKAGED DRY MATERIAL CONTENT CHARACTERISTICS

The various characteristics relating to the packaged dry material content that should be reported in the Material Data Sheet are summarized in Table 1.2, together with the referenced test methods. For all reported packaged dry material content characteristics (Section 4.1 to 4.5), the test method(s) used should be explicitly stated.

4.1—Total sulfur trioxide (SO_3)

State the total SO_3 content as a percentage by mass of cementitious constituents determined in accordance with [ASTM C114](#). If sulfate levels are above those contributed from portland cement, the material manufacturer should provide data and methods used to establish suitability for the recommended uses ([Chapter 3](#)).

4.2—Total alkali content

State the total alkali content as a percentage by mass of cementitious constituents determined as sodium equivalent alkali in accordance with [ASTM C114](#).

4.1C—Total sulfur trioxide (SO_3)

Gypsum or other calcium sulfates are added to portland cement to prevent flash set. [ASTM C563](#) is generally used by cement manufacturers to determine the optimum SO_3 content based on maximization of the 24-hour compressive strength of a standard mortar mixture. In cement analysis, the convention is to report the chemical constituents at their highest oxidation state, which for sulfur is sulfur trioxide. Additions of sulfates beyond the optimum levels determined by [ASTM C563](#), or even beyond the maximum limits of [ASTM C150/C150M](#), are sometimes used to accelerate the strength development or improve the shrinkage compensation of formulated products ([Taylor 1990](#)). [ASTM C845/C845M](#) defines three types of expansive cements, all of which would indicate elevated levels of sulfate in this analysis. [Hewlett \(2004\)](#) describes the expansive nature of different sulfates in contact with portland cement. Exposure to different sulfate solutions (either from the outside environment or from internal additions) can cause what is commonly known as sulfate attack or an uncontrolled destructive expansion. Due to concern for potential over-expansion or susceptibility to deterioration in some environments, the total SO_3 is to be reported and expressed as a percentage by mass of cementitious materials. Evaluation of sulfate resistance per [ASTM C1012/C1012M](#) is addressed in [Section 6.2](#).

4.2C—Total alkali content

In the past, the typical means for controlling the alkali content of concrete mixtures in the United States has been to establish a maximum limit content in the portland cement. Cement with an alkali content of less than 0.6%, expressed as equivalent Na_2O , was previously referred to as low-alkali cement ([ASTM C150/C150M](#)).

For repair materials, the disadvantage of establishing an alkali limit based on the alkali of the portland cement alone is that many proprietary materials contain blends of different cements, additives, admixtures, supplementary cementitious materials, and other constituents that contain alkalis or may influence alkali-aggregate reaction (AAR). In either a concrete or mortar mixture, it is the sum of the alkalis from all sources that determines the potential reaction with a reactive aggregate. While this has been recognized in some national codes, the reported range of maximum specified alkali contents in the concrete is rather wide (3.0 to 7.6 lb/yd³ [1.2 to 4.5 kg/m³]) and in practice, the use of low-alkali cement and limitation of the alkali content in concrete is not a sufficient safeguard in all cases ([ACI 201.2R](#)). The low-alkali terminology and the 0.6% limit have been abandoned in [ASTM C150/C150M](#).

4.3—Chloride content

State the total water-soluble (ASTM C1218/C1218M) and acid-soluble (ASTM C1152/C1152M) chloride contents as a percentage by mass of the mortar or concrete, consistent with ASTM standards.

A cautionary statement may be required 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, taking into account the considerations of chloride-ion content discussed in ACI 222R.

4.4—pH

Report the pH of the repair material for both the fresh and hardened states. In absence of a standard test method for determination of the pH in cementitious materials, the following procedures are recommended:

Fresh material

(a) Stir 0.35 oz. (10 g) of the mixed material into 3.2 oz. (90 g) of distilled or deionized water for 1 minute.

(b) After settling, insert the pH meter or pH paper into the solution and record the stable pH reading to the first decimal.

