Designation: C1697 – 16

Standard Specification for Blended Supplementary Cementitious Materials[1]

This standard is issued under the fixed designation C1697; 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.

1. Scope

1.1 This specification covers blended supplementary cementitious materials that result from the blending or intergrinding of two or three ASTM compliant supplementary cementitious materials, for use in concrete or mortar where hydraulic or pozzolanic action, or both, is desired. The supplementary cementitious materials include slag cement conforming to Specification C989/C989M, natural pozzolans and coal fly ash conforming to Specification C618 and silica fume conforming to Specification C1240.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

NOTE 1—The incorporation of supplementary cementitious materials as separate additions or as a manufactured blend may significantly alter the properties of fresh and hardened concrete. The user should be aware of these changes and is referred to the *ACI Manual of Concrete Practice*[2] for information and guidelines. Specific reference is made to:

ACI 232.1R	Use of Natural Pozzolans in Concrete
ACI 232.2R	Use of Fly Ash in Concrete
ACI 233R	Slag Cement in Concrete and Mortar
ACI 234R	Guide for the Use of Silica Fume in Concrete

1.3 *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]

C114 Test Methods for Chemical Analysis of Hydraulic Cement

C125 Terminology Relating to Concrete and Concrete Aggregates

C150/C150M Specification for Portland Cement

C151/C151M Test Method for Autoclave Expansion of Hydraulic Cement

C183/C183M Practice for Sampling and the Amount of Testing of Hydraulic Cement

C311/C311M Test Methods for Sampling and Testing Fly Ash or Natural Pozzolans for Use in Portland-Cement Concrete

C618 Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete

C989/C989M Specification for Slag Cement for Use in Concrete and Mortars

C1240 Specification for Silica Fume Used in Cementitious Mixtures

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of other terms used in this specification, refer to Terminology C125.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *slag cement, n*—granulated blast furnace slag that is ground to cement fineness with or without additions and meets Specification C989/C989M.

3.2.2 *supplementary cementitious material, n*—a slag cement or pozzolan that contributes to the properties of concrete or mortar through hydraulic or pozzolanic activity, or both.

3.2.3 *silica fume, n*—as defined in Specification C1240.

4. Classification

4.1 This specification applies to a hydraulic or pozzolanic material composed of a blend of multiple supplementary cementitious materials as defined in Table 1. The supplementary cementitious materials of the blend are identified in accordance with the Type listed in the first column of Table 1. For the purpose of conformance to the requirements of this specification, the blend is classified according to the predominant supplementary cementitious material. For blended supplementary cementitious matierals that have no predominant constituent, the manufacturer selects the blend type.

4.2 The naming practice for reporting blended supplementary cementitious materials is as follows:

$$SCMb - Axx/Byy/Czz$$

[1] This specification is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.24 on Supplementary Cementitious Materials.

Current edition approved Oct. 1, 2016. Published October 2016. Originally approved in 2010. Last previous edition approved in 2010 as C1697-10. DOI: 10.1520/C1697-16.

[2] 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.

TABLE 1 Classification of Supplementary Cementitious Materials

Type	Name
N	Class N Pozzolan meeting Specification C618
F	Class F fly ash meeting Specification C618
C	Class C fly ash meeting Specification C618
SF	Silica Fume meeting Specification C1240
S	Slag cement meeting Specification C989/C989M

where:

SCMb = designation of the product as a blended supplementary cementitious material,

A = targeted mass % of the predominant supplementary cementitious material in the blended supplementary cementitious material expressed by mass of the final blended supplementary cementitious material,

xx = predominant supplementary cementitious material—use Type designation in accordance with Table 1,

B = targeted mass % of the secondary supplementary cementitious material in the blended supplementary cementitious material expressed by mass of the final blended supplementary cementitious material,

yy = secondary supplementary cementitious material—use Type designation in accordance with Table 1,

C = targeted mass % of the tertiary supplementary cementitious material in the blended supplementary cementitious material expressed by mass of the final blended supplementary cementitious material. This would be required only for ternary mixtures, and

zz = tertiary supplementary cementitious material—use Type designation in accordance with Table 1

