Designation: C469/C469M − 22

Standard Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression[1]

This standard is issued under the fixed designation C469/C469M; 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 (*1*) chord modulus of elasticity (Young's) and (*2*) Poisson's ratio of molded concrete cylinders and diamond-drilled concrete cores when under longitudinal compressive stress. Chord modulus of elasticity and Poisson's ratio are defined in Terminology E6.

1.2 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.

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *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:*[2]

C31/C31M Practice for Making and Curing Concrete Test Specimens in the Field

C39/C39M Test Method for Compressive Strength of Cylindrical Concrete Specimens

C42/C42M Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

C174/C174M Test Method for Measuring Thickness of Concrete Elements Using Drilled Concrete Cores

C192/C192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C617 Practice for Capping Cylindrical Concrete Specimens

C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

E4 Practices for Force Calibration and Verification of Testing Machines

E6 Terminology Relating to Methods of Mechanical Testing

E83 Practice for Verification and Classification of Extensometer Systems

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

2.2 *ASTM Adjuncts:*

Compressometers (two drawings) and Extensometers (two drawings)[3]

3. Significance and Use

3.1 This test method provides a stress to strain ratio value and a ratio of lateral to longitudinal strain for hardened concrete at whatever age and curing conditions may be designated.

3.2 The modulus of elasticity and Poisson's ratio values, applicable within the customary working stress range (0 to 40 % of ultimate concrete strength), are used in sizing of reinforced and nonreinforced structural members, establishing the quantity of reinforcement, and computing stress for observed strains.

3.3 The modulus of elasticity values obtained will usually be less than moduli derived under rapid load application (dynamic or seismic rates, for example), and will usually be greater than values under slow load application or extended load duration, given other test conditions being the same.

4. Apparatus

4.1 *Testing Machine*—Use a testing machine capable of imposing a load at the rate and of the magnitude prescribed in

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.61 on Testing for Strength.

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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.

[3] Available from ASTM International Headquarters. Order Adjunct No. ADJC0469-E-PDF. Adjunct converted to digital format in 2021.

*A Summary of Changes section appears at the end of this standard

6.4. The machine shall conform to the requirements of Practices E4 (Constant-Rate of-Traverse CRT-Type Testing Machines section). The spherical head and bearing blocks shall conform to the Apparatus Section of Test Method C39/C39M.

4.2 *Compressometer*[3]—For determining the modulus of elasticity use a bonded (Note 1) or unbonded sensing device that measures to the nearest 5 millionths the average deformation of two diametrically opposite gauge lines, each parallel to the axis, and each centered about midheight of the specimen. The effective length of each gauge line shall be not less than three times the maximum size of the aggregate in the concrete nor more than two thirds the height of the specimen; the preferred length of the gauge line is one half the height of the specimen. Either use gauge points embedded in or cemented to the specimen, and read deformation of the two lines independently; or use a compressometer (such as is shown in Fig. 1) consisting of two yokes, one of which (see *B*, Fig. 1) is rigidly attached to the specimen and the other (see *C*, Fig. 1) attached at two diametrically opposite points so that it is free to rotate. At one point on the circumference of the rotating yoke, midway between the two support points, use a pivot rod (see *A*, Fig. 1) to maintain a constant distance between the two yokes. At the opposite point on the circumference of the rotating yoke, the change in distance between the yokes (that is, the gauge reading) is equal to the sum of the displacement due to specimen deformation and the displacement due to rotation of the yoke about the pivot rod (see Fig. 2).

4.2.1 Measure deformation by a dial gauge used directly or with a lever multiplying system, by a wire strain gauge, or by a linear variable differential transformer. If the distances of the pivot rod and the gauge from the vertical plane passing through the support points of the rotating yoke are equal, the deformation of the specimen is equal to one-half the gauge reading. If these distances are not equal, calculate the deformation as follows:

$$d = ge_r/(e_r + e_g) \quad (1)$$

where:

d = total deformation of the specimen throughout the effective gauge length, µm [µin.],
g = gauge reading, µm [µin.],
e_r = the perpendicular distance, measured to the nearest 0.2 mm [0.01 in.] from the pivot rod to the vertical plane passing through the two support points of the rotating yoke, and
e_g = the perpendicular distance, measured to the nearest 0.2 mm [0.01 in.] from the gauge to the vertical plane passing through the two support points of the rotating yoke.

Procedures for calibrating strain-measuring devices are given in Practice E83.

NOTE 1—Although bonded strain gauges are satisfactory on dry specimens, they may be difficult, if not impossible, to mount on specimens continually moist-cured until tested.

