Repair-Material Data-Sheet Protocol

By Fred Goodwin

The Guideline for Inorganic Repair-Material Data-Sheet Protocol (Protocol) has evolved over the past 10 years in response to a recognized industry need for a standardized method of reporting descriptions and properties of concrete repair materials. Frequently, test data have been reported or required in specifications that are inappropriate for the material, or use modified or in-house test methods. Descriptions of material limitations, packaging, storage, label contents, application instructions, material composition, and material properties can be inconsistent, confusing, missing, or misleading. The Protocol is a first in the industry to provide this information in a standardized, logical, and consistent format so that repair materials can be appropriately selected and specified.

The concept of the Protocol first appeared in "Performance Criteria for Concrete Repair Materials Phase II, Field Studies" (REMR-CS-60)[1] in 1998 as the result of a detailed comparison of the published information from 12 proprietary repair materials. A draft document was included in the subsequent report REMR-CS-62.[2] The Protocol document was discussed and refined at the 1999 workshop "Predicting the Performance of Concrete Repair Materials"[3] that was hosted by the National Institute of Standards and Technology (NIST) and sponsored by Conproco, Master Builders, Sika, W.R. Grace & Co., and Structural Preservation Systems. One of the outcomes of the workshop was the formation of a task group to develop the Protocol that consisted of representatives from material suppliers, specifiers, and academics. Over the next several years, the task group refined and identified the appropriate industry organizations for adoption of the document. At the time of writing of this paper, the Protocol has undergone ballot for adoption by the International Concrete Repair Institute (ICRI) and, upon completion of the review by their Technical Activities Committee, will become a publication of this organization. ACI Committee 364 has formed a task group to take the ICRI document and incorporate it into their publications.

The Protocol

The Protocol is divided into five sections. A brief introduction of the contents of each section is described here:

Section 1, **Repair Material Description**, is divided into three subsections: Recommended Use; Benefits; and Limitations. Examples of *Recommended Use* include repair materials designed for vertical application, traffic bearing surfaces, cosmetic repairs, and structural components. *Benefits* include claims such as shrinkage compensated, colored, and rapid hardening. *Limitations* require reporting the minimum and maximum application thickness, the minimum and maximum application temperature, any material modifications (that is, aggregate extension), and the recommended curing regimen.

Section 2, **Compositional Data**, provides a means of classifying the binder chemistry, defines the number of components, and requires determination of possible deleterious components within the proprietary composition. Examples of typical binder chemistries might be ordinary portland cement, high alumina cement, alkali-activated pozzolan, calcium sulfoaluminate cement, or combinations of these materials. The levels of sulfate, sodium equivalent alkali, and total chloride are to be reported based on a percentage by weight basis of the cementitious content, which is defined as the portion of the dry material passing a 0.1 mm (170-mesh) sieve. Analytical methods for the determination of these levels are specified by referencing ASTM C 114[4] for sulfate and alkali, and ASTM C 1142[5] for total chloride. The reporting of these three components is not intended to disclose proprietary information, but is based on references to compositional limits from ASTM C 150[6] and ACI 222[7].

The intent of reporting the pH is to determine if steel passivation can occur when the repair material is applied onto reinforcing steel in the concrete. The pH of the repair material when freshly mixed with water is to be reported by mixing 10.0 g of the dry powder with 90.0 g of distilled water, allowing to settle for 1 min and determine the PH with either pH papers or a pH meter. Likewise, the pH of the hardened repair material is to be reported by crushing a sample of the hardened material to pass a 0.1-mm (170-mesh) sieve and stirring into distilled water, and then using the same method as with the dry powder.

The aggregate characteristics in the repair material are described in accordance with the sections of ASTM C 33[8] using the material retained on a 0.1-mm (170-mesh) sieve. For fine aggregates the description should include the reportable parameters from the section requirements of General Characteristics, Grading, Deleterious Substances, and Soundness. For coarse aggregates the description should include those items covered by the section headings of General Characteristics, Grading, and Deleterious Substances.

Section 3, **Material Properties**, typically specifies different tests for mortar and concrete materials. The test method used for the reported result must also be reported, as some results may be determined by specified alternate methods. Plastic properties are reported first and include:

- Density and Yield (ASTM C 185[9] [mortar] or C 138[10] [concrete])
- Setting Time (ASTM C 266[11] or C 191[12]) at both the minimum and maximum stated application temperatures (the mortar fraction should be sieved from concrete materials for setting time)
- Air Content (ASTM C 185[9] [mortar] or C 231[13] [concrete])

The hardened properties are also reported in Section 3. A different demolding and curing regimen is specified based upon the speed of hardening and polymer modification (Table 1).

Table 1: Demolding and curing regimen based on material type

Material	Demold time	Curing regimen
Normal setting non-polymer modified	1 day	ASTM C 511[14]
Normal setting polymer modified	1 day	ASTM C 1439[15]
Rapid hardening non-polymer modified	2 h after final set	ASTM C 511[14]
Rapid hardening polymer modified	2 h after final set	ASTM C 1439[15]

Different tests are typically specified for mortar and concrete mixtures. These are detailed in Table 2.