NOTE 2—Examples of the naming practice are as follows:
A binary mixture of 65 % Class C fly ash and 35 % slag cement would be:

$$SCMb - 65C/35S$$

A ternary mixture of 60 % Class F fly ash, 35 % slag cement and 5 % silica fume would be:

$$SCMb - 60F/35S/5SF$$

5. Ordering Information

5.1 Orders for material under this specification shall include the following:

5.1.1 Specification number,

5.1.2 The composition of the blend using the naming convention in 4.2.

5.1.3 Any optional requirements as delineated in Table 2.

NOTE 3—In advance of ordering, it is important to check for market availability of blended supplementary cementitious materials.

6. Materials and Manufacture

6.1 All individual constituents used in the manufacture of the blended supplementary cementitious material shall conform to their applicable specification.

6.2 All blended supplementary cementitious materials shall consist of a uniform mixture of constituents within the limits specified in Section 9.

7. Chemical Composition

7.1 The individual constituents and the blended supplementary cementitious material shall be chemically analyzed using applicable analytical methods of Test Methods C311/C311M or Test Methods C114. Analyze for major and minor oxides present in greatest quantity that together, including loss-on-ignition constitutes at least 98 % of the total mass of the material.

7.2 There are no chemical requirements for the blended supplementary cementitious material but the chemical composition of the constituents and of the blended supplementary cementitious material are necessary to verify blend proportions.

8. Physical and Optional Properties

8.1 Blended supplementary cementitious materials shall conform to the physical requirements in Table 3, where the blend type is in accordance with Section 4.

8.2 Blended supplementary cementitious materials shall conform to the optional requirements in Table 2, only when specifically requested by the purchaser. The blend type is in accordance with Section 4.

9. Permissible Variations in Blending Accuracy

9.1 The amount of pozzolan or slag cement in the finished blended supplementary cementitious material shall not vary from the target value by more than ±2.5 percentage points for silica fume and not more than ±5 percentage points for other supplementary cementitious materials, with a 99 % probability of compliance.

NOTE 4—To satisfy the 99 % probability of compliance, the blending process must be capable of producing a blend containing silica fume such that the standard deviation of the measured mass percentage of silica fume in the blend is less than 1 %. For constituents other than silica fume, the standard deviations of their measured mass percentages have to be less than 1.9 %.

9.2 The chemical composition of the individual constituents and of the finished blended supplementary cementitious material shall be determined in accordance with Section 7. The composition of the blend in terms of mass percentage of the constituents shall be calculated.

NOTE 5—Appendix X1 provides an example to illustrate how the composition of the blend can be calculated from the various measured chemical compositions.

10. Sampling

10.1 The manufacturer shall sample and test the finished blended supplementary cementitious material in order to verify compliance with this specification.

10.1.1 Upon request of the purchaser, the manufacturer shall furnish the sampling procedure used to certify compliance with this specification.

10.2 If the purchaser desires to verify product compliance with this specification, appropriate sampling and testing procedures shall be used. For guidance, refer to standard Practice C183/C183M.

11. Storage and Inspection

11.1 The blended supplementary cementitious materials shall be protected from the detrimental effects of exposure to the environment and stored in such a manner as to permit easy access for proper inspection and identification.

TABLE 2 Optional Requirements

	Blend Type				
	N	F	C	S	SF
Increase of drying shrinkage of mortar bars at 28 days, max, difference, in %, over control[A]	0.03	0.03	0.03	...	...
Uniformity Requirements:[B]					
Density - max variation from average, %	5	5	5	...	...
% retained on 45-μm (No. 325) sieve, max variation from average, %	5	5	5	5	5
When air-entraining concrete is specified, the quantity of air-entraining agent required to produce an air content of 18.0 vol % of mortar shall not vary from the average established by the ten preceding tests or by all preceding tests if less than ten, by more than, %	20	20	20	...	20
Effectiveness in Controlling Alkali-Silica Reaction:					
Expansion of test mixture as percentage of low-alkali cement control, at 14 days, max, %[C]	100	100	100	...	...
Expansion of mortar bars at 14 days, max, %[D]	...	...	...	0.020	...
Reduction of mortar expansion at 14 days, min, %	...	...	...	75[D]	80[E]
Effectiveness in Contributing to Sulfate Resistance:					
Procedure A:[F]					
Expansion of test mixture:					
For moderate sulfate exposure after 6 months exposure, max, %	0.10[G]	0.10[G]	0.10[G]	0.10[D]	0.10[E]
For high sulfate exposure after 6 months exposure, max, %	0.05[G]	0.05[G]	0.05[G]	0.05[D]	0.05[E]
For very high sulfate exposure after 12 months exposure, max, %	...	...	...	...	0.05[D]
Procedure B:					
Expansion of test mixture as a percentage of sulfate resistance cement control after at least 6 months exposure, max,%[G]	100	100	100	...	...

