Designation: C 1012 – 03

Standard Test Method for Length Change of Hydraulic-Cement Mortars Exposed to a Sulfate Solution[1]

This standard is issued under the fixed designation C 1012; 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 the determination of length change of mortar bars immersed in a sulfate solution. Mortar bars made using mortar described in Test Method C 109/C 109M are cured until they attain a compressive strength of 20.0 ± 1.0 MPa (3000 ± 150 psi), as measured using cubes made of the same mortar, before the bars are immersed.

1.2 The values stated in SI units are to be regarded as the standard. The values shown in parentheses are for information purposes only.

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:*

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

C 114 Test Method for Chemical Analysis of Hydraulic Cement[2]

C 150 Specification for Portland Cement[3]

C 157/C 157M Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete[3]

C 215 Test Method for Fundamental Transverse, Longitudinal, and Torsional Frequencies of Concrete Specimens[3]

C 305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency[2]

C 348 Test Method for Flexural Strength of Hydraulic Cement Mortars[2]

C 349 Test Method for Compressive Strength of Hydraulic Cement Mortars (Using Portions of Prisms Broken in Flexure)[2]

C 452 Test Method for Potential Expansion of Portland-Cement Mortars Exposed to Sulfate[2]

C 490 Practice for Use of Apparatus for the Determination of Length Change of Hardened Cement Paste, Mortar, and Concrete[2]

C 511 Standard Specification for Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes[2]

C 595 Specification for Blended Hydraulic Cements[2]

C 597 Test Method for Pulse Velocity Through Concrete[3]

C 618 Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Concrete[3]

C 684 Test Method for Making, Accelerated Curing, and Testing of Concrete Compression Test Specimens[3]

C 778 Specification for Standard Sand[2]

C 917 Test Method for Evaluation of Cement Strength Uniformity From a Single Source[2]

C 989 Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars[3]

D 1193 Specification for Reagent Water[4]

E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials[5]

3. Significance and Use

3.1 This test method provides a means of assessing the sulfate resistance of mortars made using portland cement, blends of portland cement with pozzolans or slags, and blended hydraulic cements. Method C 452 is suitable for evaluating portland cements but not blended cements or blends of portland cement with pozzolans or slags.

3.2 The standard exposure solution used in this test method, unless otherwise directed, contains 352 moles of Na_2SO_4 per m^3(50 g/L). Other sulfate concentrations or other sulfates such as $MgSO_4$ may be used to simulate the environmental exposure of interest. Further discussion of these and other technical issues is given in the Appendix.

4. Apparatus

4.1 *Mixer*, conforming to the requirements of Practice C 305.

[1] This test method is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.29 on Sulfate Resistance.

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[2] *Annual Book of ASTM Standards*, Vol 04.01.

[3] *Annual Book of ASTM Standards*, Vol 04.02.

[4] *Annual Book of ASTM Standards*, Vol 11.01.

[5] *Annual Book of ASTM Standards*, Vol 03.01.

4.2 *Cube Molds*, conforming to the requirements of Test Method C 109/C 109M.

4.3 *Bar Molds*, conforming to the requirements of Specification C 490.

4.4 *Comparator*, conforming to the requirements of Specification C 490.

4.5 *Containers*—The containers in which the bars are immersed shall be corrosion resistent such as plastic, glass, or ceramic. Support the bars so that no end or side of a bar rests against the container. Seal the container with a lid so that the sulfate solution cannot evaporate.

4.6 *Curing Tank*, conforming to the requirements of Test Method C 684.

5. Reagents and Materials

5.1 *Purity of Reagents*—USP or technical grade chemicals may be used, provided it is established that any reagent used is of sufficiently high purity to permit its use without lessening the accuracy of the determination. When tests are made that are expected to produce results that are close to an acceptance-rejection value, it is recommended that reagent grade chemicals be used. Such chemicals shall conform to the specifications of the Committee on Analytical Reagents for the American Chemical Society where such specifications are available.[6]

5.2 *Purity of Water*—Unless otherwise indicated, references to water shall be understood to mean reagent water conforming to Type IV of Specification D 1193.

5.3 *Sodium Sulfate* (Na_2SO_4)—Check the water content by loss on ignition each time the solution is prepared. Any anhydrous or hydrated sodium sulfate may be used if the water content of the salt is checked by loss on ignition and proper corrections made to account for the specified sulfate concentration.