Section 4, **Packaging and Storage**, requires labelling of the packages in accordance with the "Product Marking" section of either ASTM C 928[36] or C 1107[37]. The package label must contain the volume yield of the product as cubic meters (or cubic feet) per package, the shelf life listed as a "use-by" date, and the minimum and maximum storage temperatures and conditions.

Section 5, **How to Use the Material**, includes reporting the aggregate extension grading requirements per ASTM C 33 and the mass quantity of aggregate to add per unit (if applicable). Concrete surface preparation is described in accordance with ICRI Technical Guideline No. 03730[24] and includes the proper Concrete Surface Profile (CSP) for the product application. The type and amount (or range of addition) of mixing liquid is to be listed. Instructions for application of the material, minimum and maximum application and curing temperatures, finishing guidelines, curing regimen, minimum and maximum application thickness, and cleanup recommendations are listed in this section. A safety caveat also is included referencing the manufacturer's MSDS[38] and local regulatory requirements.

Further developments underway with the Protocol are to add a commentary to the document providing additional detail for the significance and use of the test methods selected to characterise concrete repair materials. Several test methods will also be updated as follows:

- The AASHTO T 259[32] "Resistance of Concrete to Chloride Ion Penetration" ponding test has been adapted by ASTM as ASTM C 1543[39] "Standard Test Method for Determining the Penetration of Chloride Ion into Concrete by Ponding."
- The AASHTO PP 34[35] provisional "Cracking Tendency Using a Ring Specimen" test method has been replaced the ASTM C 1581[40], "Standard Test Method for Determining Age at Cracking and Induced Tensile Stress Characteristics of Mortar and Concrete under Restrained Shrinkage."
- ACI 503R Appendix A has been replaced with ICRI Technical Guideline No. 03739[41] "Guide to Using In-Situ Tensile Pull-Off Tests to Evaluate Bond of Concrete Surface Materials," since ICRI now has their own test method developed especially for concrete repair materials.

The Protocol, as approved by the ICRI Repair Materials and Methods Committee and reviewed by the Technical Activities Committee, will soon become available for general use by the industry. A task group has also been formed within the ACI 364 Committee on Rehabilitation to adopt the Protocol as one of their consensus documents. The development of similar Protocols for other types of formulated construction materials using this document as a template is being discussed in several organizations. A high level of interest already exists in the North American engineering and specifying communities to allow comparison of different concrete repair materials through the use of the Guideline for Inorganic Repair Material Data Sheet Protocol.

References

1. Emmons, P. H., et al, "Performance Criteria for Concrete Repair Materials Phase II, Field Studies," (REMR-CS-60), United States Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi, 1998

2. Vaysburd, A. M., McDonald, J. E., "Performance Criteria for Concrete Repair Materials, Phase II Summary Report," (REMR-CS-62), United States Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi, 1999

3. Vaysburd, A. M.; Carino, N.; Bissonnette, B., "Predicting the Performance of Concrete Repair Materials," (NISTIR 6402), NIST, United States Department of Commerce Technology Administration, 2000

