Designation: C580 – 02 (Reapproved 2012)

Standard Test Method for Flexural Strength and Modulus of Elasticity of Chemical-Resistant Mortars, Grouts, Monolithic Surfacings, and Polymer Concretes[1]

This standard is issued under the fixed designation C580; 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 U.S. Department of Defense.

1. Scope

1.1 This test method covers the determination of flexural strength and modulus of elasticity in flexure of cured chemical-resistant materials in the form of molded rectangular beams. These materials include mortars, brick and tile grouts, structural grouts, machinery grouts, monolithic surfacings (60 mils or greater), and polymer concretes. These materials shall be based on resin, silicate, silica, or sulfur binders.

1.2 A bar of rectangular cross section is tested in flexure as a simple beam in center point loading: the bar rests on two supports and the load is applied by means of a loading nose midway between supports.

1.3 Method A outlines the testing procedure generally used for systems containing aggregate less than 0.2 in. (5 mm) in size. Method B covers the testing procedure generally used for systems containing aggregate from 0.2 to 0.4 in. (10 mm) in size. Method C is used for systems containing aggregate larger than 0.4 in.

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]

C904 Terminology Relating to Chemical-Resistant Nonmetallic Materials

C1312 Practice for Making and Conditioning Chemical-Resistant Sulfur Polymer Cement Concrete Test Specimens in the Laboratory

E4 Practices for Force Verification of Testing Machines

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 is generally applicable to rigid and semirigid materials. Although flexural strength cannot be determined for those materials that do not break, tangent modulus of elasticity can be determined.

4.2 The results obtained by this test method should serve as a guide in, but not as the sole basis for, selection of a chemical-resistant material for a particular application. No attempt has been made to incorporate into this test method all the various factors that may affect the performance of a material when subjected to actual service.

4.3 In addition to the tangent modulus of elasticity, a secant modulus is calculated at the point on the stress-strain (load-deflection) graph where the strain is 50 % of the maximum strain.

5. Apparatus

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

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[1] This test method is under the jurisdiction of ASTM Committee D01 on Paint and Related Coatings, Materials, and Applications and is the direct responsibility of Subcommittee D01.46 on Industrial Protective Coatings.

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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 Materials,* shall consist of a container of suitable size, preferably corrosion-resistant, a spatula, trowel, or mechanical mixer, and a ⅜ in. diameter rod with a rounded end, for use in casting specimens.

5.3 *Specimen Molds:*

5.3.1 *Method A*—Molds to permit the casting of bars 1 ± 1⁄16 in. (25 ± 1 mm) square by 10 in. (250 mm) minimum length.

5.3.1.1 For sulfur mortars, the following additional equipment is required:

(1) Cover Plate, of a size sufficient to enclose the open side of the bar mold. The base plate from another similar bar mold has been found to be acceptable.

(2) C-Clamp, large enough to fasten the cover plate securely over the bar mold.

(3) Melting Chamber, of sufficient volume and heat capacity to melt the sulfur mortar sample and maintain the temperature of the melt between 260 and 290°F (127 and 143°C).

(4) Laboratory Mixer, of such a type and speed to be capable of lifting the aggregate without beating air into the melt.

(5) Ladle, of sufficient capacity to completely pour one bar.

(6) Masking Tape, 1 in. (25 mm), or an equivalent.

5.3.2 *Method B*—Molds to permit the casting of bars 2 ± ⅛ in. (50 ± 3 mm) square by 12 in. (300 mm) minimum length.

5.3.3 *Method C*—Molds to permit casting of rectangular beams shall have a minimum cross-sectional dimension of 2 in. and at least three times the nominal maximum size of the coarse aggregate in the polymer concrete (Note 1). The bar length shall be at least three times the beam depth plus 2 in.

NOTE 1—The nominal maximum size of coarse aggregate is that size next larger than the largest sieve on which at least 15 % of the coarse aggregate by weight is retained.

5.4 *Testing Machine*—The testing machine shall be of any type sufficient to provide the required load and the rate of deflection prescribed. It shall have been verified to have an accuracy of 1.0 % or better within twelve months of the time of use in accordance with Practices E4. It shall be equipped with an appropriate device to record deflection and produce a graph of load versus deflection.

5.5 *Loading Nose and Supports*—The loading nose and supports shall have cylindrical surfaces. To avoid excessive indentation, the radius of the nose and supports shall be at least ⅛ in. for Method A specimens, ¼ in. for Method B specimens, and ½ in. for Method C specimens.

