



Designation: C989/C989M – 12a

Standard Specification for Slag Cement for Use in Concrete and Mortars¹

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 Department of Defense.

1. Scope*

1.1 This specification covers three strength grades of 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 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 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.*

1.4 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 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.

Current edition approved July 15, 2012. Published October 2012. Originally approved in 1982. Last previous edition approved in 2012 as C989/C989M-12. DOI: 10.1520/C0989_C0989M-12a.

² ACI 233R-03 Slag Cement in Concrete and Mortar. Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333.

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** Specification for Portland Cement
- C185** Test Method for Air Content of Hydraulic Cement Mortar
- C188** Test Method for Density of Hydraulic Cement
- C227** Test Method for Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method)
- C204** Test Methods for Fineness of Hydraulic Cement by Air-Permeability Apparatus
- C430** Test Method for Fineness of Hydraulic Cement by the 45- μ m (No. 325) Sieve
- C441** Test Method for Effectiveness of Pozzolans or Ground Blast-Furnace Slag in Preventing Excessive Expansion of Concrete Due to the Alkali-Silica Reaction
- 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** Specification for Blended Hydraulic Cements
- C1012** Test Method for Length Change of Hydraulic-Cement Mortars Exposed to a Sulfate Solution
- C1038** Test Method for Expansion of Hydraulic Cement Mortar Bars Stored in Water
- C1260** Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)
- C1293** Test Method for Determination of Length Change of Concrete Due to Alkali-Silica Reaction
- C1567** Test Method for Determining the Potential Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregate (Accelerated Mortar-Bar Method)

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
TABLE 2 Chemical Requirements

Sulfide sulfur (S), max, %	2.5
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3. Terminology

3.1 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** 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**. 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**.

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 SO₃ 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 comply with the standard chemical and physical requirements of Specification **C150**, Type I or Type II, and with the additional requirements of total alkali content and compressive strength limits as shown in **Table 3**. 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.

TABLE 1 Physical Requirements

Item		
Fineness:		
amount retained when wet screened on a 45- μ m (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, min, %		
7-Day Index		
Grade 80
Grade 100	75	70
Grade 120	95	90
28-Day Index		
Grade 80	75	70
Grade 100	95	90
Grade 120	115	110

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

Total Alkalies (Na ₂ O + 0.658 K ₂ O)	min %	0.60
	max %	0.90
Compressive Strength, MPa, min, 28 days ^A		35 [5000 psi]

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

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.⁴

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 a flow of 110 ± 5 %. 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:

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

- 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,

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.

10.1.6.4 Total alkalies of the reference cement (Na₂O + 0.658 K₂O),

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 following precision statements are applicable when the slag activity index with portland cement is based on results of tests of two cubes from single batches of reference cement and 50-50 slag cement-reference cement mortars mixed on the same day. They are applicable to the slag activity index determined at 7 or 28 days.

10.1.7.1 The single-laboratory coefficient of variation has been found to be 4.1 %. Therefore, the slag activity indices of properly conducted tests based on single batches of mortar mixed on the same day should not differ by more than 11.6 % of their average.

10.1.7.2 The multilaboratory coefficient of variation has been found to be 5.7 %. Therefore, the slag activity indices of properly conducted tests of single batches by different laboratories should not differ by more than 16.1 %.

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 SO₃*—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 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 8—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 9—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](#) provides limits on the C_3A for sulfate-resistant cements. Specification [C150](#) Type V requirements provide for a limit on the tetracalcium aluminoferrite (C_4AF) plus twice the C_3A . The [C150](#) 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