Designation: C 469 – 94$^{\epsilon 1}$

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 C 469; 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.

ϵ^1 NOTE—Figure number 2 was editorially updated June 2002.

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 E 6.

1.2 The values stated in inch-pound units are to be regarded as 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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 31 Practice for Making and Curing Concrete Test Specimens in the Field[2]

C 39 Test Method for Compressive Strength of Cylindrical Concrete Specimens[2]

C 42 Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete[2]

C 174 Test Method for Measuring Length of Drilled Concrete Cores[2]

C 192 Practice for Making and Curing Concrete Test Specimens in the Laboratory[2]

C 617 Practice for Capping Cylindrical Concrete Specimens[2]

E 4 Practices for Load Verification of Testing Machines[2]

E 6 Terminology Relating to Methods of Mechanical Testing[3]

E 83 Practice for Verification and Classification of Extensometers[3]

E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods[2]

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), may be 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, other test conditions being the same.

4. Apparatus

4.1 *Testing Machine*—Any type of testing machine capable of imposing a load at the rate and of the magnitude prescribed in 6.4 may be used. The machine shall conform to the requirements of Practices E 4 (Constant-Rate of-Traverse CRT-Type Testing Machines section). The spherical head and bearing blocks shall conform to the Apparatus Section of Test Method C 39.

4.2 *Compressometer*[4]—For determining the modulus of elasticity a bonded (Note 1) or unbonded sensing device shall be provided for measuring to the nearest 5 millionths the average deformation of two diametrically opposite gage lines, each parallel to the axis, and each centered about midheight of the specimen. The effective length of each gage 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 gage line is one half the height of the specimen. Gage points may be embedded in or cemented to the specimen, and deformation of the two lines

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

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

[4] Copies of working drawings of strain measuring apparatus are available from ASTM International Headquarters. Request adjunct No. ADJC0469.

read independently; or a compressometer (such as is shown in Fig. 1) may be used 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, a pivot rod (see *A*, Fig. 1) shall be used 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 gage 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 Deformation may be measured by a dial gage used directly or with a lever multiplying system, by a wire strain gage, or by a linear variable differential transformer. If the distances of the pivot rod and the gage 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 gage reading. If these distances are not equal, the deformation shall be calculated as follows:

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

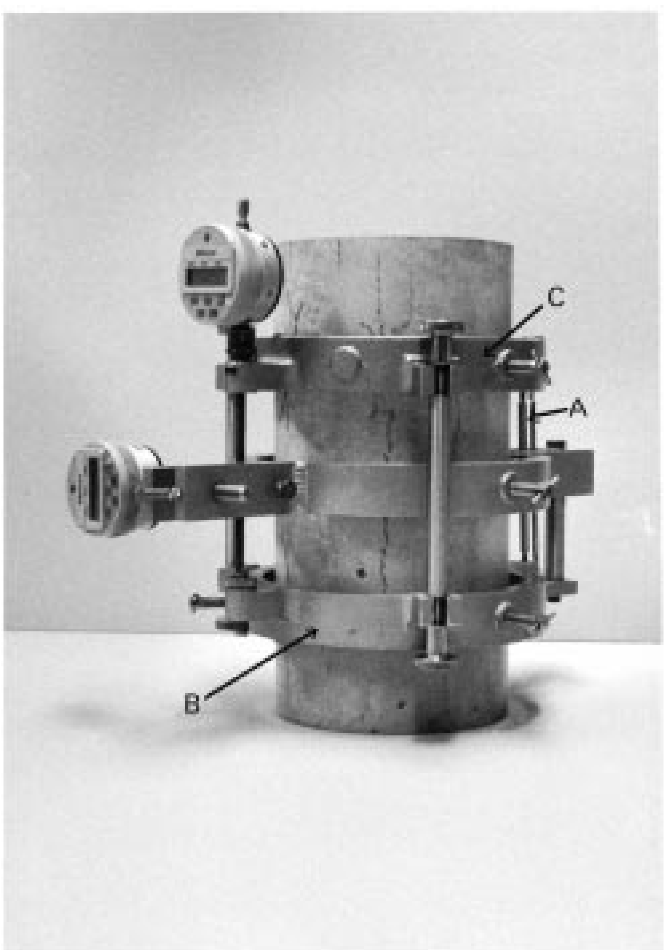
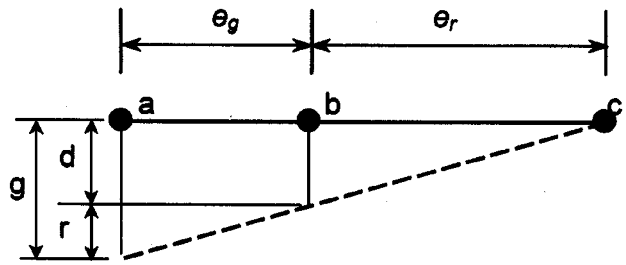