6. Test Specimens

6.1 All specimens for a single determination shall be made from a single mix containing sufficient amounts of the components in the proportions and in the manner specified by the manufacturer of the materials. If the proportions so specified are by volume, the components shall be weighed and the corresponding proportions by weight shall be reported.

6.1.1 *Number of Specimens*—Prepare a minimum of six test bar specimens for each material tested. Additional specimens may be required to establish the cross head speed in 9.3.2.

6.2 *Specimen Size:*

6.2.1 For Method A, the specimen shall be 1 ± 1⁄16 in. (25 ± 1 mm) square by 10 to 14 in. (254 to 356 mm) long.

6.2.2 For Method B, the specimens shall be 2 ± ⅛ in. (25 ± 1 mm) square by 12 to 16 in. (305 to 406 mm) long.

6.2.3 For Method C, the specimens shall be rectangular beams with cross section as in 5.3.3 and with a length equal to the span plus 2 to 12 in. (51 to 305 mm).

6.3 *Specimen Preparation Temperature:*

6.3.1 *Resin, Silicate, and Silica Materials*—The standard temperature of the materials, molds, apparatus, and the ambient temperature of the mixing area shall be 73 ± 4°F (23 ± 2°C), unless otherwise specified by the manufacturer. Record the actual temperature.

6.3.2 *Sulfur Mortars*—The material shall be maintained at 275 ± 15°F. The temperature of the molds and the ambient temperature of the mixing area shall be 73 ± 4°F (23 ± 2°C). Record the actual temperature.

6.3.3 *For Sulfur Concrete,* the material, mold, apparatus, and mixing equipment shall be 275 ± 15°F (135 ± 8°C), unless otherwise specified by the manufacturer. Refer to Practice C1312.

6.4 *Molding Test Specimens:*

6.4.1 Lubricate the mold by applying a thin film of an appropriate mold release or lubricant.

6.4.2 *Resin, Silicate, and Silica Materials*—Mix a sufficient amount of the components in the proportions and in the manner specified by the manufacturer of the materials. Fill the molds one-half full. Remove any entrapped air by using a cutting and stabbing motion with a spatula or rounded-end rod. Fill the remainder of the mold, working down into the previously placed portion. Upon completion of the filling operation, the tops of the specimens should extend slightly above the tops of the molds. When the molds have been filled, strike off the excess material, even with the top of the mold. Permit the material to remain in the mold until it has set sufficiently to allow removal without danger of deformation or breakage.

6.4.3 *Silicate Materials*—Some silicates may require covering during the curing period. After removal from the molds, acid-treat the specimens, if required, in accordance with the recommendations given by the manufacturer. No other treatment shall be permitted. Record the method of treatment in the report section under Conditioning Procedure.

6.4.4 *Sulfur Mortars:*

6.4.4.1 Assemble the mold described in 5.3.1 for the specimens. Cover the bolt hole in the mold end piece with 1 in. (25 mm) masking tape or other material.

6.4.4.2 Carefully place the cover plate onto the mold, covering only one of the end pieces. Apply a C-clamp around the mold and cover plate in such a manner as to hold the longitudinal mold pieces firmly in place with the cover plate.

6.4.4.3 Remove the uncovered end piece, being careful not to disturb the side bars.

6.4.4.4 Stand the mold on end, supporting it in such a manner that it will not tip.

6.4.4.5 Slowly melt approximately 5 lb (2.3 kg) of sulfur mortar in the melt chamber at a temperature of 275 ± 15°F while stirring gently with the laboratory mixer. (The mixer speed should be controlled so that it is sufficient to lift the aggregate without beating air into the melt.)

6.4.4.6 Using the ladle, fill each mold completely, allowing the molten material to just reach the upper end of the mold.

6.4.4.7 Carefully watch the end of the fresh casting and continually "top-off" the pour as shrinkage occurs (approximately three times).

6.4.5 *Sulfur Concrete*—Refer to Practice C1312.

7. Conditioning

7.1 *Resin, Silica, and Silicate Materials*—Age the test specimens for a period of seven days, including the cure period in the mold, at 73 ± 4°F (23 ± 2°C) and relative humidity less than 80 % before testing.

7.2 *Sulfur Materials*—Before testing, condition the specimens at 73 ± 4°F. The time between casting the specimens and testing the specimens shall be at least 24 h.

7.3 If longer or shorter conditioning time is used, the conditioning time shall be reported.

8. Procedure

8.1 *Measurement of Specimens*—Measure the depth and width of all test specimens to the nearest 0.001 in. (0.025 mm) using a micrometer. Make two measurements for each dimension *near* the middle of the beam's length and average them.