4.3 *Extensometer*[3]—If Poisson's ratio is desired, the transverse strain shall be determined (*1*) by an unbonded extensometer capable of measuring to the nearest 0.5 µm [25 µin.] the change in diameter at the midheight of the specimen, or (*2*) by two bonded strain gauges (Note 1) mounted circumferentially at diametrically opposite points at the midheight of the specimen and capable of measuring circumferential strain to the nearest 5 millionths. A combined compressometer and extensometer (Fig. 3) is a convenient unbonded device. This apparatus shall contain a third yoke (consisting of two equal

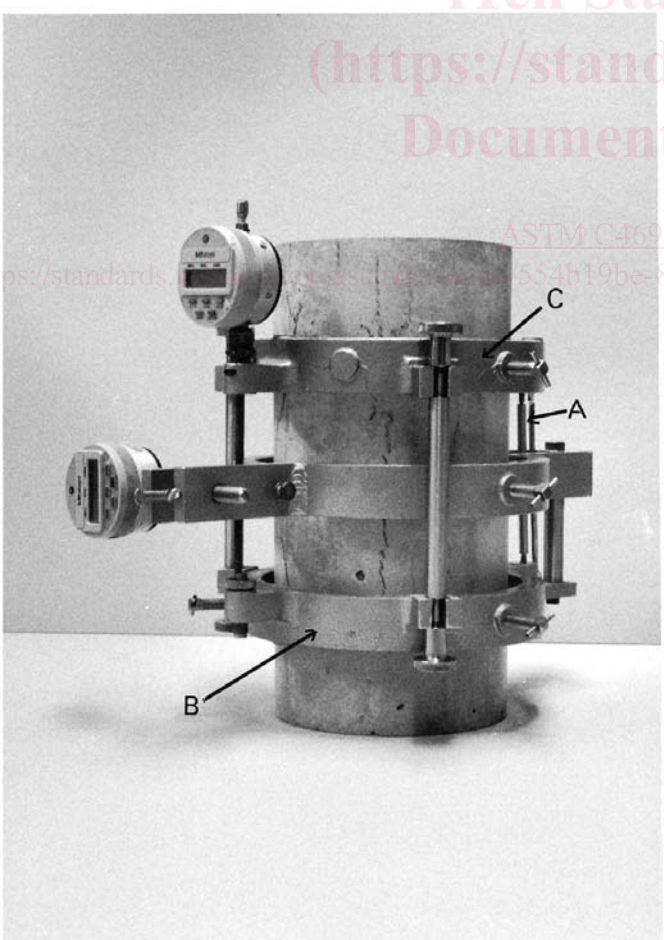
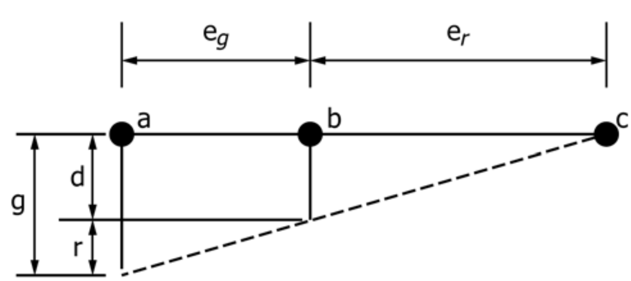


FIG. 1 Suitable Compressometer



d = displacement due to specimen deformation
r = displacement due to rotation of the yoke about the pivot rod
a = location of gauge
b = support point of the rotating yoke
c = location of pivot rod
g = gauge reading

