Designation: C1910/C1910M – 23

Standard Test Methods for Cements that Require Carbonation Curing[1]

This standard is issued under the fixed designation C1910/C1910M; 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 These test methods cover procedures for testing cements that require carbonation curing and are intended for use in concrete.

1.2 The procedures are organized in the following sections:

Casting and Carbonation Curing Test Specimens	Section 8
Compressive Strength	Section 9
Bound Carbon Dioxide	Section 10

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 nonconformance with this standard. Some values only have SI units because the inch-pound equivalents are not used in standard.

1.4 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, Annex A in Form and Style for ASTM Standards, www.astm.org/COMMIT/Blue_Book.pdf.

1.5 The text of this standard refers to 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 standard.

1.6 *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—**Common cementitious mixtures are caustic and may cause burns to skin and tissue upon prolonged exposure.[2]

1.7 *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)

C219 Terminology Relating to Hydraulic and Other Inorganic Cements

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

C778 Specification for Standard Sand

C1872 Test Method for Thermogravimetric Analysis of Hydraulic Cement

E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in these test methods, refer to Terminology C219.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *curing, carbonation, n*—action taken to maintain moisture, temperature, and carbon dioxide conditions in a freshly-placed cement mixture so the potential properties of the mixture that require carbonation reactions may develop.

3.2.1.1 *Discussion*—Carbonation curing requires a confined chamber and control of temperature and moisture conditions as well as carbon dioxide concentration in the chamber.

4. Significance and Use

4.1 These test methods are used to develop data for comparison with the requirements of Test Methods C1910/C1910M or other specifications for cements that require carbonation curing. These test methods are based on standardized testing in the laboratory and are not intended to simulate job conditions. All tests are performed with mortar and

[1] These test methods are under the jurisdiction of ASTM Committee C01 on Cement and are the direct responsibility of Subcommittee C01.14 on Non-hydraulic Cements.

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[2] Section on Safety Precautions, Manual of Aggregate and Concrete Testing, Annual Book of ASTM Standards, Vol. 04.02.

[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.

therefore, the results may not provide a direct correlation of how the tested cementitious material will perform in concrete.

4.2 *Compressive Strength*—The test for compressive strength is used to determine whether the cement tested will develop a minimum level of strength when carbonated under laboratory conditions.

4.3 *Chemically Bound Carbon Dioxide*—Determined using mortar cube specimens prepared for determining compressive strength, the test for chemically bound carbon dioxide is used as an estimate of the mass of carbon dioxide bound during the carbonation curing process and is expressed as a percent of the mass of cement in the test mixture. The actual amount of carbon dioxide bound in a manufactured product is affected by the carbonation process and the cement used, and the physical characteristics of the manufactured product.

5. Materials

5.1 *Graded Standard Sand*—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—Follow precautions provided in Test Method C109/C109M to prevent segregation of the graded sand.

5.2 *Carbon Dioxide (CO_2) Gas,* commercial grade with a minimum purity of 95 % CO_2 by volume.

6. Apparatus

6.1 *Carbonation Curing Chamber,* shall be capable of maintaining a CO_2-rich curing environment using a CO_2 gas source with a purity of at least 95 %, supplied to the chamber at a gauge pressure of 35 kPa ± 15 kPa [5 psi ± 2 psi]. The chamber shall have a pressure relief valve and a manual venting valve. The curing chamber shall be capable of maintaining a chamber temperature of 80 °C ± 3 °C [175 °F ± 5 °F], and a relative humidity of 80 % ± 10 %.

NOTE 2—The source of water to maintain the required relative humidity may be contained in a shallow pan placed at the bottom of the carbonation curing chamber. The amount of water required will depend on the chamber design and excess water should remain in the pan after completion of curing.

6.1.1 Provisions shall be made to keep all test specimens protected from dripping water in the carbonation curing chamber. It may be necessary to use forced convection in the carbonation curing chamber to ensure a uniform temperature throughout.

6.1.2 The carbonation curing chamber shall have a wire rack to support the specimens above the bottom of the chamber or over the water pan when it is used and provide a minimum 10 mm [⅜ in.] gap between the specimens and the chamber bottom or water pan.

