Designation: C989/C989M – 16$^{\varepsilon 1}$

Standard Specification for Slag Cement for Use in Concrete and Mortars[1]

This standard is issued under the fixed designation C989/C989M; 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 U.S. Department of Defense.

ε[1] NOTE—Footnote 4 was corrected editorially in March 2017.

1. Scope*

1.1 This specification covers slag cement for use as a cementitious material in concrete and mortar.

NOTE 1—The material described in this specification may be used for blending with portland cement to produce a cement meeting the requirements of Specification C595/C595M or as a separate ingredient in concrete or mortar mixtures. The material may also be useful in a variety of special grouts and mortars, and when used with an appropriate activator, as the principal cementitious material in some applications.

NOTE 2—Information on technical aspects of the use of the material described in this specification is contained in Appendix X1, Appendix X2, and Appendix X3. More detailed information on that subject is contained in ACI 233R-03.[2]

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the inch-pound units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard. Values are stated in only SI units when inch-pound units are not used in practice.

1.3 The text of this standard references notes and footnotes that provide explanatory information. These notes and footnotes (excluding those in tables) shall not be considered as requirements of this standard.

1.4 The following safety hazards caveat pertains only to the test methods described in this specification. *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.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C109/C109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)
C114 Test Methods for Chemical Analysis of Hydraulic Cement
C125 Terminology Relating to Concrete and Concrete Aggregates
C150/C150M Specification for Portland Cement
C185 Test Method for Air Content of Hydraulic Cement Mortar
C188 Test Method for Density of Hydraulic Cement
C204 Test Methods for Fineness of Hydraulic Cement by Air-Permeability Apparatus
C430 Test Method for Fineness of Hydraulic Cement by the 45-μm (No. 325) Sieve
C452 Test Method for Potential Expansion of Portland-Cement Mortars Exposed to Sulfate
C465 Specification for Processing Additions for Use in the Manufacture of Hydraulic Cements
C595/C595M Specification for Blended Hydraulic Cements
C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
C1012/C1012M Test Method for Length Change of Hydraulic-Cement Mortars Exposed to a Sulfate Solution
C1038/C1038M Test Method for Expansion of Hydraulic Cement Mortar Bars Stored in Water
C1437 Test Method for Flow of Hydraulic Cement Mortar
C1778 Guide for Reducing the Risk of Deleterious Alkali-Aggregate Reaction in Concrete

[1] This specification is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.27 on Ground Slag.

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[2] ACI 233R-03 Slag Cement in Concrete and Mortar. Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333-9094, http://www.concrete.org.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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

D3665 Practice for Random Sampling of Construction Materials

3. Terminology

3.1 *Definitions*—For definitions of terms used in this test method, refer to Terminology C125.

4. Classification

4.1 Slag cement is classified by performance in the slag activity test in three grades: Grade 80, Grade 100, and Grade 120 (see Table 1).

5. Ordering Information

5.1 The purchaser shall specify the grade of slag cement desired and the optional chemical or physical data to be reported.

6. Additions

6.1 Slag cement covered by this specification shall contain no additions except as follows:

6.1.1 It is permissible to add calcium sulfate to slag cement provided it has been demonstrated by Test Method C1038/C1038M that a test mixture will not develop expansion in water exceeding 0.020 % at 14 days. In the test mixture, 50 % of the mass of portland cement shall be replaced by an equal mass of slag cement. The portland cement used in the test mixture shall meet the requirements of Specification C150/C150M. When the manufacturer supplies cement under this provision, upon request, supporting data shall be supplied to the purchaser.

6.1.2 When processing additions are used in the manufacture of slag cement, the maximum amount used shall comply with the requirements of Specification C465 when tested using a blend that is 50 % slag cement and 50 % portland cement by mass.