FIG. 2 Diagram of Displacements

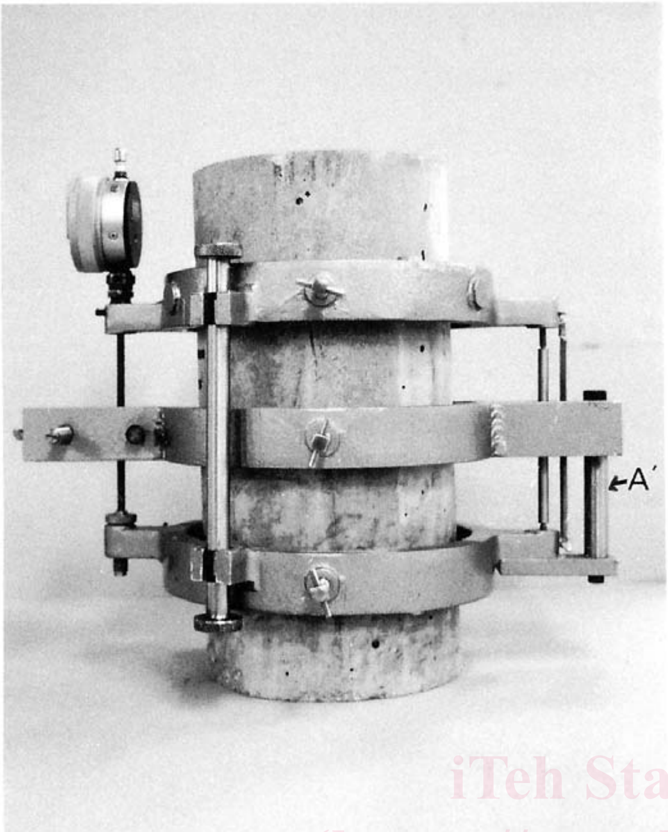


FIG. 3 Suitable Combined Compressometer-Extensometer

segments) located halfway between the two compressometer yokes and attached to the specimen at two diametrically opposite points. Midway between these points use a short pivot rod (*A*′, see Fig. 3), adjacent to the long pivot rod, to maintain a constant distance between the bottom and middle yokes. Hinge the middle yoke at the pivot point to permit rotation of the two segments of the yoke in the horizontal plane. At the opposite point on the circumference, connect the two segments through a dial gauge or other sensing device capable of measuring transverse deformation to the nearest 1.27 µm [50 µin.]. If the distances of the hinge and the gauge from the vertical plane passing through the support points of the middle yoke are equal, the transverse deformation of the specimen diameter is equal to one-half the gauge reading. If these distances are not equal, calculate the transverse deformation of the specimen diameter in accordance with Eq 2.

$$d' = g'e'_h/(e'_h + e'_g) \tag{2}$$

where:

d' = transverse deformation of the specimen diameter, µm [µin.],
g' = transverse gauge reading, µm [µin.],
e'_h = the perpendicular distance, measured to the nearest 0.2 mm [0.01 in.] from the hinge to the vertical plane passing through the support points of the middle yoke, and
e'_g = the perpendicular distance, measured to the nearest 0.2 mm [0.01 in.] from the gauge to the vertical plane passing through the support points of the middle yoke.

4.4 *Balance or Scale,* accurate to 50 g [0.1 lb] shall be used if necessary.

5. Test Specimens

5.1 *Molded Cylindrical Specimens*—Mold test cylinders in accordance with the requirements for compression test specimens in Practice C192/C192M, or in Practice C31/C31M. Subject specimens to the specified curing conditions and test at the age for which the elasticity information is desired. Test specimens within 1 h after removal from the curing or storage room. Specimens removed from a moist room for test shall be kept moist by a wet cloth covering during the interval between removal and test.

5.2 *Drilled Core Specimens*—Cores shall comply with the requirements for drilling, and moisture conditioning applicable to compressive strength specimens in Test Method C42/C42M, except that only diamond-drilled cores having a length-to-diameter ratio greater than 1.50 shall be used. Requirements relative to storage and to ambient conditions immediately prior to test shall be the same as for molded cylindrical specimens.

5.3 The ends of the test specimens shall be made perpendicular to the axis ±0.001 rad [±0.5°] and plane within 0.05 mm [0.002 in.]. If the specimen as cast does not meet the planeness requirements, planeness shall be accomplished by capping in accordance with Practice C617, or by lapping, or by grinding. It is not prohibited to repair aggregate popouts that occur at the ends of specimens, provided the total area of popouts does not exceed 10 % of the specimen area and the repairs are made before capping or grinding is completed (Note 2). Planeness will be considered within tolerance when a 0.05 mm [0.002 in.] feeler gauge will not pass between the specimen surface and a straight edge held against the surface.

NOTE 2—Repairs may be made by epoxying the dislodged aggregate back in place or by filling the void with capping material and allowing adequate time for it to harden.

5.4 Measure the diameter of the test specimen by caliper to the nearest 0.2 mm [0.01 in.] by averaging two diameters measured at right angles to each other near the center of the length of the specimen. Use this average diameter to calculate the cross-sectional area. Measure and report the length of a molded specimen, including caps, to the nearest 2 mm [0.1 in.]. Measure the length of a drilled specimen in accordance with Test Method C174/C174M; report the length, including caps, to the nearest 2 mm [0.1 in.].

6. Procedure

6.1 The temperature surrounding the specimen shall not vary by more than 2 °C [4 °F] during a test.

6.2 Except as provided in 6.5, use at least two companion specimens to determine the compressive strength in accordance with Test Method C39/C39M prior to the test for modulus of elasticity.

6.3 Place the specimen, with the strain-measuring equipment attached, on the lower platen or bearing block of the testing machine. Carefully align the axis of the specimen with the center of thrust of the spherically-seated upper bearing block. Note the reading on the strain indicators. Before applying the load on the specimen, tilt the movable portion of the spherically seated block by hand so that the bearing face appears to be parallel to the top of the test specimen based on visual observation.

6.4 Load the specimen at least three times. Do not record any data during the first loading. Base calculations on the average of the results of the subsequent loadings.