5.4 *Sulfate Solution*—Each litre of solution shall contain 50.0 g of Na_2SO_4 dissolved in 900 mL of water, and shall be diluted with additional distilled or deionized water to obtain 1.0 L of solution. Mix the solution on the day before use, cover, and store at 23.0 ± 2.0°C (73.5 ± 3.5°F). Determine the pH of the solution before use; reject the solution if the pH range is outside 6.0 to 8.0. Maintain the volume proportion of sulfate solution to mortar bars in a storage container at 4.0 ± 0.5 volumes of solution to 1 volume of mortar bars. For mortar bars 1 by 1 by 11¼ in. (volume of 184 mL or 11.25 $in.^3$), this is 645 to 830 mL of solution per mortar bar in the storage container. For mortar bars 25 by 25 by 285 mm (volume 178 mL), this is 625 to 800 mL of solution per mortar bar in the storage container.

5.5 *Materials*:

5.5.1 *Graded Standard Sand*, as specified in Specification C 778.

5.5.2 *Stainless Steel Gage Studs*, as specified in Specification C 490.

6. Hazards

6.1 **Warning—**Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.[7]

7. Preparing Mortars

7.1 Make mortars as described in Test Method C 109/C 109M, that is, 1 part cement to 2.75 parts of sand by mass. Use a water-cement ratio by mass of 0.485 for all non-air-entraining portland cements and 0.460 for all air-entraining portland cements. Use a water-cement ratio by mass of 0.485 for non-air-entraining portland-pozzolan (IP) and portland-blast furnace slag (IS) cements. For blends of portland cement with a pozzolan or slag, use a water-cement ratio that develops a flow within ±5 of that of the portland-cement mortar at a water-cement ratio of 0.485.

8. Specimen Molds

8.1 Prepare the specimen molds in accordance with the requirements of Specification C 490 except the interior surfaces of the mold shall be covered with a release agent. A release agent will be acceptable if it serves as a parting agent without affecting the setting of the cement and without leaving any residue that will inhibit the penetration of water into the specimen.

NOTE 1—TFE-fluorocarbon tape complies with the requirements for a mold release agent.

9. Procedure

9.1 *Molding and Initial Curing of Specimens*—Mold the test bars in accordance with Test Method C 157/C 157M. Mold the cubes in accordance with Test Method C 109/C 109M. A set of specimens to test one cement consists of 6 bars and up to 21 cubes (Note 2). Immediately after molding, cover the molds with a rigid steel, glass, or plastic plate, seal the plate to the mold so as to be watertight, and place the mold in the curing tank in water at 35 ± 3°C (95 ± 5°F) for 23½ h ± 30 min, as in Test Method C 684, Procedure A (Warm-Water Method). Place the sealed molds in the curing tank with the bottom of the bars as cast down, that is, in the same relative position in which the bars were cast. At 23½ h ± 30 min, remove molds from tank and demold the specimens.

NOTE 2—The set of cubes consists of 21 cubes to be tested as described herein when significant information on the strength development rate is not available. When information is available (as for example, from the use of the procedures of Test Method C 917) that would justify making fewer cubes, only those needed to confirm the time the mortar achieves 20.0 ± 1.0 MPa (3000 ± 150 psi) are needed.

9.2 *Subsequent Curing and Preparation for Test*—After demolding, store all bars and cubes, except the two to be broken, in a curing tank of saturated limewater at 23.0 ± 2.0°C (73.5 ± 3.5°F). Break two cubes in compression in accordance

[6] *Reagent Chemicals, American Chemical Society Specifications*, American Chemical Society, Washington, DC. For Suggestions on the testing of reagents not listed by the American Chemical Society, see *Annual Standards for Laboratory Chemicals*, BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopeia and National Formulary*, U.S. Pharmacopeial Convention, Inc. (USPC), Rockville, MD.

[7] See *Manual of Cement Testing*, Section on Safety, *Annual Book of ASTM Standards*, Vol 04.01.

with Test Method C 109/C 109M after demolding when the specimens have cooled to ambient temperature under moist cloths. If the mean strength of the two cubes is 20 MPa (2850 psi) or more, observe and record comparator readings in accordance with Specification C 490 and as prescribed in the section on Measurements of Length Change and place all the bars in the sulfate solution. If 20 MPa (2850 psi) is not achieved, store the demolded cubes and mortar bars in the curing tank and test additional cubes. Predict from the first two cubes when a compressive strength of at least 20 MPa (2850 psi) will be reached. Verify the prediction, and at that time observe and record comparator readings and place all the bars in the sulfate solution (Note 3). This measurement is designated as the initial length. The storage temperature and test temperature shall be 23.0 ± 2.0°C (73.5 ± 3.5°F).