7. Chemical Composition

7.1 Slag cement shall conform to the chemical requirements prescribed in Table 2.

TABLE 1 Physical Requirements

Item		
Fineness:		
Amount retained when wet screened on a 45-µm (No. 325) sieve, max %		20
Specific surface by air permeability, Test Methods C204 shall be determined and reported although no limits are required.		...
Air Content of Slag Mortar, max %		12
	Average of Last Five Consecutive Samples	Any Individual Sample
Slag Activity Index^{A}		
28-Day Index, min %		
Grade 80	75	70
Grade 100	95	90
Grade 120	115	110

^{A} 7-Day Slag Activity Index shall be determined on Grades 100 and 120, and reported for informational purposes.

TABLE 2 Chemical Requirements

Sulfide sulfur (S), max, %	2.5

8. Physical Properties

8.1 Slag cement shall conform to the physical requirements of Table 1.

9. Sampling

9.1 The following sampling and testing procedures shall be used by the purchaser to verify compliance with this specification.

NOTE 3—Sulfur in granulated blast-furnace slag is present predominantly as sulfide sulfur. In most cases, instrumental analyses, such as x-ray fluorescence, cannot differentiate sulfide sulfur from sulfate. Determine and report the sulfide sulfur content separately, and do not include it in the SO_3 calculations.

9.2 Take random grab samples either from a delivery unit or at some point in the loading or unloading process so that no sample represents more than 115 Mg [125 tons] (Note 4). If samples are taken from rail cars or trucks, take at least two separate 2-kg [5-lb] portions and thoroughly mix them to obtain a test sample (Note 5). Sample by removing approximately a 300-mm [12-in.] layer of slag cement. Make a hole before obtaining a sample to avoid dust collector material that has discharged into the delivery unit after the predominant slag cement flow has ceased. Sample at a rate of one sample per month or one sample for each 2300 Mg [2500 tons] of shipments, whichever is more frequent.

NOTE 4—Standard statistical procedures are recommended for ensuring that samples are selected by a random procedure; see Practice D3665. These procedures can be used to select the days within a month or within a week that samples will be taken. The delivery unit or time of day then should be chosen randomly.

NOTE 5—The quantity of sample specified is more than adequate for the testing required. A 2-kg [5-lb] portion should be retained in a sealed container for retesting if that is considered necessary to verify compliance.

10. Test Methods

10.1 *Slag-Activity Tests with Portland Cement:*

10.1.1 Slag activity shall be evaluated by determining the compressive strength of portland-cement mortars and the corresponding mortars made with the same mass of a blend that is 50 % slag cement and 50 % portland cement by mass.

NOTE 6—Appendix X1 discusses the effects of cement, temperature, and amount of slag cement used on performance with portland cement.

10.1.2 *Reference Cement*—The portland cement used in the slag activity tests shall be the common reference cement supplied by CCRL[4] that complies with the standard chemical and physical requirements of Specification C150/C150M, Type I or Type II, and with the additional requirements of total alkali content and compressive strength limits as shown in Table 3. Alternatively, a portland cement source meeting the standard

[4] The sole source of commercially available reference portland cement known to the committee at this time is CCRL, 4441 Buckeystown Pike, Suite C; Frederick, Maryland 21704; www.CCRL.us. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

TABLE 3 Alkali and Strength Limits of Reference Portland Cement for Slag Activity Tests

Total Alkalies (Na_2O + 0.658 K_2O)	min %	0.60
	max %	0.90
Compressive Strength, MPa, min, 28 days[A]		35 [5000 psi]

[A] The minimum strength limit is based solely on the strength of the Test Method C109/C109M mortar cubes, as required in Specification C150/C150M, regardless of the strength of the flow-controlled Specification C989 mortar cubes.

chemical and physical requirements for a C150, Type I or Type II, including the additional limits in Table 3, is permitted to be used. Sufficient cement shall be reserved to avoid changing reference cement more often than every two months. After the initial testing to determine compliance with the compressive strength requirement of Table 3, the reference cement shall be re-qualified at least every six months.