6.4.1 Apply the load continuously and without shock. Set testing machines of the screw type so that the moving head travels at a rate of about
1 mm/min [0.05 in./min] when the machine is running idle. In hydraulically operated machines, apply the load at a constant rate within the range 250 kPa/s ± 50 kPa/s [35 psi/s ± 7 psi/s]. Load the specimen until the applied load is 40 % of the average ultimate load of the companion specimens. This is the maximum load for the modulus of elasticity test.

6.4.2 During the first loading, observe the performance of the gauges (Note 3). Correct any attachment or alignment defects that may be causing erratic readings prior to the second loading. For the second and subsequent loadings, obtain each set of readings as follows: Record, without interruption of loading, the applied load and longitudinal strain at the point (*1*) when the longitudinal strain is 50 microstrain and (*2*) when the applied load is equal to 40 % of the ultimate load of the companion specimens (see 6.5). Longitudinal strain is defined as the measured longitudinal deformation of the specimen divided by the effective gauge length.

NOTE 3—The first loading is primarily for the seating of the gauges. If a dial gauge is used to measure longitudinal deformation, it is convenient to set the gauge before each loading so that the indicator will pass the zero point at a longitudinal strain of 50 microstrain.

6.4.3 If Poisson's ratio is to be determined, record the transverse strain at the same points. The transverse strain is the measured change in specimen diameter divided by the original diameter.

6.4.4 If a stress-strain curve is to be determined, take readings at two or more intermediate points without interruption of loading; or use an instrument that makes a continuous record of the gauge readings.

6.4.5 Upon reaching the maximum load, except on the final loading, reduce the load to zero at the same rate at which it was applied.

6.5 It is not prohibited to obtain the modulus of elasticity and strength on the same loading provided that the gauges are expendable, removable, or adequately protected so that it is possible to comply with the requirement for continuous loading given in Test Method C39/C39M. In this case, record several intermediate readings to obtain a stress-strain curve up to at least 40 % of the ultimate load and determine the strain value at 40 % of the ultimate by interpolation.

6.6 If intermediate readings are taken, plot the results of each of the tests with the longitudinal strain as the abscissa and the compressive stress as the ordinate. Calculate the compressive stress by dividing the testing machine load by the cross-sectional area of the specimen calculated from the diameter determined in accordance with 5.4.

7. Calculation

7.1 Calculate the modulus of elasticity, to the nearest 200 MPa [50 000 psi] as follows:

$$E = (S_2 - S_1)/(\varepsilon_2 - 0.000050) \quad (3)$$

where:

E = chord modulus of elasticity, MPa [psi],
S_2 = stress corresponding to 40 % of ultimate load,
S_1 = stress corresponding to a longitudinal strain, ε_1, of 50 millionths, MPa [psi], and
ε_2 = longitudinal strain produced by stress S_2.

7.2 Calculate Poisson's ratio, to the nearest 0.01, as follows:

$$\mu = (\varepsilon_{t2} - \varepsilon_{t1})/(\varepsilon_2 - 0.000050) \quad (4)$$

where:

μ = Poisson's ratio,
ε_{t2} = transverse strain at midheight of the specimen produced by stress S_2, and
ε_{t1} = transverse strain at midheight of the specimen produced by stress S_1.

8. Report

8.1 Report the following information:
8.1.1 Specimen identification number,
8.1.2 Dimensions of specimen, in millimetres [inches],
8.1.3 Curing and environmental histories of the specimen,
8.1.4 Age of the specimen,
8.1.5 Strength of the concrete, if determined,
8.1.6 Unit weight of the concrete, if determined,
8.1.7 Stress-strain curves, if plotted,
8.1.8 Chord modulus of elasticity, and
8.1.9 Poisson's ratio, if determined.

9. Precision and Bias

9.1 *Modulus of Elasticity:*

9.1.1 *Single Operator Precision*—The single-operator coefficient of variation for test determinations has been found to be as shown in the second column of Table 1. Therefore, the modulus of elasticity from two properly conducted tests by the same operator on specimens of the same concrete are not expected to differ from each other by more than the value in the third column of Table 1. The acceptable difference between two test determinations is expressed as a percentage of their average.

NOTE 4—The precision of this test method was determined from an interlaboratory study conducted in 2017 (ILS1477). The study involved three concrete mixtures with modulus of elasticity values of approximately 27 GPa [4 psi × 10^6 psi], 42 GPa [6 psi × 106 psi] and 49 GPa [7 psi × 10^6 psi]. Two cylinder sizes were used: 100 mm by 200 mm [4 in. by 8 in.] and 150 mm by 300 mm [6 in. by 12 in.]. Only 100 mm by 200 mm [4 in. by 8 in.] cylinders were used for the mixture with the highest modulus of elasticity. Three test determinations were obtained for each combination of specimen size and concrete mixture. Ten laboratories were involved in determining the precision for modulus of elasticity, except for