[A] Determination of compliance or noncompliance with the requirement relating to increase in drying shrinkage will be made only at the request of the purchaser. Test method in accordance with Test Methods C311/C311M.

[B] Test in accordance with Test Methods C311/C311M or Specification C1240 as appropriate.

[C] Blended supplementary cementitious materials meeting this requirement are considered as effective in controlling alkali aggregate reactions as the use of the low-alkali control cement used in the evaluation. However, the blended supplementary cementitious material shall be considered effective only when used at percentages by mass of the total cementitious material equal to or exceeding that used in the tests and when the alkali content of the cement to be used does not exceed that used in the tests by more than 0.05 %. See Appendix XI, Test Methods C311/C311M. Test method in accordance with Test Methods C311/C311M.

[D] Refer to the Appendix of Specification C989/C989M.

[E] As delineated in Specification C1240.

[F] Only one limit shall be specified.

[G] Blended supplementary cementitious materials shall be considered effective only when the blended supplementary cementitious material is used at percentages, by mass, of the total cementitious material within 2 % of those that are successful in the test mixtures or between two percentages that are successful, and when the C_3A content of the project cement is less than, or equal to, that which was used in the test mixtures. See Appendix X2 of Test Methods C311/C311M. Test method in accordance with Test Methods C311/C311M.

11.2 Inspection of the material shall be made as agreed upon by the purchaser and the seller as part of the purchase contract.

12. Rejection and Rehearing

12.1 The purchaser has the right to reject material that fails to conform to the requirements of this specification. Rejection shall be reported to the manufacturer or supplier promptly and in writing. In case of dissatisfaction with the results of the tests, the manufacturer or supplier is not prohibited from making a claim for retesting.

13. 13. Certification

13.1 Upon request, the purchaser shall be furnished certification that all material has been tested as directed in this specification and the specified requirements have been met.

13.1.1 When requested by the purchaser or when specified in the purchase order or contract, a report of individual constituents including source and specification compliance shall be furnished.

13.1.2 When requested by the purchaser or when specified in the purchase order or contract, a report of the blended supplementary cementitious material test results, including chemical composition and physical properties shall be furnished.

14. Packaging and Package Marking

14.1 When blended supplementary cementitious material is delivered in packages, the composition of the blend using the naming practice in 4.2, the name and brand of the manufacturer, and the mass contained therein shall be plainly marked on each package. Similar information shall be provided in the shipping invoices accompanying the shipment of bulk blended supplementary cementitious material.

15. Keywords

15.1 blend; fly ash; pozzolan; silica fume; slag cement; supplementary cementitious material

TABLE 3 Physical Requirements

	Blend Type				
	N	F	C	S	SF
% retained when wet sieved on 45-μm (No. 325) sieve[A]	Report only	Report only	Report only	Report only	Report only
Activity Index, min, % of control[B]					
7 day Index	75[C]	75[C]	75[C]	Report only	105
28 day Index	75[C]	75[C]	75[C]	75[D]	...
Water Requirement, % of control[E]	Report only	Report only	Report only	Report only	...
Autoclave, expansion or contraction, max, %[F]	0.8	0.8	0.8	...	...