NOTE 7—Different reference cements may produce different Slag Activity Index results. Reference portland cement meeting the requirements of 10.1.2 is available from CCRL.[5]

10.1.3 *Preparation of Specimens*—Prepare mortars in accordance with Test Method C109/C109M, except that sufficient water shall be used in each batch to produce mortar at a flow of 105 to 115 % as defined in Test Method C1437. The proportions of dry ingredients shall be as follows:

Reference Cement Mortar:
- 500 g portland cement
- 1375 g graded standard sand

Slag Cement-Reference Cement Mortar:
- 250 g portland cement
- 250 g slag cement
- 1375 g graded standard sand

10.1.3.1 Mix a reference cement batch each day that a slag cement-reference cement batch is mixed until at least five batches have been mixed with the reference cement. Thereafter, reference cement batches need not be mixed more often than once a week whenever slag cement is being produced or shipped.

10.1.4 *Test Ages*—Determine the compressive strength of mortar specimens at 7 and 28 days age in accordance with Test Method C109/C109M.

10.1.5 *Calculation*—Calculate the slag activity index to the nearest percent for both 7 days and 28 days as follows:

$$\text{Slag activity index, } \% = (SP/P) \times 100 \qquad (1)$$

where:

SP = average compressive strength of slag cement-reference cement mortar cubes at designated ages, MPa [psi], and
P = average compressive strength of reference cement mortar cubes at designated age, MPa [psi].

The reference cement-mortar strength used to calculate a slag activity index shall, when a reference cement mortar is mixed on the same day as a slag cement-reference cement mortar, be the result for that batch. Otherwise, the average of tests of the five most recent reference cement-mortar batches shall be used.

10.1.6 *Report*—The report should include the following:

10.1.6.1 Slag activity index, %,

10.1.6.2 Compressive strength at 7 and 28 days, of slag cement-reference cement mortar,

10.1.6.3 Compressive strength at 7 and 28 days, of portland cement mortar,

10.1.6.4 Total alkalies of the reference cement (Na_2O + 0.658 K_2O),

10.1.6.5 Fineness of reference cement, and

10.1.6.6 Potential compound composition of the reference portland cement.

10.1.7 *Precision*—The single and multilaboratory statements are based on slag activity index tests using one slag cement, in duplicate, at 7 and 28 days after fabrication of samples. The same slag cement and CCRL reference cement were used at each of 22 laboratories (Note 8).

NOTE 8—The precision of this test method was determined from an interlaboratory study (ILS) under the jurisdiction of ASTM Subcommittee C09.27. The ILS program was conducted in 2015. Practice C670 was followed for the design and analysis of the data. The details are given in RR:C09-1048.[6]

10.1.7.1 The single-laboratory standard deviation has been found to be 1.65 % at 7 days and 2.62 % at 28 days. Therefore, the slag activity indices of properly conducted tests based on single batches of mortar mixed on the same day would not be expected to differ by more than 4.6 % at 7 days and 7.3 % at 28 days in more than one case in 20.

10.1.7.2 The multilaboratory standard deviation has been found to be 6.88 % at 7 days and 4.78 % at 28 days Therefore, the slag activity indices of properly conducted tests of single batches by different laboratories would not be expected to differ by more than 19.3 % at 7 days or 13.4 % at 28 days in more than one case in 20.

10.2 *Slag Cement Density*—Determine in accordance with Test Method C188.

10.3 *Amount of Slag Cement Retained on a 45-µm (No. 325) Sieve*—Determine in accordance with Test Method C430.

10.4 *Slag Cement Fineness by Air Permeability*—Determine in accordance with Test Methods C204.

10.5 *Sulfate Ion in Slag Cement Reported as SO_3*—Determine as sulfur trioxide in accordance with Test Methods C114, except the sample need not be completely decomposed by acid.

10.6 *Sulfide Sulfur in Slag Cement*—Determine in accordance with Test Methods C114.

10.7 *Chloride Content of Slag*—Determine in accordance with Test Methods C114.