4. ASTM C 114, "Standard Test Methods for Chemical Analysis of Hydraulic Cement," V. 4.01

5. ASTM C 1142, "Standard Test Method for Clay Lumps and Friable Particles in Aggregates," V. 4.02

6. ASTM C 150, "Standard Specification for Portland Cement," V. 4.01

7. ACI Committee 222 "Corrosion of Metals in Concrete," American Concrete Institute, Farmington Hills, Mich.

8. ASTM C 33, "Standard Specification for Concrete Aggregates," V. 4.02

9. ASTM C 185, "Standard Test Method for Air Content of Hydraulic Cement Mortar," V. 4.01

10. ASTM C 138, "Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete," V. 4.02

11. ASTM C 266, "Standard Test Method for Time of Setting of Hydraulic-Cement Paste by Gillmore Needles," V. 4.01
12. ASTM C 191, "Standard Test Method for Time of Setting of Hydraulic Cement by Vicat Needle," V. 4.01
13. ASTM C 231, "Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method," V. 4.02
14. ASTM C 511, "Standard Specification for Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes," V. 4.01
15. ASTM C 1439, "Standard Test Methods for Polymer-Modified Mortar and Concrete," V. 4.02
16. ASTM C 109, "Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)," V. 4.01
17. ASTM C 39, "Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens," V. 4.02
18. ASTM C 348, "Standard Test Method for Flexural Strength of Hydraulic-Cement Mortars," V. 4.01
19. ASTM C 78, "Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)," V. 4.02
20. ASTM C 496, "Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens," V. 4.02
21. CRD C 164, "Standard Test Method for Direct Tensile Strength of Cylindrical Concrete or Mortar Specimens," Handbook for Concrete and Cement, United States Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi
22. ASTM C 469, "Standard Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression," V. 4.02
23. ACI 503R, "Use of Epoxy Compounds With Concrete," American Concrete Institute, Farmington Hills, Mich.,
24. ICRI Technical Guideline No. 03730 "Guide for Surface Preparation for the Repair of Deteriorated Concrete Resulting from Reinforcing Steel Corrosion," International Concrete Repair Institute, 1995
25. ASTM C 157, "Standard Test Method for Length Change of Hardened Hydraulic-Cement, Mortar, and Concrete," V. 4.02
26. ASTM C 596, "Standard Test Method for Drying Shrinkage of Mortar Containing Hydraulic Cement," V. 4.01
27. CRD C 39-81, "Test Method for Coefficient of Linear Thermal Expansion of Concrete," Handbook for Concrete and Cement, http://www.wes.army.mil/SL/MTC/handbook/handbook.htm
28. ASTM C 666, "Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing," V. 4.02
29. ASTM C 672, "Standard Test Method for Scaling Resistance of Concrete Surfaces Exposed to Deicing Chemicals," V. 4.02
30. ASTM C 512, "Standard Test Method for Creep of Concrete in Compression," V. 4.02
31. ASTM C 1202, "Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration," V. 4.02
32. AASHTO T 259, "Resistance of Concrete to Chloride Ion Penetration," Standard Specifications for Transportation Materials and Methods of Sampling and Testing
33. ASTM C 1012, "Standard Test Method for Length Change of Hydraulic-Cement Mortars Exposed to a Sulfate Solution," V. 4.01
34. ASTM D 1308, "Standard Test Method for Effect of Household Chemicals on Clear and Pigmented Organic Finishes," V. 6.02
35. AASHTO PP 34-99, "Cracking Tendency Using a Ring Specimen," Standard Specifications for Transportation Materials and Methods of Sampling and Testing
36. ASTM C 928, "Standard Specification for Packaged, Dry, Rapid-Hardening Cementitious Materials for Concrete Repairs," V. 4.02
37. ASTM C 1107, "Standard Specification for Packaged Dry, Hydraulic-Cement Grout (Nonshrink)," V. 4.02
38. "Material Safety Data Sheet (MSDS)," Federal Register, Occupational Safety and Health Administration, U.S. Department of Labor, Washington, D.C., V. 48, No. 228, 1983

Table 2: Hardened properties tests

Property	Test method for mortar	Test method for concrete
Compressive strength	ASTM C 109[16]	ASTM C 39[17]
Flexural strength	ASTM C 348[18]	ASTM C 78[19]
Splitting tensile strength	ASTM C 496[20] 50 x 100 mm cylinders	ASTM C 496[20] 75 x 150 mm cylinders
Direct tensile strength	CRD C 164[21] 50 x 100 mm specimen	CRD C 164[21] 75 x 150 mm specimen
Modulus of elasticity	ASTM C 469[22] 75 x 150 mm specimen	ASTM C 469[22] 75 x 150 mm specimen
Bond strength	ACI 503R[23] on CSP 3[24] 28 to 34 MPa concrete substrate	ACI 503R[23] on CSP 3[24] 28 to 34 MPa concrete substrate
Length change	ASTM C 157[25] 75 x 75 x 275 mm bar* @ 3, 7, 14, 30, 60, and ultimate per ASTM C 596[26]	ASTM C 157[25] 75 x 75 x 275 mm bar* @ 3, 7, 14, 30, 60, and ultimate per ASTM C 596[26]
Coefficient of thermal expansion	CRD C 39[27] with C157[25] bars* 60 to 5 °C cycle @ 50% relative humity and > 95% relative humity	CRD C 39[27] with C157[25] bars* 60 to 5 °C cycle @ 50% relative humity and > 95% relative humity
Freezing-and-thawing resistance	ASTM C 666[28]A on 25 mm overlay applied to F/T durable substrate	ASTM C 666[28]A on 25 mm overlay applied to F/T durable substrate
Scaling resistance	ASTM C 672[29] start @ 28 D	ASTM C 672[29] start @ 28 D
Compressive creep	ASTM C 512[30]	ASTM C 512[30]
Rapid chloride permeability	ASTM C 1202[31] @ 28 D	ASTM C 1202[31] @ 28 D
Chloride ponding	AASHTO T 259[32]	AASHTO T 259[32]
Sulfate resistance	ASTM C 1012[33]	ASTM C 1012[33]
Chemical resistance	ASTM D 1308[34] with C 157[25] bars*	ASTM D 1308[34] with C 157[25] bars*
Cracking resistance	AASHTO PP 34[35]	AASHTO PP 34[35]

*use specimens from ASTM C 157 length change

39. ASTM C 1543 "Standard Test Method for Determining the Penetration of Chloride Ion into Concrete by Ponding," V. 4.02
40. ASTM C 1581, "Standard Test Method for Determining Age at Cracking and Induced Tensile Stress Characteristics of Mortar and Concrete under Restrained Shrinkage," V. 4.02
41. ICRI Technical Guideline No. 03739 "Guide to Using In-Situ Tensile Pull-Off Tests to Evaluate Bond of Concrete Surface Materials," International Concrete Repair Institute, 2004

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