# Designation: C1709 – 11

# Standard Guide for Evaluation of Alternative Supplementary Cementitious Materials (ASCM) for Use in Concrete[1]

This standard is issued under the fixed designation C1709; 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 Guide is intended to provide a technical approach to the evaluation of alternative supplementary cementitious materials such as pozzolans and hydraulic materials that fall outside the scope of Specifications C618, C989, and C1240. This Guide provides the initial steps for a comprehensive evaluation of an ASCM that provides due diligence for its specific intended uses in concrete; however, it does not evaluate conformance to all possible performance criteria for all types of concrete mixtures.

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

1.3 Performing the tests or meeting the test limits in this guide should not imply that the material tested meets the requirements of Specifications C618, C989, and C1240. These materials should not be represented as such and each specific source is to be evaluated separately.

1.4 *This guide does not purport to address all environmental and safety concerns, if any, associated with its use. It is the responsibility of the user of this guide to establish the appropriate environmental, health, and safety issues, and identify appropriate risk management procedures.*

## 2. Referenced Documents

2.1 *ASTM Standards:*[2]

C39/C39M Test Method for Compressive Strength of Cylindrical Concrete Specimens

C78 Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)

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

C138/C138M Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete

C143/C143M Test Method for Slump of Hydraulic-Cement Concrete

C157/C157M Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete

C186 Test Method for Heat of Hydration of Hydraulic Cement

C204 Test Methods for Fineness of Hydraulic Cement by Air-Permeability Apparatus

C231/C231M Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method

C232/C232M Test Method for Bleeding of Concrete

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

C403/C403M Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance

C430 Test Method for Fineness of Hydraulic Cement by the 45-μm (No. 325) Sieve

C457/C457M Test Method for Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete

C469 Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression

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

C666/C666M Test Method for Resistance of Concrete to Rapid Freezing and Thawing

C672/C672M Test Method for Scaling Resistance of Concrete Surfaces Exposed to Deicing Chemicals

C989 Specification for Slag Cement for Use in Concrete and Mortars

C1012/C1012M Test Method for Length Change of Hydraulic-Cement Mortars Exposed to a Sulfate Solution

C1064/C1064M Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete

C1202 Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration

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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.

C1218/C1218M Test Method for Water-Soluble Chloride in Mortar and Concrete
C1240 Specification for Silica Fume Used in Cementitious Mixtures
C1293 Test Method for Determination of Length Change of Concrete Due to Alkali-Silica Reaction
C1543 Test Method for Determining the Penetration of Chloride Ion into Concrete by Ponding
C1556 Test Method for Determining the Apparent Chloride Diffusion Coefficient of Cementitious Mixtures by Bulk Diffusion
C1567 Test Method for Determining the Potential Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregate (Accelerated Mortar-Bar Method)
C1585 Test Method for Measurement of Rate of Absorption of Water by Hydraulic-Cement Concretes
C1679 Practice for Measuring Hydration Kinetics of Hydraulic Cementitious Mixtures Using Isothermal Calorimetry
C1702 Test Method for Measurement of Heat of Hydration of Hydraulic Cementitious Materials Using Isothermal Conduction Calorimetry
D3987 Practice for Shake Extraction of Solid Waste with Water
D4326 Test Method for Major and Minor Elements in Coal and Coke Ash By X-Ray Fluorescence

2.2 *ACI Standards:*[3]

ACI 211.1 Standard Practice for Selecting Proportions for Normal, Heavyweight and Mass Concrete
ACI 318 Building Code Requirements for Structural Concrete and Commentary

## 3. Terminology

3.1 *Definitions:*

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

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *alternative supplementary cementitious materials (ASCM), n*—inorganic materials that react pozzolanically or hydraulically, and beneficially contribute to the strength, durability, workability, or other characteristics of concrete, and does not meet Specifications C618, C989, and C1240.

3.2.2 *supplementary cementitious materials (SCM), n*—a slag cement or pozzolan that contributes to the properties of concrete or mortar through hydraulic or pozzolanic activity or both; and meets one of the following: Specification C618, C989, or C1240.

## 4. Significance and Use

4.1 Common types of SCM include fly ash, slag cement, calcined clays, and silica fume. The introduction and widespread use of fly ash, slag cement, calcined clay, and silica fume have been characterized and supported by significant research and development programs, preconstruction testing, field testing and long term performance monitoring. As the technical and economic benefits of SCM have been recognized, and as sustainability and environmental awareness resulted in the need to develop new materials and new ways to use materials not previously utilized, new sources of potential SCM are being proposed for use in concrete as ASCM.