10.8 *Air Content of Slag Cement Mortar*—Determine in accordance with Test Method C185, except use 350 g of slag

[5] The sole source of commercially available reference portland cement known to the committee at this time is CCRL, 4441 Buckeystown Pike, Suite C; Frederick, Maryland 21704; www.CCRL.us. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

[6] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:C09-1048. Contact ASTM Customer Service at service@astm.org.

cement in the standard mortar batch. Calculate using the appropriate density of the slag cement.

11. Rejection and Rehearing

11.1 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 tests, the producer or supplier is not prohibited from making a claim for retesting.

NOTE 9—In the event of a Slag Activity Index dispute, the purchaser should request a sample of the producer's reference cement for retest.

12. Certification

12.1 Upon request of the purchaser in the contract or order, a manufacturer's report shall be furnished at the time of shipment stating the results of tests made on samples of the material taken during production or transfer and certifying that the slag cement conforms to applicable requirements of this specification.

12.2 When specified in the purchase order or contract, test data shall be furnished on the chloride ion content of the slag cement.

NOTE 10—Guidance on preparing the manufacturer's report is provided in Appendix X4.

13. Manufacturer's Statement

13.1 At the request of the purchaser, the manufacturer shall state in writing the nature, amount, and identity of any processing or other additions made to the slag cement.

14. Package Marking and Shipping Information

14.1 When the slag cement is delivered in packages, the classification of the slag cement, the name and brand of the manufacturer, and the mass of the slag cement contained therein shall be plainly marked on each package. Similar information shall be provided in the shipping invoices accompanying the shipment of packaged or bulk slag cement. All packages shall be in good condition at the time of inspection.

15. Storage

15.1 The slag cement shall be stored to permit easy access for proper inspection and identification of each shipment and in a suitable weather-tight building that will protect the slag cement from dampness and minimize quality deterioration.

16. Keywords

16.1 blast furnace slag; granulated blast furnace slag; slag activity index; slag cement

APPENDIXES

(Nonmandatory Information)

X1. CONTRIBUTION OF SLAG CEMENT TO CONCRETE STRENGTH

X1.1 When slag cement is used in concrete with portland cement, the levels and rate of strength development will depend importantly on the properties of the slag cement, the properties of the portland cement, the relative and total amounts of slag cement and portland cement, and the concrete curing temperatures.

X1.2 The reference cement used to test slag activity in this specification must have a minimum 28-day strength of 35 MPa [5000 psi] and an alkali equivalent between 0.6 and 0.9 %. Performance of the slag cement with other portland cements may be significantly different. The slag-activity test also can be used to evaluate relative hydraulic activity of different slag cements with a specific cement or of different shipments of the same slag cement. Such comparisons will be improved if all tests are made with a single sample of cement. To properly classify a slag cement, the reference portland cement must conform to the limits on strength and alkali content. Even within these limits, performance will depend to some extent on the particular cement used. The results of the slag activity test do not provide quantitative predictions of strength performance in concrete. Performance in concrete will depend on a large number of factors including the properties and proportions of the slag cement, the portland cement, and other concrete ingredients, concrete temperatures, and curing conditions; and other conditions.

X1.3 Concrete strengths at 1, 3, and even 7 days may tend to be lower using slag cement-portland cement combinations, particularly at low temperatures or at high slag cement percentages. Concrete proportions will need to be established considering the importance of early strengths, the curing temperatures involved and the properties of the slag cement, the portland cement, and other concrete materials. Generally a higher numerical grade of slag cement can be used in larger amounts and will provide improved early strength performance; however, tests must be made using job materials under job conditions.

X2. SULFATE RESISTANCE

X2.1 *General*—Concrete manufactured with high percentages of slag cement is generally considered to have greater resistance to attack by sulfates than do portland cements, based largely upon comparisons of these mixtures with similar mixtures containing ordinary (Type I) portlands. These high volume slag cement mixtures (containing 60 % or more slag) are widely used for sulfate and sea-water resistant concretes throughout the world.