8.2 The testing machine shall be set up to test the specimens in simple bending with two supports and the load being applied by means of a loading nose midway between the supports.

8.2.1 *Method A*—The span shall be 9 ± 0.1 in. (230 ± 2 mm).

8.2.2 *Method B*—The span shall be 10 ± 0.1 in. (254 ± 3 mm).

8.2.3 *Method C*—The span shall be beam depth times 3 ± 2 %.

8.3 *Cross Head Speed:*

8.3.1 In order to achieve a strain rate of 0.01 ± 0.001 per minute at the top and bottom of the beam, set the testing machine to produce a cross head speed as determined by the following formula:

$$\text{Speed} = \frac{0.00167 \times L^2}{d} \tag{1}$$

where:

speed = the cross head speed, in./min (mm/min),
L = span, in. (mm), and
d = depth of beam tested, in. (mm).

8.3.2 For sulfur concrete, load the specimen continuously and without shock. The load may be applied rapidly up to approximately 50 % of the breaking load. Thereafter, apply the load at such a rate that constantly increases the extreme fiber stress between 125 and 175 psi/min (0.86 and 1.21 MPa/min), when calculated in accordance with 9.1, until rupture occurs.

8.4 Place the specimen in the testing machine in such a manner that the faces of the beam that were in contact with the true plane surfaces of the mold are in contact with the supports and the center loading nose. Center the beam over the specimen supports.

8.5 Apply the load to the specimen at the speed calculated in 8.3.1 (this is the cross head speed of the machine when running without load) and record load deflection data. Deflection shall be measured by either a transducer under the specimen and in contact with it at the center of the span, or by the measurement of the motion of the loading nose relative to the supports.

8.5.1 Stop the test when the specimen breaks or the load drops off 25 % from its highest value.

9. Calculations

9.1 *Flexural Strength*—The flexural strength is equal to the stress calculated at maximum load. It is calculated as follows:

$$S = 3\ PL/2\ bd^2 \tag{2}$$

where:

S = stress in the specimen at midspan, psi (MPa),
P = the maximum load at or prior to the moment of crack or break, lbf (or N),
L = span, in. (mm),
b = width of beam tested, in. (mm), and
d = depth of beam tested, in. (mm).

9.2 *Modulus of Elasticity (Tangent)*—The tangent modulus of elasticity is the ratio, within the elastic limit, of stress to corresponding strain, and shall be expressed in psi (MPa). It is calculated by drawing a tangent line to the steepest initial portion of the load-deformation curve and calculating as follows:

$$E_T = L^3\ M_1/4\ bd^3 \tag{3}$$

where:

E_T = tangent modulus of elasticity in bending, psi (GPa),
L = span, in. (mm),
b = width of beam tested, in. (mm),
d = depth of beam tested, in. (mm), and
M_1 = slope of the tangent to the initial straight-line portion of the load-deflection curve, lbf/in. (N/mm) deflection.

9.3 *Modulus of Elasticity (Secant):*

9.3.1 The secant modulus of elasticity is the ratio of stress to corresponding strain at any specified point of the stress strain curve. It shall be expressed in psi (GPa).

9.3.2 Under this procedure the secant modulus of elasticity shall be calculated at the point at which the deflection is 50 % of the maximum deflection. It shall be calculated as follows:

$$E_S = L^3\ M_2/4\ bd^3 \tag{4}$$

where:

E_S = the secant modulus of elasticity in bending, psi (GPa),
L = span, in. (mm),
b = width of beam tested, in. (mm),
d = depth of beam tested, in. (mm), and
M_2 = the slope of a line drawn from the origin through the point on the load deflection curve where the deflection = 50 % of the maximum deflection, lbf/in. (N/mm).

10. Report

10.1 Report the following information:

10.1.1 Manufacturer, product trade name, generic type, and lot number;

10.1.2 Method used, bar dimensions, and testing span;

10.1.3 Mixing ratio and component weights;

10.1.4 Conditioning procedure and duration in days;

10.1.5 Test conditions (temperature and humidity);

10.1.6 Load-deflection curve for each specimen tested; and

10.1.7 Individual and average results of flexural strength, tangent modulus of elasticity, and secant modulus of elasticity.

11. Precision and Bias

11.1 Precision and bias for this test method have not been established.

11.2 Test specimens that are manifestly faulty should be rejected and not considered in determining the flexural strength and modulus of elasticity.