4.2 If an ASCM does not yet have a significant record of performance in concrete, a comprehensive evaluation based on this Guide should be undertaken, and it should be recognized that this ASCM might be introduced for a specific project or into a limited marketplace to initially demonstrate its performance. The user should bear in mind the intended end use of the ASCM and use appropriate test methods to establish its suitability. An ASCM that demonstrates good performance through a comprehensive evaluation as outlined in this guide could then be considered to have access to broader markets and could be considered for inclusion in an ASTM standard for SCM. For this reason, the test program to demonstrate acceptable performance should include concrete mixtures with a range of characteristics specific to the ASCM's intended use.

4.3 In the absence of long-term durability or acceptable field performance, prospective users are advised to apply appropriate risk management and engineering practice in the use of an ASCM.

## 5. Evaluation Program

5.1 *Classification of Materials*—The performance of the evaluated ASCM should be compared to that of one of the existing types of SCM as listed in 1.1. The ASCM should not be classified as being a variant of, or equivalent to, an existing type of SCM. The material should be described as an "alternative supplementary cementitious material (ASCM)." The process that is responsible for generating the ASCM should be indicated on any reports such that any significant variations in that process would be noted when it occurs.

5.2 *Evaluation of the Material:*

5.2.1 *General*—Evaluate the ASCM in a comprehensive laboratory test program followed by field trials. A sample of the ASCM used for this evaluation should be representative of its source. A phased program suitable for many types of ASCMs is as follows:

Stage I—Characterization of the Material
Stage II—Determination of Suitable Fineness
Stage III—Testing to Specification C618, C989, or C1240
Stage IV—Concrete Performance Tests
Stage V—Field Trials and Long-Term Performance and Durability

5.2.2 *Stage I:* Characterization of the Material—Conduct a chemical analysis of the material. The chemical analysis should include the quantity of major, minor, and trace element constituents using any relevant method including x-ray fluorescence, atomic absorption spectroscopy, inductively coupled plasma spectroscopy, and any appropriate standard methods in Test Methods C114, C311, and D4326. When interpreting the data, consideration should be given to the potential for the compounds present to be injurious to the hydration of cement or properties of the concrete. If such compounds are present, then suitable tests should be conducted

[3] Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333-9094, http://www.concrete.org.

to determine the "availability" of these compounds to participate in hydration reactions.

5.2.3 *Stage II:* Determination of Suitable Fineness—If the production process of the ASCM includes size classification or crushing and grinding, guidance for the selection of the suitable fineness can be obtained from compressive strength, durability, and workability tests on mortar made with ASCM and hydraulic cement. It can be expected that for most ASCMs, fineness will play a major role in the level of performance of the ASCM in concrete. The appropriate fineness for the desired property should be selected by the manufacturer.

Useful data will be obtained from the testing of several levels of fineness or specific surface area, and several different particle size distributions of the ASCM. Fineness and specific surface area can be measured using the appropriate test methods in Test Methods C311, C204, and C430, or gas absorption BET (Brunauer, Emmett and Teller) technique for specific surface area. Particle size distribution can be measured by laser diffraction particle size analyzer; or other appropriate test methods.

Mortar tests should comply with Test Method C109/C109M. The test program should include a control portland cement mortar mixture for comparison with a similar test mixture made with an ASCM at the typical proposed replacement level. Compressive strength tests should be made at 1, 3, 7, and 28 days, and may include other appropriate long-term test ages.

5.2.4 *Stage III:* The ASCM should be tested for comparison with the chemical, physical, and uniformity requirements of Specification C618 (including the supplemental optional physical requirements), C989, or C1240. In addition, determine and report the following:

*(1)* Chlorides (Test Method C1218/C1218M)

*(2)* Free calcium oxide (Test Methods C114, Section 28)

*(3)* Soluble alkalis (Test Method C114)

*(4)* Leachable heavy metals (Test Method D3987)

*(5)* Air void stability—For ASCM similar to fly ash, the stability of the air bubbles formed during mixing a paste suspension may be an indication of the air void stability in concrete made with the same materials. In this test, 60 mL of distilled water is placed in a 250 mL wide-mouth glass jar. Then, 30 g of ASCM is added to the water. The jar is capped and vigorously shaken for 15 s. A measured quantity of air-entraining admixture is then added, and the jar is shaken for an additional 15 s. The jar is then placed upright for 30 s, and then the cap is removed. If the foam is breaking rapidly or if voids appear on the water mixture surface after 30 s, add more air-entraining admixture, and repeat the shaking and observation procedure. Continue to incrementally add air entraining admixture until the foam is stable for 30 s, and then shake the mixture for an additional 15 s. The foam is in a stable state when the foam is not breaking rapidly and no voids in the foam appear on the water mixture surface for at least 60 s. Measure and report on the quantity of air-entraining admixture required to maintain the foam in a stable state and the amount of time that the foam remained in a stable state.

5.2.5 *Stage IV:* Concrete Performance Tests

5.2.5.1 *General*—A series of mixtures should be tested. The performance of the ASCM in fresh and hardened concrete should be evaluated in a broad range of concrete mixtures to reflect the intended use of the material. The test program should include at least one commercially available SCM conforming to an applicable standard similar to the ASCM, commonly used admixtures and control mixtures without the ACSM.