FIG. 1 Suitable Compressometer



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

FIG. 2 Diagram of Displacements

where:

d = total deformation of the specimen throughout the effective gage length, µin. (µm),
g = gage reading, µin. (µm),
e_r = the perpendicular distance, measured in inches (millimetres) to the nearest 0.01 in. (0.254 mm) 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 in inches (millimetres) to the nearest 0.01 in. (0.254 mm) from the gage to the vertical plane passing through the two support points of the rotating yoke.

Procedures for calibrating strain-measuring devices are given in Practice E 83.

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

4.3 *Extensometer*[4]—If Poisson's ratio is desired, the transverse strain shall be determined (*1*) by an unbonded extensometer capable of measuring to the nearest 25 µin. (0.635 µm) the change in diameter at the midheight of the specimen or (*2*) by two bonded strain gages (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 segments) located halfway between the two compressometer yokes and attached to the specimen at two diametrically opposite points. Midway between these points a short pivot rod (*A*′, see Fig. 3), adjacent to the long pivot rod, shall be used to maintain a constant distance between the bottom and middle yokes. The middle yoke shall be hinged 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, the two segments shall be connected through a dial gage or other sensing device capable of measuring transverse deformation to the nearest 50 µin. (1.27 µm). If the distances of the hinge and the gage from the vertical plane passing through the support points of the middle yoke are equal, the transverse deformation of the specimen

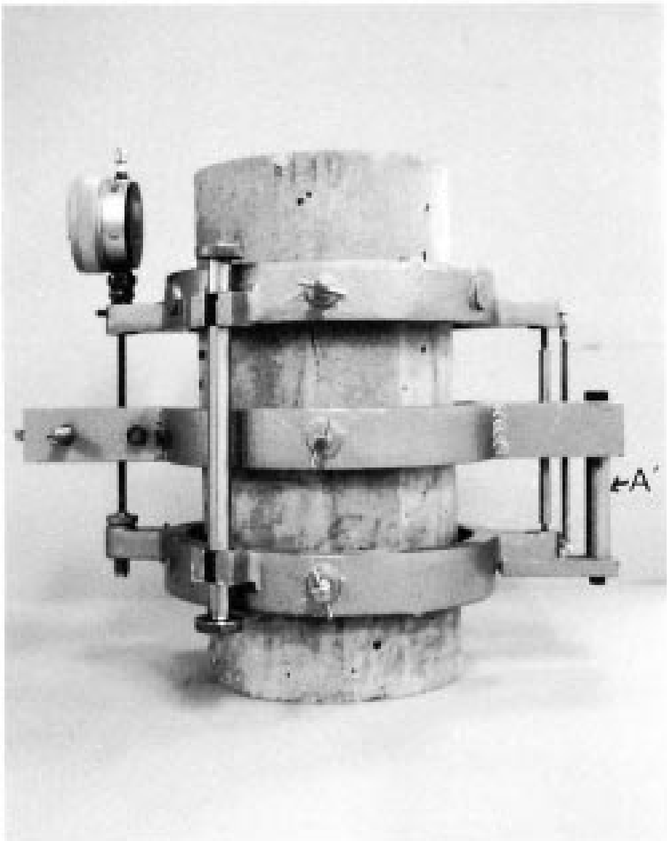


FIG. 3 Suitable Combined Compressometer-Extensometer

diameter is equal to one-half the gage reading. If these distances are not equal, the transverse deformation of the specimen diameter may be calculated in accordance with Eq 2.

$$d' = g'e'_h/(e'_h + e'_g) \quad (2)$$

where:

d' = transverse deformation of the specimen diameter, µin. (µm),
g' = transverse gage reading, µin. (µm),
e'_h = the perpendicular distance, measured in inches (millimeters) to the nearest 0.01 in. (0.254 mm) from the hinge to the vertical plane passing through the support points of the middle yoke, and
e'_g = the perpendicular distance, measured in inches (millimeters) to the nearest 0.01 in. (0.254 mm) from the gage to the vertical plane passing through the support points of the middle yoke.

