Designation: C531 – 00 (Reapproved 2012)

Standard Test Method for Linear Shrinkage and Coefficient of Thermal Expansion of Chemical-Resistant Mortars, Grouts, Monolithic Surfacings, and Polymer Concretes[1]

This standard is issued under the fixed designation C531; 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.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This test method covers the measurement of the linear shrinkage during setting and curing and the coefficient of thermal expansion of chemical-resistant mortars, grouts, monolithic surfacings, and polymer concretes.

1.2 A bar of square cross-section is cast to a prescribed length in a mold that holds measuring studs that are captured in the ends of the finished casting.

1.2.1 The change in length after curing is measured and used to calculate shrinkage.

NOTE 1—Shrinkage determinations should not be made on sulfur mortars, since this test method cannot truly reflect the overall linear shrinkage of a sulfur mortar.

1.2.2 The change in length at a specific elevated temperature is measured and used to calculate the coefficient of thermal expansion.

1.3 This test method is limited to materials with aggregate size of 0.25 in. (6 mm) or less.

1.4 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.5 *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:*[2]

C287 Specification for Chemical-Resistant Sulfur Mortar

C490 Practice for Use of Apparatus for the Determination of Length Change of Hardened Cement Paste, Mortar, and Concrete

C904 Terminology Relating to Chemical-Resistant Nonmetallic Materials

3. Terminology

3.1 *Definitions*—For definitions of terms used in this test method, see Terminology C904.

4. Significance and Use

4.1 This test method offers a means of comparing the relative linear shrinkage and coefficient of thermal expansion.

4.1.1 The material to be tested is placed in the mold in a fluid or plastic state. As the material makes a transition to a solid state, it adheres to and captures the end studs.

4.1.2 The linear shrinkage measured is the change in length that occurs after the material is rigid enough and strong enough to move the studs.

4.2 This test method can be used for research purposes to provide information on linear changes taking place in the test materials. Other dimensional changes may occur that do not manifest themselves as changes in length.

5. Apparatus

5.1 *Weighing Equipment,* shall be capable of weighing materials or specimens to ±0.3 % accuracy.

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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.

5.2 *Equipment for Mixing,* consisting of a container of suitable size preferably made of corrosion-resistant metal, or a porcelain pan, and a sturdy spatula or trowel.

5.3 *Specimen Mold,* (see Practice C490) permitting the molding of bars with a metal stud embedded in each end. The bars shall be 1 in. (25 mm) square by 10 in. (250 mm) between studs when molded. A standard 10-in. (250-mm) metal bar shall be provided; this is used to space the studs.

5.4 *Studs*—Nickel alloy studs, which have linear coefficient of thermal expansion of 7.2×10^{-6} per °F (4×10^{-6} per °C), knurled on one end and threaded on the other (for securing in end blocks), approximately 0.8 in. (20 mm) long. Remove any machining burrs from the flat end of the stud.

5.5 *Comparator*—A direct-reading dial or digital micrometer to permit readings to 0.0001 in. (0.0025 mm).

5.6 *Micrometers,* one having a range suitable for measuring the studs (0.8 in.), and one having a range suitable for measuring the standard 10-in. (254-mm) bar, both readable to 0.0001 in. (0.0025 mm).

5.7 *Constant-Temperature Oven*—An oven capable of attaining temperatures to 210°F (99°C) is required. The oven should be capable of maintaining a set temperature constant to ±3°F (±1.5°C).

6. Test Specimens

6.1 *Temperature*—The standard temperature of the product constituents, mold apparatus, and the temperature in the vicinity of the mixing operation shall be 73 ± 4°F (23 ± 2°C), unless otherwise specified by the manufacturer. The actual temperature shall be recorded.

6.2 *Number of Specimens*—A minimum of four test bar specimens shall be prepared for each material tested.

6.3 *Preparation of Materials:*

6.3.1 Mix the material in the proportions specified by the manufacturer of the materials. If the proportions so specified are by volume, weigh the constituents and report the corresponding proportions by weight. Fresh material shall be used and the manufacturer shall be consulted if the age of the material is not known.

6.3.2 Mix a standard batch size of 2400 g of material and prepare four 1-in. (25-mm) square by 10-in. (250-mm) (approximate) bars.

6.3.3 For sulfur mortars, prepare the samples in accordance with the appropriate section of Specification C287.

6.4 *Molding Test Specimens:*

6.4.1 Lubricate the mold by applying a thin film of mold release or lubricant like silicone stop-cock grease.

6.4.2 Measure the standard bar with a micrometer to ±0.0001 in. (0.0025 mm).

6.4.3 Measure the lengths of the studs with a micrometer to ±0.0001 in. (0.0025 mm).

6.4.4 In assembling the mold, the end blocks must move freely in the mold before securing to the mold with machine screws.