X2.2 *Sulfate Resistance of Portland Cements*—The sulfate resistance of concrete is dependent upon a number of factors, including mortar permeability and the type and concentration of the sulfate solutions involved. Others, directly related to the cement characteristics, include calcium hydroxide concentration and the tricalcium aluminate (C_3A) content. Specification C150/C150M provides limits on the C_3A for sulfate-resistant cements. Specification C150/C150M Type V requirements provide for a limit on the tetracalcium aluminoferrite (C_4AF) plus twice the C_3A. The Specification C150/C150M table of Optional Physical Requirements includes a maximum limit on expansion of Type V cement in mortar bars when tested by Test Method C452. When this option is selected, the standard limits on tricalcium aluminate and on tetracalcium aluminoferrite plus twice the tricalcium aluminate do not apply. Test Method C1012/C1012M can be used to measure the effects of exposure to external sulfate environments on mortar or concrete.

X2.3 *Effect of Slag Cement on Sulfate Resistance*—The use of slag cement will decrease the C_3A content of the cementing materials and decrease the permeability and calcium hydroxide content of the mortar or concrete. Tests have shown that the alumina content of the slag cement also influences sulfate resistance (**1, 2**),[7] and that high alumina content can have a detrimental influence at low slag cement-replacement percentages. Data from studies of laboratory exposure of mortars to sodium and magnesium sulfate solutions provide the following general conclusions.

X2.3.1 The combinations of slag cement and portland cement, in which the slag cement content was greater than 60 to 65 %, had high sulfate resistance, always better than the portland cement alone, irrespective of the Al_2O_3 content of the slag cement. The improvement in sulfate resistance was greatest for the portland cements with the higher C_3A contents.

X2.3.2 The low alumina (11 %) slag cement tested increased the sulfate resistance independently of the C_3A content of the portland cement. To obtain adequate sulfate resistance, higher slag cement percentages were necessary with the higher C_3A portland cements.

X2.3.3 The high alumina (18 %) slag cement tested, adversely affected the sulfate resistance of portland cements when blended in low percentages (50 % or less). Some tests indicated rapid decreases in resistance for cements in the 8 and 11 % C_3A ranges with slag cement percentages as low as 20 % or less in the blends.

X2.3.4 Tests on slag cement (7 to 8 % alumina) in Ontario (**3**) have shown that a 50:50 combination by mass with Type I portland cement (having up to about 12 % C_3A) is equivalent in sulfate resistance to the Type V cement used in that study.

X2.4 *Tests for Sulfate Resistance*—When the relative sulfate resistance of a specific portland cement-slag cement combination is desired, tests should be conducted in accordance with Test Method C1012/C1012M (**4**). Studies by Subcommittee C01.29 on sulfate resistance using Test Method C1012/C1012M, as reported by Patzias (**5**), recommended the following limits for expansion of portland cement and slag cement combinations at six months of exposure:

Moderate sulfate resistance — 0.10 % max
High sulfate resistance — 0.05 % max

[7] The boldface numbers in parentheses refer to a list of references at the end of this standard.

X3. EFFECTIVENESS OF SLAG CEMENT IN PREVENTING EXCESSIVE EXPANSION OF CONCRETE DUE TO ALKALI SILICA REACTION

X3.1 *General*—If properly proportioned in concrete mixtures, slag cement has been shown to prevent excessive expansion due to alkali-silica reaction.

X3.2 *ASR in Concrete*—Alkali silica reaction occurs in concrete if certain siliceous aggregates are placed in a highly alkaline environment and, in the presence of water, form an expansive gel. When this gel forms, tensile stresses develop in the concrete around the expanding gel which can cause the concrete to crack. The extent of the reaction is directly related to the alkalinity of the solution, the reactivity of the aggregate, and the availability of water, which fuels the reaction.

X3.3 *Mitigating ASR with Slag Cement*—Slag cement mitigates ASR by reducing the total alkalis in the system and by consuming alkalis in the hydration reaction, making them unavailable for the alkali aggregate reaction. The percentage of slag cement required to mitigate alkali silica reaction is dependent on the reactivity of the aggregate and the alkali loading of the concrete. For concretes containing very reactive aggregates or for concretes with a high alkali loading, higher percentages of slag cement may be required to insure mitigation. For more information on ASR mitigation, including test methods, see Guide C1778.