4.4 *Balance or Scale*, accurate to 0.1 lb (0.045 kg) shall be provided if necessary.

5. Test Specimens

5.1 *Molded Cylindrical Specimens*—Test cylinders shall be molded in accordance with the requirements for compression test specimens in Practice C 192, or in Practice C 31. Specimens shall be subjected to the specified curing conditions and tested at the age for which the elasticity information is desired. Specimens shall be tested 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 C 42, 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 (± 0.5°) and plane (within 0.002 in.). If the specimen as cast does not meet the planeness requirements, planeness shall be accomplished by capping in accordance with Practice C 617, or by lapping, or by grinding. Aggregate popouts which occur at the ends of specimens may be repaired 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 0.002 in. (0.05 mm) feeler gage 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 The diameter of the test specimen shall be measured by caliper to the nearest 0.01 in. (0.25 mm) by averaging two diameters measured at right angles to each other near the center of the length of the specimen. This average diameter shall be used for calculating the cross-sectional area. The length of a molded specimen, including caps, shall be measured and reported to the nearest 0.1 in. (2.54 mm). The length of a drilled specimen shall be measured in accordance with Test Method C 174; the length, including caps, shall be reported to the nearest 0.1 in.

6. Procedure

6.1 Maintain the ambient temperature and humidity as constant as possible throughout the test. Record any unusual fluctuation in temperature or humidity in the report.

6.2 Use companion specimens to determine the compressive strength in accordance with Test Method C 39 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. As the spherically-seated block is brought slowly to bear upon the specimen, rotate the movable portion of the block gently by hand so that uniform seating is obtained.

6.4 Load the specimen at least twice. Do not record any data during the first loading. Base calculations on the average of the results of the subsequent loadings. At least two subsequent loadings are recommended so that the repeatability of the test may be noted. During the first loading, which is primarily for the seating of the gages, observe the performance of the gages (Note 3) and correct any unusual behavior prior to the second loading. Obtain each set of readings as follows: 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 0.05 in. (1.25 mm)/min when the machine is running idle. In hydraulically operated machines, apply the load at a constant rate within the range 35 ± 5 psi (241 ± 34 kPa)/s. Record, without interruption of loading, the applied load and longitudinal strain at the point (*1*) when the longitudinal strain is 50 millionths and (*2*) when the applied load is equal to 40 % of the ultimate load (see 6.5). Longitudinal strain is defined as the total longitudinal deformation divided by the effective gage length. If Poisson's ratio is to be determined, record the transverse strain at the same points. If a stress-strain curve is desired, take readings at two or more intermediate points without interruption of loading; or use an instrument that makes a continuous record. Immediately upon reaching the maximum load, except on the final loading, reduce the load to zero at the same rate at which it was applied. If the observer fails to obtain a reading, complete the loading cycle and then repeat it. Record the extra cycle in the report.

NOTE 3—Where a dial gage is used to measure longitudinal deformation, it is convenient to set the gage before each loading so that the indicator will pass the zero point at a longitudinal strain of 50 millionths.

6.5 The modulus of elasticity and strength may be obtained on the same loading provided that the gages are expendable, removable, or adequately protected so that it is possible to comply with the requirement for continuous loading given in Test Method C 39. In this case record several readings 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 three tests with the longitudinal strain as the abscissa and the compressive stress as the ordinate. Calculate the compressive stress by dividing the quotient of the testing machine load by the cross-sectional area of the specimen determined in accordance with 5.4.

7. Calculation

7.1 Calculate the modulus of elasticity, to the nearest 50 000 psi (344.74 MPa) as follows:

$$E = (S_2 - S_1)/(\epsilon_2 - 0.000050)$$

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

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

$$\mu = (\epsilon_{t2} - \epsilon_{t1})/(\epsilon_2 - 0.000050)$$

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 inches (or millimetres),

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 *Precision*—The single-operator-machine multibatch precision is ± 4.25 % (R1S %) max, as defined in Practice E 177, over the range from 2.5 to 4×10^6 psi (17.3 to 27.6×10^9 Pa); therefore, the results of tests of duplicate cylinders from different batches should not depart more than 5 % from the average of the two.

9.2 *Bias*—This test method has no bias because the values determined can only be defined in terms of the test method.