



Designation: C 989 – 06

# Standard Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars<sup>1</sup>

This standard is issued under the fixed designation C 989; 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 ( $\epsilon$ ) 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 finely ground granulated blast-furnace slag 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 C 595 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, formerly ACI 226.1R.

1.2 The values stated in SI units are to be regarded as standard.

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.

## 2. Referenced Documents

2.1 *ASTM Standards:*<sup>2</sup>

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)

<sup>1</sup> 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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<sup>2</sup> 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.

- C 114 Test Methods for Chemical Analysis of Hydraulic Cement
  - C 125 Terminology Relating to Concrete and Concrete Aggregates
  - C 150 Specification for Portland Cement
  - C 185 Test Method for Air Content of Hydraulic Cement Mortar
  - C 188 Test Method for Density of Hydraulic Cement
  - C 204 Test Methods for Fineness of Hydraulic Cement by Air-Permeability Apparatus
  - C 430 Test Method for Fineness of Hydraulic Cement by the 45- $\mu$ m (No. 325) Sieve
  - C 441 Test Method for Effectiveness of Pozzolans or Ground Blast-Furnace Slag in Preventing Excessive Expansion of Concrete Due to the Alkali-Silica Reaction
  - C 452 Test Method for Potential Expansion of Portland-Cement Mortars Exposed to Sulfate
  - C 465 Specification for Processing Additions for Use in the Manufacture of Hydraulic Cements
  - C 595 Specification for Blended Hydraulic Cements
  - C 1012 Test Method for Length Change of Hydraulic-Cement Mortars Exposed to a Sulfate Solution
  - D 3665 Practice for Random Sampling of Construction Materials
- 2.2 *American Concrete Institute Reports:*
- 226.1R Ground Granulated Blast-Furnace Slag as a Cementitious Constituent in Concrete<sup>3</sup>
  - 233R-03 Slag Cement in Concrete and Mortar<sup>3</sup>

## 3. Terminology

3.1 Definition:

3.1.1 *blast-furnace slag*—the nonmetallic product, consisting essentially of silicates and aluminosilicates of calcium and other bases that is developed in a molten condition simultaneously with iron in a blast furnace (see Terminology C 125).

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *granulated blast-furnace slag*—the glassy granular material formed when molten blast-furnace slag is rapidly

<sup>3</sup> Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333.

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

chilled as by immersion in water (see Terminology C 125), with or without compositional adjustments made while the blast-furnace slag is molten.

3.2.2 *slag*—granulated blast-furnace slag, as defined and described in 3.1.1 and 3.2.1, and ground to cement fineness with or without additions meeting the requirements of the section on additions.

**4. Classification**

4.1 Slag 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 slag desired and the optional chemical or physical data to be reported.

**6. Additions**

6.1 The slag covered by this specification shall contain no additions except as follows:

6.1.1 When used, calcium sulfate shall be added in the amounts such that the limits in Table 2 for sulfur trioxide are not exceeded.

6.1.2 When processing additions are used in the manufacture of the slag, the maximum amount used shall comply with the requirements of Specification C 465 when tested using a 50-50 blend by mass and the portland cement.

**7. Chemical Composition**

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

**8. Physical Properties**

8.1 Slag 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.

**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 Method C 204 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 2 Chemical Requirements**

Sulfide sulfur (S), max, %	2.5
Sulfate reported as SO <sub>3</sub> , max, %	4.0

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<sub>3</sub> 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. Make a hole before obtaining a sample to avoid dust collector material that has discharged into the delivery unit after the predominant slag 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 D 3665. 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 both portland-cement mortars and corresponding mortars made with the same mass of 50-50 mass combinations of slag and portland cement. Appendix X1 discusses the effects of cement, temperature, and amount of slag 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 C 150 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.

NOTE 6—Different reference cements may produce different Slag Activity Index results.

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

Total Alkalies (Na <sub>2</sub> O + 0.658 K <sub>2</sub> O)	min %	0.60
	max %	0.90
Compressive Strength, MPa, min, 28 days <sup>A</sup>		35 (5000 psi)

<sup>A</sup>The minimum strength limit is based solely on the strength of the Test Method C 109/C 109M mortar cubes, as required in Specification C 150, regardless of the strength of the flow-controlled Specification C 989 mortar cubes.