X4. MANUFACTURER'S CERTIFICATION (MILL TEST REPORT)

X4.1 To provide uniformity for reporting the results of tests performed on slag cements under this specification, as required by Section 12 of Specification C989/C989M entitled "Certification," an example Mill Test Report is shown in Fig. X4.1.

X4.2 The identity information given should unambiguously identify the cement production represented by the Mill Test Report and may vary depending upon the manufacturer's designation and purchaser's requirements.

X4.3 The Manufacturer's Certification statement may vary depending upon the manufacturer's procurement order, or legal requirements, but should certify that the slag cement shipped is represented by the certificate and that the cement conforms to applicable requirements of the specification at the time it was tested (or retested) or shipped.

X4.4 The sample Mill Test Report has been developed to reflect the chemical and physical requirements of this specification and recommends reporting all analyses and tests normally performed on slag cements meeting Specification C989/C989M. Purchaser reporting requirements should govern if different from normal reporting by the manufacturer or from those recommended here.

X4.5 Slag cements may be shipped prior to later-age test data being available. In such cases, the test value may be left blank. Alternatively, the manufacturer can generally provide estimates based on historical production data. The report

ABC Cement Company
Qualitytown, NJ

Plant: Example — Slag Cement ASTM C989 Grade 100 — December 7, 2009

Production Period November 15, 2009 to November 30, 2009

CHEMICAL

Item	Test Result	ASTM C989 Spec Limit
Sulfide Sulfur (S), %	1.1	2.5 max.
Sulfate Sulfur (as SO_3), %	2.7	[A]
Aluminum Oxide (as Al_2O_3)	10.5	[A]

PHYSICAL

Item	Test Result	ASTM C989 Spec Limit
Compressive Strength[B]		
7 Day (psi)	3669	[A]
28 Day (psi)	5695	[A]
Slag Activity Index (%)		
7 Day	94	[A]
28 Day	118	95
Fineness		
Blaine (m^2/kg)	495	[A]
45 micron (% retained)	3	20 max.
Air Content, %	2	12 max.
Specific Gravity	2.93	

[A] Not applicable.
[B] Reference cement chemical and physical data furnished upon request.

We certify that the above described slag cement, at the time of shipment, meets the chemical and physical requirements of ASTM C989 – 09 or (other) _______ specification.

Signature: ________________________ Title: ________________________________ Date: _________.

FIG. X4.1 Example Mill Test Report

should indicate if such estimates are provided.

REFERENCES

(1) Locher, F. W., "The Problems of the Sulfate Resistance of Slag Cements," *Zement-Kalk-Gips*, No. 9, September, 1966.
(2) Van Aardt, J. H. P., and Visser, S., "The Behavior of Mixtures of Milled Granulated Blast-Furnace Slag and Portland Cement in Sulfate Solutions," *Bulletin 47*, National Building Research Institute, South Africa, 1967.
(3) Chojnacki, B., "Sulfate Resistance of Blended (Slag) Cement," *Report EM-52*, Ministry of Transport and Communications, Ontario, Canada 1981.
(4) Hooton, R. D., and Emery, J. J., "Sulfate Resistance of a Canadian Slag Cement," *ACI Materials Journal*, Vol *87*, No. 6, November–December 1990.
(5) Patzias, T., "The Development of ASTM Method C1012/C1012M with Recommended Acceptance Limits for Sulfate Resistance of Hydraulic Cements," *Cement, Concrete, and Aggregates*, Vol 13, No. 1, ASTM, 1991.

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this standard since the last issue (C989/C989M – 14) that may impact the use of this standard. (Approved Dec. 15, 2016.)

(1) Revised Appendix X3 to clarify that slag cement mitigates only ASR and direct users to Guide C1778.
(2) Revised 2.1 to add Guide C1778.
(3) Revised 10.1.3.
(4) Added Test Method C1437 to Section 2.
(5) Revised 10.1.7 – 10.1.7.2.