Confirmation of Orcem's Exclusive Use of GBFS from Iron Ore 7/19/17

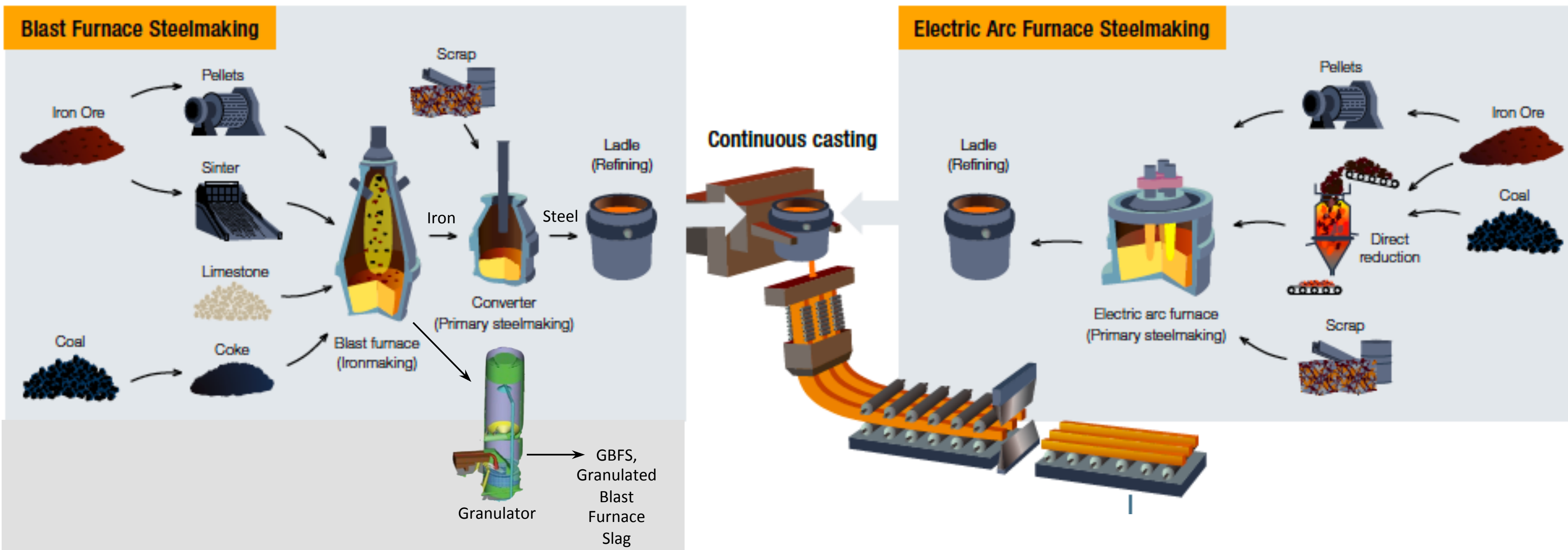
The 2014 Orcem Application originally stated on page 30 as follows: *"The primary raw material utilized at the Orcem Project is granulated blast furnace slag ("GBFS"), a recycled beneficiated byproduct from the first stage in the production of steel. It is a byproduct of converting iron ore to metallic iron in a blast furnace."* In response to City staff's request for clarification, Orcem has provided the supplemental information below explaining that GBFS is derived from the processing of iron.

The Orcem product is known as ground granulated blast furnace slag ("GGBFS"), governed in the USA and several other countries in the world by specification ASTM C-989. GGBFS is produced by grinding granulated blast furnace slag ("GBFS") in a mill such as the one proposed for Vallejo. The slag from an iron blast furnace is called blast furnace slag ("BFS") it can be air cooled and used for limestone aggregate, or granulated by utilizing high pressure water sprays to rapidly cool the molten BFS as it is discharged from the blast furnace to produce GBFS. The primary product of the blast furnace is molten metallic iron. That iron is either cooled into ingots and sold as an intermediate product called 'pig iron', or transported in the molten state within a steel mill site and introduced as the primary ingredient into a basic oxygen furnace ("BOF") to produce steel. That BOF process also has a slag, often referred to as 'steel slag', or BOF slag, or ladle slag. It has very limited commercial value and chemically different than GBFS. Another slag, EAF slag, comes from the production of steel in an electric arc furnace using scrap steel as the primary raw material. We changed the word 'steel' to 'iron' to more accurately specify the exact slag in the steel production process we will process for people less familiar with the industries.