[A]Refer to Test Methods C311/C311M.
[B]The activity index with portland cement is not to be considered a measure of the compressive strength of concrete containing the pozzolan or slag. The tests are conducted as follows - for N, F, C refer to Specification C618; for S refer to Specification C989/C989M; for SF refer to Specification C1240.
[C] Meeting the 7 day or 28 day activity index will indicate specification compliance.
[D]Requirement is for the average of last 5 consecutive samples; no individual sample shall be more than 5 % less than the average requirement.
[E]Refer to test method in Test Methods C311/C311M. Refer to the applicable activity index procedure for determining the water requirement of the test mixture compared with the control.
[F]In accordance with Test Method C151/C151M, except the specimens shall be molded from a paste composed of 25 parts by mass of blended supplementary cementitious material and 100 parts by mass of a portland cement conforming to Specification C150/C150M.

APPENDIX

(Nonmandatory Information)

X1. VERIFYING BLEND PROPORTIONS

X1.1 This Appendix provides information for purchasers of blended supplementary cementitious materials about typical methods that manufacturers use to control the blend production process and verify product conformance.

X1.2 Mechanical methods, such as weighing individual constituents as each goes to the blending system are adequate to provide production control but chemical analysis as described below is required by this specification for verifying actual blend proportions:

X1.2.1 Ensure weighfeeders are maintained and calibrated before production. Weigh feeders are to provide for general control and adjustment during production.

X1.2.2 Ensure that the analysis method, X-ray fluorescence (XRF) or other qualified method is calibrated within the ranges of materials being tested.

X1.2.3 Sample and chemically analyze individual constituents before production begins and at established frequencies during production.

X1.2.4 Sample and chemically analyze finished blended supplementary cementitious materials at established frequencies during production runs for quality control purposes and verification of blend proportions.

X1.2.5 Proportion analysis, as used here, is a calculation using the chemical analysis of the individual constituents and the resultant blend.

X1.2.5.1 The individual constituents are analyzed and predominant elements are chosen as chemical identifiers.

X1.2.5.2 Those chosen identifiers are then used to calculate the mass % of constituents in the blended supplementary cementitious material.

An example of this calculation follows. This is a basic example for illustrative purposes using one element. A more detailed analysis using multiple elements can be performed using a spreadsheet program such as EXCEL Solver.

Target: A blended supplementary cementitious material with 10 % silica fume and 90 % slag cement.

Individual constituent analysis: Silica Fume with 90 % SiO_2 and Slag cement with 30 % SiO_2

Finished product analysis: 36 % SiO_2

Calculation:

$$(10\,\%\ Silica\ Fume \cdot 90\,\%\ SiO_2) + (90\,\%\ Slag\ cement \cdot 30\,\%\ SiO_2) = 36\,\%\ SiO_2$$

Evaluation: The proportions of the constituents, mass %, are as targeted (10 % Silica fume / 90 % slag cement) because the finished product SiO_2 equals the calculated SiO_2 at the targeted blend ratio.

Additional analysis to determine if the proportions are within allowable tolerances is shown below:

Target: A blended supplementary cementitious material with 10 % silica fume and 90 % slag cement.

Allowable tolerance of silica fume = ± 1 %

Calculation using the same constituent analysis as above:

$$(9\,\%\ Silica\ Fume \cdot 90\,\%\ SiO_2) + (91\,\%\ Slag\ cement \cdot 30\,\%\ SiO_2) = 35.4\,\%\ SiO_2$$

$$(11\,\%\ Silica\ Fume \cdot 90\,\%\ SiO_2) + (89\,\%\ Slag\ cement \cdot 30\,\%\ SiO_2) = 36.6\,\%\ SiO_2$$

Evaluation: The blend proportions would be within allowable tolerances if the SiO_2 of the blend is between 35.4 % and 36.6 %

X1.2.6 During manufacturing, feeder adjustments would be made as necessary to achieve the targeted proportions. However, it is normal to apply “Statistical Process Control” rules to the proportion results in order to prevent unnecessary reactions to normal process variation.

X1.2.7 Proportion analysis with other equipment such as colorimeter or induction furnace sulfur analyzers can be used

for quality control during production but should not be used for "Manufacturers Certification" unless they are qualified to Test Methods C114.