5.2.5.2 *Concrete Mixture Proportions*—A series of mixtures should be proportioned with total cementitious materials content varying from 200 to 400 kg/m$^3$. Concrete tested for resistance to freezing and thawing is to have an air content and water-cementitious material ratio in accordance with ACI 318 that is appropriate for the expected exposures. The ASCM should be tested at various replacement levels that include a mixture with a high replacement level. The test program should include mixtures with various types of commonly used chemical admixtures to determine compatibility. Mortar of the proposed mixtures can be screened for compatibility using Test Method C1679. Commonly used chemical admixtures include air entraining agents, water reducers, setting time accelerators and setting time retarders. The test report should include information on the mixture proportions, water-cementitious material ratio, yield, density and source of materials.

5.2.5.3 *Fresh Concrete Testing*—The following tests should be performed to evaluate the effects of the ASCM on the properties of freshly mixed concrete:

*(1)* slump, air content, and temperature (Test Method C143/C143M, C231/C231M and C1064/C1064M)

*(2)* time of setting (Test Method C403/C403M)

*(3)* fresh density (Test Method C138/C138M)

*(4)* bleeding (Test Method C232/C232M)

5.2.5.4 *Hardened Concrete and Mortar Testing*—The following tests should be performed to evaluate the effects of the ASCM on the properties of the hardened concrete:

*(1)* compressive strength (Test Method C39/C39M) at 1, 3, 7, 28, 90 days, and 1 year

*(2)* flexural strength (Test Method C78) at 28 days

*(3)* length change (drying shrinkage) (Test Method C157/C157M)

*(4)* air void system parameters (Test Method C457/C457M)

*(5)* modulus of elasticity (Test Method C469)

*(6)* sulfate resistance (Test Method C1012/C1012M)

*(7)* length change of mortar bars due to ASR (Test Method C1567 or C1293) with an aggregate known to be susceptible to ASR

5.2.5.5 *Other Tests Pertinent and Specific to Use*—5.2.5.2-5.2.5.4 outline a test program using concrete mixtures that reflect the proportions and properties of concrete produced for general use. Concrete is also produced to meet specialized needs, including high strength, low permeability, low heat of hydration, resistance to freezing and thawing, and resistance to surface scaling in concrete exposed to cycles of freezing and thawing in the presence of de-icing chemicals. When the ASCM will be used in concrete with properties to resist exposure to specific environmental conditions, additional testing is required. Such testing may involve proportioning of the concrete mixture using higher or lower contents of the ASCM compared with the replacement level proposed for most concrete applications. The additional testing to meet specialized needs will depend on the proposed use of the ASCM. The following tests may be applicable:

*(1)* resistance to rapid freezing and thawing (Test Method C666/C666M)

*(2)* scaling resistance of concrete surfaces (Test Method C672/C672M)

*(3)* heat of hydration (Test Method C186 or C1702)

*(4)* resistance to fluid penetration (Test Method C1202, C1585, C1543, or C1556)

5.2.6 *Stage V:* Field Trials and Long-Term Performance and Durability

5.2.6.1 *General*—Concrete construction field trials using the ASCM should normally be carried out when acceptable performance has been demonstrated in the laboratory tests. The use of an ASCM on a project should be approved by the engineer of record and noted in the project specifications.

5.2.6.2 At least three field evaluations, each of at least one year in duration should be performed (these field evaluations may run concurrently). The short term and long term evaluations should be relevant to the intended use, and provide:

*(1)* observations on the effect of the ASCM on the finishing characteristics of the concrete

*(2)* variations of the properties of the fresh concrete, including slump, air content, and time of setting

*(3)* compatibility with chemical admixtures

*(4)* confirmation of the performance characteristics, including strength and durability parameters

*(5)* evaluation of exposed concrete in a challenging environment specific to the ASCM's intended usage, for example, freeze-thaw cycles in the presence of de-icing chemicals at an installation suitable for such performance monitoring.

5.2.6.3 Long term field performance and durability evaluations (such as ASR, sulfate resistance, resistance to freezing and thawing) should be relevant to the intended use. Until an evaluation period of acceptable performance and durability has been completed, inform the end-users that the ASCM is in a durability evaluation stage. Reports of field performance should be available to end-users and updated when there are significant changes in the field performance.

5.3 *Sampling and Testing*—After commercial production of the ASCM commences, the producer should follow the sampling and testing procedures for the existing SCM covered by Specification C618, C989, or C1240 that most resemble the ASCM, and establish a procedure to perform the sampling and testing at a greater frequency for the initial 6 months of continuous operations to determine uniformity.

## 6. Keywords

6.1 alternative supplementary cementitious materials; ASCM; chemical admixtures; concrete; fly ash; pozzolans; SCM; silica fume; slag cement; supplementary cementitious material