Hardened material

(a) Using a hardened sample of the cementitious repair material from the specimens tested in compression at 28 days, crush it to pass a No. 170 (90 μ m) mesh sieve, then stir 0.35 oz. (10 g) of the crushed material into 3.2 oz. (90 g) of distilled or deionized water for 1 minute.

(b) After settling, insert the pH meter or pH paper into the solution and record the stable pH reading to the first decimal.

As recommended in ACI 364.17T, prior to the tests, calibrate the pH meter or pH paper with three pH calibration solutions supplied by the pH meter manufacturer or an independent chemical supplier, with pH values of 7, 10, and 12. Immediately after each reading, clean the measuring tip of the pH meter by dipping it in a clean container of fresh distilled water and wiping it dry with a clean paper towel prior to the pH reading. Perform testing in standard laboratory conditions (73.5 $\pm$ 3.5°F [23 $\pm$ 2°C]).

Include the testing temperatures recorded for both fresh and hardened conditions in the reported information.

4.5—Characteristics of aggregate

Use the +170 mesh (90 μ m) fraction obtained by wet sieving in accordance with ASTM C117 and report the following characteristics, for both fine and coarse aggregates:

Comprehensive guidance on the risk and mitigation of alkali-aggregate reaction can be found in ASTM C1778 to identify the potential for deleterious AARs and selecting appropriate preventive measures, based on a prescriptive-based or performance approach, to minimize the risk of deleterious reactions.

4.3C—Chloride content

The presence of chlorides in concrete exposed to moist environments is responsible for many instances of reinforcing steel corrosion. Allowable chlorides in the hardened repair material should be much lower than the critical chloride concentration to initiate corrosion. A range of allowable chloride limits can be found in various ACI documents, depending on the exposure conditions and on the type of structure being considered (Trejo et al. 2016). ACI 222R recommends respective maximum water-soluble (ASTM C1218/C1218M) and acid-soluble (ASTM C1152/C1152M) chloride contents by mass of cementitious materials of 0.06 and 0.08% in prestressed concrete, 0.15 and 0.20% for reinforced concrete exposed to moisture, and 0.25 and 0.30% for reinforced concrete kept dry or protected from moisture in service.

4.4C—pH

Reporting of the pH of the freshly mixed material is useful information for the applicator of the product. The pH of the hardened material provides an indication of the amount of hydroxide ion present in the pore solution and, thus, of the degree of passivation that is imparted to embedded reinforcing steel. For complementary information on the measurement of pH in hardened concrete, refer to ACI 364.17T.

4.5C—Characteristics of aggregate

Reporting the amount of fine and coarse aggregate, and the gradations of these components, provides useful information to the applicator regarding selection of mixing and pumping

- (a) General characteristics
- (b) Grading
- (c) Deleterious substances
- (d) Soundness (per **ASTM C88/C88M**)
- (e) Reactivity (per **ASTM C1778**)

Where applicable, report the values obtained from specific tests (for example, amount of clay lumps and friable particles, coal and lignite, magnesium sulfate soundness) in comparison to the allowable limits for the intended use in **ASTM C33/C33M**.

equipment. In addition, it provides guidance concerning requirements for additional aggregate used for extension. The committee that develops and maintains ASTM C33/C33M has determined that the listed characteristics are the minimum requirements needed for assurance of suitability for use in concrete and mortar materials.

ASTM C1778 provides recommendations for identifying the potential for deleterious AAR and selecting appropriate preventive measures, based on a prescriptive-based or performance-based approach, to minimize the risk of deleterious reaction. In regions where occurrences of AAR are rare or the aggregate sources in use have a satisfactory field performance record verified by following the guidance in this guide, it is reasonable to continue to rely on the previous field history without subjecting the aggregates to laboratory tests for AAR. In regions where AAR problems have occurred or the reactivity of aggregates is known to vary from source to source, it may be necessary to follow a testing program to determine potential reactivity and evaluate preventive measures.

