Designation: C1928/C1928M – 23

Standard Test Method for Compressive Strength of Alkali Activated Cementitious Material Mortars (Using 2-in. [50 mm] Cube Specimens)[1]

This standard is issued under the fixed designation C1928/C1928M; 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 test method covers determination of the compressive strength of alkali activated cementitious material mortars, using 2-in. [50 mm] cube specimens.

1.2 This test method references notes and footnotes that provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the test method.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. 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. If required results obtained from another standard are not reported in the same system of units as used by this standard, it is permitted to convert those results using the conversion factors found in the SI Quick Reference Guide.

1.4 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.* (**Warning—***Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.*[2])

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

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)

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

C219 Terminology Relating to Hydraulic and Other Inorganic Cements

C230/C230M Specification for Flow Table for Use in Tests of Hydraulic Cement

C305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency

C511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes

C778 Specification for Standard Sand

C1005 Specification for Reference Masses and Devices for Determining Mass and Volume for Use in Physical Testing of Hydraulic Cements

C1433 Specification for Precast Reinforced Concrete Monolithic Box Sections for Culverts, Storm Drains, and Sewers

C1437 Test Method for Flow of Hydraulic Cement Mortar

2.2 *IEEE/ASTM:*[4]

SI 10 American National Standard for Metric Practice

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in this test method, refer to Terminology C219.

3.2 *Definitions of Terms Specific to This Standard:*

[1] This test method is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.14 on Non-hydraulic Cements.

Current edition approved Feb. 15, 2023. Published May 2023. DOI: 10.1520/C1928_C1928M-23.

[2] See the section on Safety, Manual of Cement Testing, Annual Book of ASTM Standards, Vol 04.01.

[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.

[4] Available from Institute of Electrical and Electronics Engineers, Inc. (IEEE), 445 Hoes Ln., Piscataway, NJ 08854-4141, http://www.ieee.org.

3.2.1 *AACM precursor, n*—substance consisting of one or more finely divided solids as the major constituent containing both alumina and silica that will react and harden when mixed with an alkali activator.

3.2.2 *alkali activator, n*—source of cations of sodium or potassium or both and, in some cases, magnesium or calcium or a combination thereof, as major constituents that, when incorporated in aqueous or solid form, induces reaction, setting, and hardening of an AACM.

3.2.2.1 *Discussion*—Common examples of alkali activators include hydroxides, silicates, aluminates, and sulfates of sodium or potassium.

3.2.3 *alkali-activated cementitious material (AACM), n*—substance consisting of an inorganic precursor or blend of such precursors that, when combined with an alkali activator, and with water as the reaction medium, reacts to produce a hardened monolithic material.

3.2.3.1 *Discussion*—An alkali-activated cementitious material may also be known as an alkali-activated cementitious binder. Some AACMs are also known as geopolymer cements.

3.2.4 *binder solids, n*—part of an AACM consisting of all solids and dissolved solids.

3.2.4.1 *Discussion*—Calculated by subtraction of the water content from the overall mass of the AACM.

3.2.5 *major constituent, n*—powder, usually aluminosilicate, which is present in an AACM in a proportion exceeding 5 % by mass of the total material, and which is not the alkali activator.

3.2.5.1 *Discussion*—An AACM may contain more than one major constituent.

3.2.6 *manufacturer, n*—the producer that assembles the AACM from a range of raw ingredients.

3.2.7 *mixing protocol, n*—process for combining the AACM precursor, alkali activator, aggregate, admixture and water as defined by the manufacturer.

3.2.8 *mixing water, n*—amount of water added during the mixing of AACM.

3.2.8.1 *Discussion*—Mixing water does not include water which is provided as part of the alkaline activator or as part of an admixture, if these are added as aqueous solutions.

3.2.9 *total water content, n*—amount of added mixing water plus water in the liquid activators and as admixtures.