6.2 *Drying Oven*—The oven shall be capable of being heated continuously at 80 °C ± 3 °C [175 °F ± 5 °F] and the rate of evaporation, at this range of temperature, shall be at least 25 g/h for 4 h, during which period the doors of the oven shall be kept closed. This rate shall be determined by the loss of water from 1 L Griffin low-form beakers, each initially containing 500 g of water at a temperature of 21 °C ± 2 °C [70 °F ± 3 °F], placed at each corner and the center of each shelf of the oven. The evaporation requirement is to apply to all test locations when the oven is empty except for the beakers of water.

6.3 *Cube Molds*—The cube molds shall meet the requirements of Test Method C109/C109M.

6.4 *Thermogravimetric analyzer (TGA)*—The TGA analyzer shall meet the requirements of Test Method C1872.

6.5 *Drill Press,* capable of holding a 3.2 mm [⅛ in.] drill bit.

6.6 *Masonry Drill Bit,* 3.2 mm [⅛ in.] diameter.

6.7 *Sieve,* 150 µm [No. 100] as described in Specification E11.

6.8 *Mortar and Pestle.*

7. Preparing Test Mortars

7.1 *Proportions*—For all test methods covered in this standard, the proportions of the test mortar shall be 1 part cement to 2.75 parts sand by mass. The water to cement ratio shall be 0.485. Table 1 provides proportions for cube mortar mixtures.

7.2 *Mixing Mortar*—Mechanically mix mortar mixtures in accordance with the procedure in Practice C305.

8. Casting and Carbonation Curing Test Specimens

8.1 *Casting Cubes:*

8.1.1 Mold cubes in accordance with the procedure given in Test Method C109/C109M.

NOTE 3—Typically six (6) cubes are cast for testing strength. When chemically bound CO_2 measurements are made, an additional six (6) cubes are required.

8.2 *Drying:*

8.2.1 Without de-molding, place the prepared mortar cubes in the drying oven. The filled molds shall remain in the oven for 5 h ± 1 h.

8.2.2 After drying, de-mold the specimens.

NOTE 4—Use caution when de-molding the specimens as they are very fragile at this point in the testing process.

8.3 *Carbonation Curing:*

8.3.1 After de-molding, place specimens on the wire rack in the carbonation curing chamber with a minimum 10 mm [⅜ in.] gap between the specimens and the sides of the curing chamber.

8.3.2 After the carbonation curing chamber has been sealed, open the CO_2 supply valve and introduce CO_2 into the chamber. Open the manual vent valve on the carbonation curing chamber to allow the CO_2 to flow and purge the air from the chamber for 15 s ± 5 s. After purging the carbonation curing chamber, close the manual vent valve.

TABLE 1 Mortar Mixture Proportions

Number of Specimens	6	9	12
Cement, g	500	740	1060
Sand, g	1375	2035	2915
Water, mL	242	359	514

8.3.3 Adjust the carbonation curing chamber pressure to 35 kPa ± 15 kPa [5 psi ± 2 psi].

8.3.4 Allow specimens to cure for 72 h ± 2 h using a carbon dioxide purity of not less than 95 % with gauge pressure of 35 kPa ± 15 kPa [5 psi ± 2 psi], a curing temperature of 80 °C ± 3 °C [175 °F ± 5 °F], and a carbonation curing chamber relative humidity between 80 % ± 10 %.

8.3.5 After carbonation curing, remove the specimens from the chamber and place them in the drying oven. The specimens shall remain in the oven for 24 h ± 1 h.

9. Compressing Strength

9.1 Cast, carbonation cure, and dry the cube samples following Section 8.

9.2 After carbonation curing and final drying, the specimens should be allowed to reach laboratory temperature by allowing them to rest in a laboratory environment for 15 min to 30 min.

9.3 Determine the compressive strength of each specimen in accordance with Test Method C109/C109M. Record the compressive strength to the nearest 0.1 MPa [10 psi].

9.4 A single test result shall be the average of compressive strength of three individual cubes.

9.5 Report the compressive strength to the nearest 0.1 MPa [10 psi].

10. Chemically Bound Carbon Dioxide

10.1 Measure the carbon dioxide bound during carbonation curing using three (3) carbonation cured cubes that are cast, carbonation cured, and dried in accordance with Section 8 and three (3) uncured cubes that are cast in accordance with 8.1 and dried in accordance with 8.2.