In ASTM C1778, the level of prevention required is a function of the reactivity of the aggregate, the nature of the exposure conditions (especially the availability of moisture), the criticality of the structure, and the availability of alkali in the concrete or mortar. To use ASTM C1778 effectively, it is necessary to define the level of risk that is acceptable, as this will determine the type and complexity of testing. The risk of deleterious expansion occurring as a result of a failure to detect deleteriously reactive aggregates can be reduced by routine testing using either petrography or laboratory expansion tests, or both. Preventive measures determined by either performance testing or the prescriptive approach described in ASTM C1778 can generally be expected to reduce the risk of expansion as a result of ASR to an acceptable level. For certain critical structures, especially those exposed to continuous moisture such as hydraulic dams, more conservative mitigation measures may be warranted.

There are no proven measures for effectively preventing damaging expansion with alkali carbonate reactive rocks in concrete and such materials need to be avoided.

CHAPTER 5—FRESH STATE CHARACTERISTICS AND PROPERTIES

The fresh state characteristics and properties that should be reported in the Material Data Sheet are summarized in Table 1.2, together with the referenced test methods. These properties should be determined on material prepared with the recommended mixing equipment, duration and sequence, as well as mixing liquid content or, if a range is recommended, most fluid/least stiff workable consistency (Section 8.4). The amount of mixing liquid used, and consistency should be reported. For all reported fresh state characteristics and properties (Section 5.1 to 5.5), the test method(s) used should be explicitly stated.

5.1—Consistency

Report the mixed material consistency, as determined in accordance with one of the following test methods:

- (a) For mortar (except self-consolidating), [ASTM C1437](#)
- (b) For extended mortar and concrete (except self-consolidating), [ASTM C143/C143M](#)
- (c) For self-consolidating mortar, extended mortar, and concrete, [ASTM C1611/C1611M](#)

In the case of ASTM C1611/C1611M, include the filling procedure (A or B), visual stability index, and spread in the reported information.

5.2—Material unit weight

Report the mixed material density (unit weight) as determined in accordance with one of the following test methods:

- (a) For mortar, [ASTM C138/C138M](#), using the 13.5 fl. oz. (400 mL) cylindrical measure of [ASTM C185](#)
- (b) For extended mortar and concrete, [ASTM C138/C138M](#).

5.3—Time of setting

Report the initial and final times of setting in standard conditions ($73.5 \pm 3.5^\circ\text{F}$ [$23.0 \pm 2.0^\circ\text{C}$]), if within the recommended range of use, and at minimum and maximum recommended application temperatures, as determined in accordance with [ASTM C191](#), [ASTM C266](#), or [ASTM C403/C403M](#). Include the testing temperature(s) in the reported information.

5.4—Air content

Report the mixed material air content as determined in accordance with [ASTM C231/C231M](#), either for mortar or concrete.

5.1C—Consistency

One of the most important fresh state properties for repair concrete is consistency or workability. Reporting consistency of the packaged material can help the designer in the selection of materials and allows the specifier to set appropriate quality control/quality assurance requirements for the selected material. The manufacturer should either specify the amount of mixing liquid (water with any admixtures or liquid polymer dispersion) or report the consistency and mixture temperature per the appropriate test.

5.2C—Material unit weight

Reporting of the wet density or unit weight of a repair material provides useful information to the specifier for estimating the dead load to be supported by the structure after repair. This parameter is also relatively easy to determine in the field and can be one indicator of contamination or improper mixing.

5.3C—Time of setting

The time of setting of hydraulic cement paste provides an indication of the relative working time and rate of strength development of repair materials. For mortars, either the Vicat or Gillmore device may be used, but the type of equipment used needs to be reported.

If the standard temperature condition is not within the manufacturer's recommended application temperature range—for example, if the product is intended for use between 36 and 68°F (2 and 20°C)—then the setting time does not need to be determined at 73.5°F (23°C).

5.4C—Air content

Air entrainment is used in some materials to provide resistance to cycles of freezing and thawing. The air content recorded in the freshly mixed material may fluctuate, depending on the mixing time and speed, air temperature, as well as other factors. For certain materials, the frost resistance does not rely on air content, but rather on their low permeability. Physical testing for resistance to freezing and thawing ([ASTM C666/C666M](#) and [Section 6.15](#)) provides the best indication of frost durability.