4. Summary of Test Method

4.1 The mortar consists of AACM precursor material, AACM alkali activator, sand, and water. The ratio of binder solids to sand is 1 to 2.75 proportioned by mass. The mixing protocol shall be applied according to the recommendations of the manufacturer of the AACM. Water content is that sufficient to obtain a flow of 110 % ± 5 % in 25 drops of the flow table. 2-in. [50 mm] test cubes are compacted by tamping in two layers. The cubes are cured according to the guidance of the manufacturer either at 23.0 °C ± 2 °C or at 60 °C ± 2 °C until tested. In the case of fast setting mortars, sufficient dose of a retarding admixture, as recommended by the manufacturer, may be added to obtain a set time of 90 min ± 30 min.

5. Significance and Use

5.1 This test method provides a means of determining the compressive strength of alkali-activated cementitious material mortars and results may be used to determine compliance with specifications.

6. Apparatus

6.1 Weights and weighing devices shall meet the requirements of Specification C1005. The weighing device shall be evaluated for precision and bias at a total load of 2000 g.

6.2 *Glass Graduates,* shall conform to the requirements of Test Method C109/C109M.

6.3 *Specimen Molds,* shall meet the requirements and conform to the tolerances stated in Test Method C109/C109M.

6.4 *Mixer, Bowl and Paddle,* with planetary and revolving motion shall conform to the requirements stated in Practice C305.

6.5 *Flow Table and Flow Mold,* shall conform to Specification C230/C230M.

6.6 *Tamper and Trowel,* conforming to Test Method C109/C109M.

6.7 *Testing Machine,* shall meet the requirements and conform to the tolerances of Test Method C109/C109M.

6.8 *Oven,* of sufficient size, capable of maintaining a uniform temperature of 140 °F ± 5 °F [60 °C ± 2 °C].

6.9 *Moist Cabinet or Room,* conforming to the requirements of Specification C511.

7. Materials

7.1 AACM Precursor.

7.2 Alkali activator.

7.3 Graded Standard Sand:

7.3.1 The sand used for making test specimens shall be natural silica sand conforming to the requirements for graded standard sand in Specification C778.

NOTE 1—*Segregation of Graded Sand*—The graded standard sand should be handled in such a manner as to prevent segregation, since variations in the grading of the sand cause variations in the consistency of the mortar. In emptying bins or sacks, care should be exercised to prevent the formation of mounds of sand or craters in the sand, down the slopes of which the coarser particles will roll. Bins should be of sufficient size to permit these precautions. Devices for drawing the sand from bins by gravity should not be used.

8. Temperature and Humidity

8.1 *Temperature*—The temperature of the air in the vicinity of the mixing slab, the dry materials, molds, base plates, and mixing bowl, shall be maintained between 73.5 °F ± 5.5 °F [23.0 °C ± 3.0 °C]. The temperature of the mixing water, moist closet or moist room, and water in the storage tank shall be set at 73.5 °F ± 3.5 °F [23 °C ± 2 °C].

8.2 *Humidity*—The relative humidity of the laboratory shall be not less than 50 %. The moist closet or moist room shall conform to the requirements of Specification C511.

9. Test Specimens

9.1 Make three specimens from a batch of mortar for each period of test or test age.

10. Preparation of Specimen Molds

10.1 Prepare molds in accordance to Test Method C109/C109M, ensuring that the mold release agent selected is compatible with the AACM mortars to be tested.

11. Procedure

11.1 *Composition of Mortars:*

11.1.1 The composition of the standard mortar shall be one part of precursor solids to 2.75 parts of graded sand, by mass, the manufacturer's recommended dosage of alkali activator, and enough water to reach a flow of 110 % ± 5 % determined in accordance with Test Method C1433. Record and report the quantity, brand and type of any chemical admixtures used preparing the mortar.

NOTE 2—Fast setting precursor materials—including some Class C fly ashes and some blends incorporating slag cement—may produce fast setting mortars. Chemical admixture (retarder/set control) may be added to fast setting mortars to control the set time.