The attached materials provide verification that GBFS is produced exclusively from iron ore processing:

1) World Steel Association schematic on steel production, found at: www.worldsteel.org/media-centre/about-steel.html modified to show where the granulator and GBFS are in the process.

2) ASTM specification for GGBFS for concrete that specifies only this slag can be utilized in the production of our product.


Blast Furnace Steelmaking
Iron Ore
Pellets
Sinter
Limestone
Coal
Coke
Scrap
Blast furnace
(Ironmaking)
Iron
Converter
(Primary steelmaking)
Steel
Ladle
(Refining)
Granulator
GBFS,
Granulated
Blast
Furnace
Slag
Continuous casting
Electric Arc Furnace Steelmaking
Pellets
Iron Ore
Coal
Direct
reduction
Electric arc furnace
(Primary steelmaking)
Ladle
(Refining)
Scrap

Designation: C 989 – 06

Standard Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars[1]

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 (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 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:* [2]

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

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-μm (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[3]

233R-03 Slag Cement in Concrete and Mortar[3]

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

[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] 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.

[3] 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_3, 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_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. 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_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 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.

10.1.3 *Preparation of Specimens*—Prepare mortars in accordance with Test Method C 109/C 109M, except that sufficient water shall be used in each batch to produce a flow of 110± 5 %. The proportions shall be as follows:

Reference Cement Mortar:

500 g portland cement

1375 g graded standard sand

Slag-Reference Cement Mortar:

250 g portland cement

250 g slag

1375 g graded standard sand

10.1.3.1 Mix a reference cement batch each day that a slag-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 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 C 109/C 109M.

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

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

SP = average compressive strength of slag-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-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-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 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-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 Density*—Determine in accordance with Test Method C 188.

10.3 *Amount of Slag Retained on a 45-μm (No. 325) Sieve*—Determine in accordance with Test Method C 430.

10.4 *Slag Fineness by Air Permeability*—Determine in accordance with Test Method C 204.

10.5 *Sulfate Ion in Slag Reported as* SO_3—Determine as sulfur trioxide in accordance with Test Methods C 114, except the sample need not be completely decomposed by acid.

10.6 *Sulfide Sulfur in the Slag*—Determine in accordance with Test Methods C 114.

10.7 *Chloride Content of Slag*—Determine in accordance with Test Methods C 114.

10.8 *Air Content of Slag Mortar*—Determine in accordance with Test Method C 185, except use 350 g of slag instead of cement in the standard mortar batch. Calculate using the appropriate density of the slag.

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 7—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 When specified in the purchase order or contract, the purchaser shall be furnished certification that samples representing each lot have been tested as directed in this specification and the specified requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished.

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

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.

14. Package Marking and Shipping Information

14.1 When the ground slag is delivered in packages, the classification of slag, the name and brand of the manufacturer, and the weight of the slag 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. All packages shall be in good condition at the time of inspection.

15. Storage

15.1 The slag 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 from dampness and minimize quality deterioration.

APPENDIXES

(Nonmandatory Information)