NOTE 3—If the value for strength at 24 h is less than 20.0 MPa (2850 psi) and additional testing on the same day is not possible, or, is unlikely to yield a value over 20.0 MPa (2850 psi) and the strength is over 21 MPa (3150 psi) when tested early the next day, it is not necessary to remake the batch.

9.3 *Storage of Test Bars during Exposure to Test Solution*—Cover the container of the bars and test solution, and seal it to prevent evaporation from the inside, or dilution with water from the outside. (See Note 4.) The storage temperature and test temperature shall be 23.0 ± 2.0°C (73.5 ± 3.5°C). (See Note 5.)

NOTE 4—Gaffers tape or duct tape has been found to be suitable for sealing the container.

NOTE 5—This is the same temperature and temperature range as that specified for moist rooms in ASTM C 511.

9.4 *Measurements of Length Change*—At 1, 2, 3, 4, 8, 13, and 15 weeks after the bars are placed in the sulfate solution, test them for length change using the length comparator in accordance with Specification C 490. Review the data at 15 weeks. If slight, gradual, and uniform length change is taking place, make the next measurements at 4, 6, 9, and 12 months. When the expansion is changing rapidly at any period in the test, adjust the interval between readings so that it is short enough to permit observing and reporting the behavior of the bars.

9.4.1 *Details of Measurement of Bars for Length Change*:

9.4.1.1 Clean the hole in the base of the comparator into which the gage stud on the lower end of the bar fits (this hole tends to collect water and sand and should be cleaned after every reading). Read and record the comparator indication of the length of the reference bar. Take one bar out of immersion, blot the pins, put the bar in the comparator, read, and record the indication. Return the bar to immersion and clean the hole in the base of the comparator. Take out the second bar and treat it in a like manner. Return the second bar to immersion, record the reading, and clean the hole in the base of the comparator. Continue the procedure until all bars have been read, returned to immersion, and the readings recorded, cleaning the hole in the bottom of the comparator each time. After reading the last bar, clean the hole in the comparator base and read and record the reference-bar indication.

9.4.1.2 When, based on cube strength of mortar, the bars are initially ready to be stored in sulfate solution, or after they have been removed from sulfate solution storage for length change test, place them in storage in fresh sulfate solution of a known pH of 6-8. At subsequent readings for length change, proceed as described above; cleaning the socket in the base of the comparator before reading the reference bar initially and after reading each mortar bar. Record reference bar and mortar bar readings. Also, read the reference bar and record the reading after the last bar. Blot only around the pins (Note 6). After reading each bar return it to used solution. Prior to replacing the solution, rinse the container once with water, pouring out water and debris. Replace the frame holding the bars in the container, fill the container with new solution of known pH of 6-8 to immerse bars, and secure on the container lid.

NOTE 6—The purpose of the minimal blotting of the pins and no blotting of the bars is to avoid drying and shrinkage of the bars. It has been observed that if the pins are blotted, and the bar placed in the comparator and the dial read, and the bar is then wiped gently with a dry cloth, the bar will shrink measurably. Therefore, drying should be minimized.

9.4.2 *Examination of Specimens After Measuring Length Change*—When the bars seem to have behaved in an unusual way or when the test is part of a research study, test the specimens for warping by placing them on a plane surface so that the ends are curved down and the maximum bowing measured. Note cracking (presence, location, type); also note surface deposits, mottling, exudations (nature, thickness, type).

9.5 *Tolerance on Time*—All references to elapsed time in 9.4 are intended to have a tolerance of ±2 %.

TABLE 1 Maximum Permissible Range of Values

Remaining No. of Specimens	Blended Cements	Portland Cement
3	0.034	0.010
4	0.037	0.011
5	0.039	0.012
6	0.041	0.012

10. Calculation

10.1 Calculate the length change at any age as follows:

$$\Delta L = \frac{L_x - L_i}{Lg} \times 100 \quad (1)$$

where:

ΔL = change in length at *x* age, %,
L_x = comparator reading of specimen at *x* age—reference bar comparator reading at *x* age, and
L_i = initial comparator reading of specimen-reference bar comparator reading, at the same time
Lg = nominal gage length, or 250 mm (10 in.) as applicable. (See C 490).

10.2 Calculate length change values for each bar to the nearest 0.001 % and report averages to the nearest 0.01 %.

11. Report

11.1 Report type of cement, and, if blending material is used, its identification and amount and whether cement and blending material, if used, meet the applicable specifications. Report the initial comparator reading of each bar at the time of immersion in sulfate solution; this is the base value for