10.2 Select as required either the three (3) carbonation cured cubes or the three (3) uncured cubes to analyze. Repeat the following procedure separately on each of the three (3) selected cubes.

10.3 Select a cube to be tested for bound carbon dioxide and obtain dust samples using a 3.2 mm [⅛ in.] diameter masonry drill bit on a drill press. Drill to a depth of half the cube depth collecting the cuttings during the drilling process. Drill sufficient holes on one side of each cube to obtain approximately 5 g to 10 g of cuttings. Pass the cuttings through a 150 µm [No. 100] sieve.

10.3.1 If material is retained on the sieve, grind the retained material with a mortar and pestle until 100 % of the cuttings pass the 150 µm [No. 100] sieve.

10.4 Obtain a sample of the cuttings collected in 10.3. Begin the TGA analysis in step 10.6 within 1 h of obtaining the final sample from 10.3.

10.5 Determine the initial sample mass ($M_{i\ cube\ n}$).

NOTE 5—The TGA apparatus used determines the initial mass and the total amount of sample to be analyzed. Consult the manufacturer's instructions. A sample size of 50 mg to 100 mg is typical.

10.6 Conduct the TGA analysis from 35 °C to 975 °C in accordance with Test Method C1872.

10.6.1 Dry the sample by heating to 35 ºC and holding that temperature for 10 min, followed by increasing the temperature at a rate of 10 ºC/min to 110 ºC.

10.6.2 Record the sample mass at 110 ºC as the dry mass of sample ($M_{dry\ cube\ n}$).

10.6.3 Continue to increase the sample temperature at the rate of 10 ºC/min to 975 ºC.

NOTE 6—The precision of the temperature and time for the TGA analysis is established by the instrument design.

10.6.4 Measure the onset and completion of calcium carbonate degradation between the temperatures of 550 °C and 950 °C. Record the mass of the sample at the onset of calcium carbonation degradation ($M_{o\ cube\ n}$) and the mass of the sample at the completion of degradation ($M_{c\ cube\ n}$).

10.7 Determine the mass loss due to calcium carbonate degradation ($M_{CO2\ cube\ n}$).

$$M_{CO2\ cube\ n} = M_{o\ cube\ n} - M_{c\ cube\ n} \quad (1)$$

10.8 Calculate the chemically bound carbon dioxide ($B_{CO2\ cube\ n}$) in the tested cube as percent carbon dioxide per mass of cement.

$$B_{CO2\ cube\ n} = (M_{CO2\ cube\ n} / M_{dry\ cube\ n}) \times 375 \quad (2)$$

10.9 Repeat 10.3 – 10.8 using the remaining two cured cubes. Average the results of three separate cube analyses and report as $B_{CO2\ cured}$ or $B_{CO2\ uncured}$, as applicable.

10.10 Repeat the procedure starting at 10.2 for the three (3) remaining cubes.

10.11 Calculate the chemically bound carbon dioxide (B_{CO2}) in the carbonated cement paste as percent carbon dioxide per mass of cement.

$$B_{CO2} = B_{CO2\ cured} - B_{CO2\ uncured} \quad (3)$$

10.12 Report the following:

10.12.1 Bound carbon dioxide, % mass of cement, nearest 0.1 %.

11. Precision and Bias

11.1 *Compressive Strength:*

11.1.1 *Single Operator Precision*—The estimated single operator coefficient of variation for the measured compressive strength is 3.8 %. This is based on data from 16 tests where a test result is the average of compressive strength tests of three cubes molded from a single batch of mortar and tested at the same age. The tests were performed by a single operator in a single laboratory, conducted over two days, using a calcium-silicate based cement. An interlaboratory study will be conducted and a complete precision statement will be completed within five years of the adoption of this test method.

11.1.2 *Bias*—There is no accepted reference material suitable for determining the bias in this test method. Therefore, no statement of bias is made.

11.2 *Chemically Bound Carbon Dioxide:*

11.2.1 *Single Operator Precision*—The estimated single operator coefficient of variation for the measured chemically bound carbon dioxide is 5.0 %. This is based on data from three tests where a test result is the average of chemically bound