6.4.5 Measure the measuring studs with micrometers and carefully adjust in the end blocks by means of the standard bar supplied with the mold.

6.4.6 Fill the molds with the material, taking care to eliminate air pockets by working the material with a spatula or thin trowel. Level the top surface with the spatula and strike off the excess evenly. In the case of sulfur mortars, at least three separate pourings shall be made.

6.4.7 After casting the specimens, remove the machine screws holding the end blocks to permit free movement of the blocks.

7. Conditioning

7.1 *Resin and Sulfur Materials*—Test specimens shall be removed from molds only after an initial curing time deemed suitable by the manufacturer.

7.2 *Silica and Silicate Materials*—Immediately after molding the specimens, cover the mold with polyethylene sheeting or other suitable material to prevent rapid evaporation of surface moisture and subsequent deformation of the specimen bar. Disassemble the mold (deviations in the time mortars, etc. are kept in the mold, are to be reported) as described in 7.1.

8. Procedure for Linear Shrinkage

8.1 Determine the length of the bar by inserting it in the length comparator.

NOTE 2—In cases where shrinkage in the specimens is great enough that comparator readings are no longer possible, insertion of a spacer (such as a metal washer) under the bottom stud holder of the comparator will enable readings to be made. When this is necessary, standard bar readings will also change and proper adjustments in calculation must be made.

8.2 The frequency of shrinkage measurement depends on the information desired; for example, if it is desired to follow the shrinkage at room temperature, or at a specific temperature, readings can be made as long as shrinkage continues. A typical schedule is as follows: daily for 2 weeks at 73 ± 4°F (23 ± 2°C), then after 3 days at 210°F (99°C) or 140°F (60°C), depending on the material (see 9.2). If the specimens are heated to induce cure, cool overnight at 73°F (23°C) before measuring.

8.2.1 Repeat heating and cooling cycles until the bars achieve a constant length when measured at 73°F (23°C).

9. Procedure for Linear Coefficient of Thermal Expansion

9.1 Use the specimens previously used for shrinkage determinations. Heat the specimens to constant length in an oven at the elevated temperature indicated in 9.2, then condition at 73°F for a minimum of 16 h.

9.2 Determine the length of each bar at 73°F by measuring with the length comparator. Then place the bars in an oven heated as follows: resin, silica, and silicate materials, 210°F (100°C); and sulfur materials, 140°F (60°C).

9.3 After at least 16 h, remove the bars quickly one at a time and measure (Note 3). Remove the bars at a rate that does not permit the temperature of the oven to drop below the established temperature. In the case of silicate materials, put the

specimens into a desiccator for cooling immediately after the reading is taken at the elevated temperature.

NOTE 3—Usually, the length can be read within 4 or 5 s after removal from the oven.

9.3.1 If the specimen does not return to its original length on cooling to 73°F, shrinkage is still taking place, and the procedure in 9.1 and 9.2 shall be repeated.

10. Calculation

10.1 *Shrinkage*—Calculate the linear shrinkage for the four specimens as follows:

$$\text{Percent shrinkage} = [(L_0 - L)/L_0] \times 100 \quad (1)$$

where:

L_0 = original length (length of standard bar), in., (mm), and
L = length as measured during or after cure, in. (mm), excluding studs.

10.2 *Linear Coefficient of Thermal Expansion*—Calculate the linear coefficient of thermal expansion per °F (°C), C, of the four specimens as follows:

$$C = (Z - Y - W)/T(W - X) \quad (2)$$

where:

Z = length of bar, including studs, at elevated temperature, in. (mm),
Y = length of stud expansion, in. (mm), = X × T × k (where k is the linear coefficient of thermal expansion per °F (°C) of the studs),
W = length of bar, including studs, at lower temperature, in. (mm),
T = temperature change, °F (°C) and
X = length of the two studs at lower temperature, in. (mm).

11. Report

11.1 Report the following information:

11.1.1 Manufacturer's name of the material and generic type,

11.1.2 Mixing ratio,

11.1.3 Conditioning procedure,

11.1.4 Test conditions, (temperature and humidity),

11.1.5 Total duration of test in days, including heat cycles, and

11.1.6 Individual and averaged results of linear shrinkage and coefficient of thermal expansion.

12. Precision

12.1 The precision of this test method has not yet been established.

13. Keywords

13.1 brick mortars; grouts; linear shrinkage; monolithic surfacings; mortars; polymer concretes; thermal expansion; tile grouts