X1. CONTRIBUTION OF SLAG TO CONCRETE STRENGTH

X1.1 When slag is used in concrete with portland cement, the levels and rate of strength development will depend importantly on the properties of the slag, the properties of the portland cement, the relative and total amounts of slag and 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 content between 0.6 and 0.9 %. Performance of the slag with other portland cements may be significantly different. The slag-activity test also can be used to evaluate relative hydraulicity of different slags with a specific cement or of different shipments of the same slag. Such comparisons will be improved if all tests are made with a single sample of cement. To properly classify a slag, 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 percentages developed in 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, 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 combinations, particularly at low temperatures or at high slag percentages. Concrete proportions will need to be established considering the importance of early strengths, the curing temperatures involved and the properties of the slag, the portland cement, and other concrete materials. Generally a higher numerical grade of slag 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*—Slag cements are generally considered to have greater resistance to attack by sulfates than do portland cements, based largely upon comparisons of high slag-content portland blast-furnace slag cements with ordinary (Type I) portlands. These cements (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 C 150 provides limits on the C_3A for sulfate-resistant cements. Specification C 150 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 C 452. 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 C 1012 can be used to measure the effects of exposure to external sulfate environments on mortar or concrete.

X2.3 *Effect of Slag on Sulfate Resistance*—The use of slag 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 also influences sulfate resistance,[4,5] and that high alumina content can have a detrimental influence at low slag-replacement percentages. The data from these studies of laboratory exposure of mortars to sodium and magnesium sulfate solutions provide the following general conclusions.

X2.3.1 The combinations of slag and portland cement, in which the slag 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. The improvement in sulfate resistance was greatest for the cements with the higher C_3A contents.

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

X2.3.3 The high alumina (18 %) slag 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 percentages as low as 20 % or less in the blends.

[4] Locher, F. W., "The Problems of the Sulfate Resistance of Slag Cements," *Zement-Kalk-Gips*, No. 9, September, 1966.

[5] 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.

X2.3.4 Tests on slag (7 to 8 % alumina) in Ontario[6] 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 cement-slag combination is desired, tests should be conducted in accordance with Test Method C 1012.[7] Studies by Subcommittee C01.29 on sulfate resistance using Test Method C 1012, as reported by Patzias [8], recommended the following limits for expansion of portland cement and ground slag combinations at six months of exposure:

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

[6] Chojnacki, B., "Sulfate Resistance of Blended (Slag) Cement," *Report EM-52*, Ministry of Transport and Communications, Ontario, Canada 1981.

[7] Hooton, R. D. and Emery, J. J., "Sulfate Resistance of a Canadian Slag Cement", *ACI Materials Journal,* Vol 87, No. 6, November-December 1990.

[8] Patzias, T., "The Development of ASTM Method C 1012 with Recommended Acceptance Limits for Sulfate Resistance of Hydraulic Cements", *Cement, Concrete, and Aggregates,* Vol 13, No. 1, ASTM, 1991.

X3. EFFECTIVENESS OF SLAG IN PREVENTING EXCESSIVE EXPANSION OF CONCRETE DUE TO ALKALI-AGGREGATE REACTION

X3.1 Tests for effectiveness of slag in preventing excessive expansion due to alkali-aggregate reaction are not considered necessary unless the slag is to be used: (*a*) with a high-alkali portland cement ($Na_2O + 0.658\ K_20 \geq 0.6\ \%$) or the concrete contains added water-soluble alkalies (added as an activator to improve early strength); and (*b*) with an aggregate that is regarded as deleteriously reactive with alkalies.

X3.2 It should be expected that the effectiveness of the slag will depend upon the amount used and the reactivity of the slag itself. Data suggest that slags used as 40 % or more of the cementitious material will generally prevent excessive expansion with cements having alkali contents up to 1.0 %; however, definitive data are not available, and tests must be made in accordance with Test Method C 441.

X3.3 When the job cement and proportions of cement to slag are known, test mortars should be proportioned in accordance with the job mixture requirements of Test Method C 441, and the average expansion of mortar bars at 14 days should not exceed 0.020 %.

X3.4 When the job cement and proportions of slag to cement are not known, tests can be made for the reduction in mortar expansion in accordance with Test Method C 441. To be considered effective the slag must reduce 14-day expansions of mixtures made with the required high-alkali cement by 75 %. The slag should be considered effective only when the ratio of slag to cement equals or exceeds that found effective in the tests.

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this specification since the last issue, C 989 – 05, that may impact the use of this specification. (Approved August 1, 2006)

(*1*) Added new Note 6.

(*2*) Added new Note 7.