11.3 If any strength value differs from the mean by more than 15 %, that value shall be rejected and the mean recalculated. Repeat this process until all test values are within 15 % of the mean.

11.3.1 If less than two-thirds of the values remain, the test shall be rerun.

12. Keywords

12.1 brick mortars; chemical resistant; flexural strength; machinery grouts; modulus of elasticity; monolithic surfacings; polymer concrete; resin materials; silicate materials; sulfur materials; tile grouts

APPENDIX

(Nonmandatory Information)

X1. TOE COMPENSATION

X1.1 In a typical stress-strain curve (Fig. X1.1) there is a toe region, AC, that does not represent a property of the material. It is a portion of the curve that reflects some displacement caused by a takeup of slack, misalignment, or improper seating of the specimen. In order to obtain correct values of such parameters as modulus and strain, this effect must be compensated for to give the corrected zero point (intersect) on the strain or deflection axis.

X1.2 In the case of a material exhibiting a region of Hookean (linear) behavior (Fig. X1.1), a continuation of the linear (CD) region of the curve is constructed through the zero-stress axis. This intersection (B) is the corrected zero-strain point from which all deflections or strains must be measured. The tangent modulus of elasticity can be determined by dividing the stress at any point along the line BD (or its extension) by the strain at the same point (measured from point B, defined as zero-strain). The secant modulus of elasticity (at 50 % of maximum deflection) can be determined by dividing the stress at any point along the line BE (or its extension) by the strain at the same point (measured from point B, defined as zero-strain). The deflection (strain) BG is one-half of the corrected maximum strain BH.

X1.2.1 For the calculation shown in 9.2, M_1 will be the slope of the line BD. For the calculation shown in 9.3.2, M_2 will be the slope of the line BE.

X1.3 In the case of a material that does not exhibit any linear region (Fig. X1.2), the same kind of toe correction for the zero-strain point can be made by constructing a tangent to the maximum slope at the inflection point (C*). This is extended to intersect the strain axis at point B.

X1.3.1 The calculations will be the same as in X1.2.1.

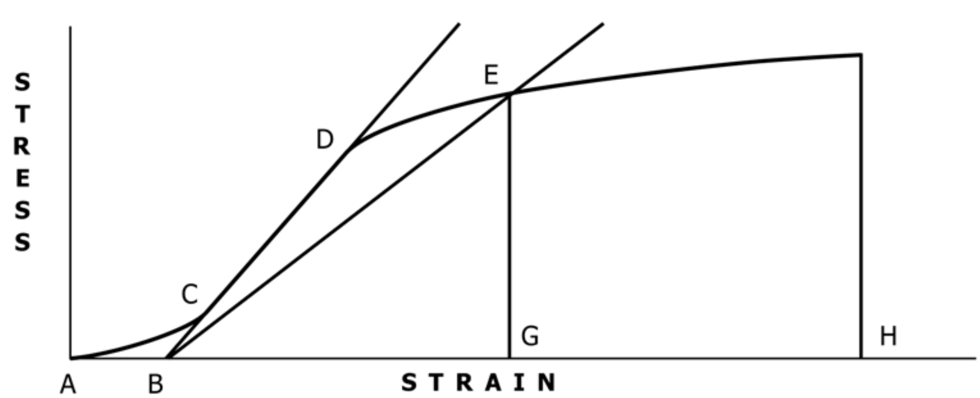

FIG. X1.1 Stress-Strain Curve (Hookean (Linear) Region)

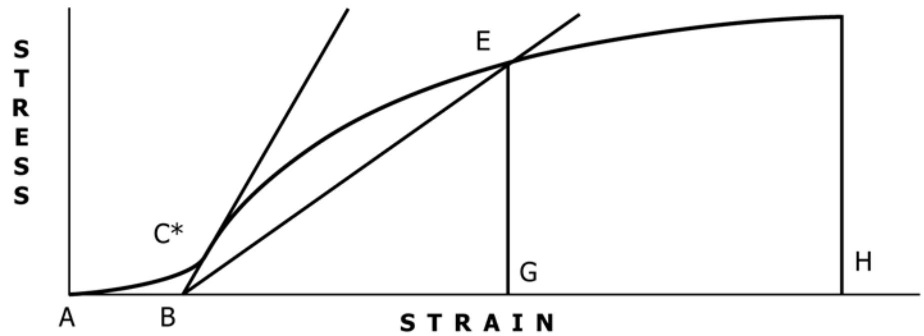

FIG. X1.2 Stress-Strain Curve (no linear region)