NOTE 3—The alkali activator may be introduced to the system as a solid powder blended with the major constituents in the dry state, or pre-dissolved in an aqueous solution, or both.

11.1.2 The proportions for a batch of mortar for making six specimens shall be as follows:

Precursor material, g	500
Sand, g	1375
Alkali Activator	per manufacturer's recommendation
Water, g (to flow of 110 + 5, %)	...

11.2 *Preparation of Mortar:*

11.2.1 Mechanically mix in accordance with the mixing protocol recommended by the manufacturer of the AACM.

11.3 *Determination of Flow:*

11.3.1 Determine flow in accordance with the procedure given in Test Method C1437.

11.3.2 When trial mortars with varying percentages of water are made to obtain the specified flow, each trial shall be made with fresh materials.

11.3.3 Immediately following completion of the flow test, return the mortar from the flow table to the mixing bowl. Quickly scrape the bowl sides and transfer into the batch the mortar that may have collected on the side of the bowl and then remix the entire batch 15 s at medium speed. Upon completion of mixing, the mixing paddle shall be shaken to remove excess mortar into the mixing bowl.

11.3.4 When a duplicate batch is made immediately for additional specimens, a flow test is not required, and the mortar shall stand in the mixing bowl a maximum of 90 s without covering. During the last 15 s of this interval, quickly scrape the bowl sides and transfer into the batch the mortar that may have collected on the side of the bowl. Remix for 15 s at medium speed.

11.4 *Molding Test Specimens:*

11.4.1 The mortar shall be consolidated in the molds by hand tamping following the procedure given in Test Method C109/C109M.

11.5 *Curing of Test Specimens:*

11.5.1 Curing is accomplished either at room temperature or using elevated temperatures, in accordance with the manufacturer's recommendations. Curing procedures to be used are defined in 11.5.2 and 11.5.3.

11.5.2 *Room Temperature Curing*—Immediately upon completion of molding, place the test specimens in a room maintained at a temperature of 73.5 °F ± 5.5 °F [23.0 °C ± 2.0 °C]. The specimens shall be kept in the molds for 24 h wrapped in polyethylene plastic film or tightly sealed plastic bag to avoid moisture loss, then removed from the molds and wrapped in polyethylene plastic film again until they reached the desired test age.

11.5.3 *Elevated Temperature Curing*—Immediately upon completion of molding, place the test specimens in an oven at a temperature of 140 °F ± 5 °F [60 °C ± 2 °C]. The specimens shall be kept in the molds and wrapped in plastic film until they reached the desired curing age.

12. Testing Time

12.1 The age of the specimens is to be determined from the time when the AACM precursor contacts an alkali activator and the mixing water.

12.2 Specimens to be tested at 1½ h , 3 h, and 6 h shall be removed from the molds a maximum of 10 min prior to time of test. After the specimens are removed from the molds, keep them covered with a damp towel until time to be tested. The cubes must be tested within 10 min of the time specified.

12.3 All other specimens shall be removed from the molds at 22 h ± 2 h. If the specimens are removed from the molds before 24 h, keep them on the shelves of the moist closet or moist room until they are 24 h old, and then immerse the specimens, except for the 24-h test, in saturated limewater for storage.

12.4 The 24-h, 7-d, and 28-d test specimens shall be broken within the permissible time tolerances prescribed in Test Method C109/C109M.

12.4.1 For elevated temperature curing, remove the test specimens from the oven at the desired test age and allow them to cool down for 2 h ± 0.5 h at a temperature of 23 °C ± 2 °C before testing.

13. Determination of Compressive Strength

13.1 Determine compressive strength using Test Method C109/C109M as modified herein.

13.2 Record and calculate the compressive strength in accordance with the Calculation section of Test Method C109/C109M.

13.3 Apply the sampling and testing requirements of Practice C183/C183M.

13.4 Apply the load to the specimen according to the procedure given in Test Method C109/C109M.

14. Calculation

14.1 Record the total maximum load indicated by the testing machine, and calculate the compressive strength as follows: