ASTM INTERNATIONAL
Helping our world work better

ASTM Standards for ACI CP-19, 23rd Edition: Concrete Strength Testing Technician

C39/C39M-18

C78/C78M-18

C617/C617M-15

C1231/C1231M-15

Stock #: CP19ACICMP

Designation: C39/C39M – 18

Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens[1]

This standard is issued under the fixed designation C39/C39M; 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 determination of compressive strength of cylindrical concrete specimens such as molded cylinders and drilled cores. It is limited to concrete having a density in excess of 800 kg/m^3 [50 lb/ft^3].

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The inch-pound units are shown in brackets. 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.*(**Warning—**Means should be provided to contain concrete fragments during sudden rupture of specimens. Tendency for sudden rupture increases with increasing concrete strength and it is more likely when the testing machine is relatively flexible. The safety precautions given in the Manual are recommended.*)*

1.4 The text of this standard references notes which provide explanatory material. These notes shall not be considered as requirements of the standard.

1.5 *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
C42/C42M Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
C125 Terminology Relating to Concrete and Concrete Aggregates
C192/C192M Practice for Making and Curing Concrete Test Specimens in the Laboratory
C617/C617M Practice for Capping Cylindrical Concrete Specimens
C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
C873/C873M Test Method for Compressive Strength of Concrete Cylinders Cast in Place in Cylindrical Molds
C943 Practice for Making Test Cylinders and Prisms for Determining Strength and Density of Preplaced-Aggregate Concrete in the Laboratory
C1077 Practice for Agencies Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Testing Agency Evaluation
C1176/C1176M Practice for Making Roller-Compacted Concrete in Cylinder Molds Using a Vibrating Table
C1231/C1231M Practice for Use of Unbonded Caps in Determination of Compressive Strength of Hardened Cylindrical Concrete Specimens
C1435/C1435M Practice for Molding Roller-Compacted Concrete in Cylinder Molds Using a Vibrating Hammer
C1604/C1604M Test Method for Obtaining and Testing Drilled Cores of Shotcrete
E4 Practices for Force Verification of Testing Machines
E18 Test Methods for Rockwell Hardness of Metallic Materials

[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.

Current edition approved Jan. 1, 2018. Published February 2018. Originally approved in 1921. Last previous edition approved in 2017 as C39/C39M – 17b. DOI: 10.1520/C0039_C0039M-18.

[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.

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

E74 Practice of Calibration of Force-Measuring Instruments for Verifying the Force Indication of Testing Machines
Manual of Aggregate and Concrete Testing

3. Terminology

3.1 *Definitions*—For definitions of terms used in this practice, refer to Terminology C125.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *bearing block, n*—steel piece to distribute the load from the testing machine to the specimen.

3.2.2 *lower bearing block, n*—steel piece placed under the specimen to distribute the load from the testing machine to the specimen.

3.2.2.1 *Discussion*—The lower bearing block provides a readily machinable surface for maintaining the specified bearing surface. The lower bearing block may also be used to adapt the testing machine to various specimen heights. The lower bearing block is also referred to as *bottom block*, *plain block*, and *false platen*.

3.2.3 *platen, n*—primary bearing surface of the testing machine.

3.2.3.1 *Discussion*—The platen is also referred to as the testing machine *table*.

3.2.4 *spacer, n*—steel piece used to elevate the lower bearing block to accommodate test specimens of various heights.

3.2.4.1 *Discussion*—Spacers are not required to have hardened bearing faces because spacers are not in direct contact with the specimen or the retainers of unbonded caps.

3.2.5 *upper bearing block, n*—steel assembly suspended above the specimen that is capable of tilting to bear uniformly on the top of the specimen.

3.2.5.1 *Discussion*—The upper bearing block is also referred to as the *spherically seated block* and the *suspended block*.

4. Summary of Test Method

4.1 This test method consists of applying a compressive axial load to molded cylinders or cores at a rate which is within a prescribed range until failure occurs. The compressive strength of the specimen is calculated by dividing the maximum load attained during the test by the cross-sectional area of the specimen.

5. Significance and Use

5.1 Care must be exercised in the interpretation of the significance of compressive strength determinations by this test method since strength is not a fundamental or intrinsic property of concrete made from given materials. Values obtained will depend on the size and shape of the specimen, batching, mixing procedures, the methods of sampling, molding, and fabrication and the age, temperature, and moisture conditions during curing.

5.2 This test method is used to determine compressive strength of cylindrical specimens prepared and cured in accordance with Practices C31/C31M, C192/C192M, C617/C617M, C943, C1176/C1176M, C1231/C1231M, and C1435/C1435M, and Test Methods C42/C42M, C873/C873M, and C1604/C1604M.

5.3 The results of this test method are used as a basis for quality control of concrete proportioning, mixing, and placing operations; determination of compliance with specifications; control for evaluating effectiveness of admixtures; and similar uses.

5.4 The individual who tests concrete cylinders for acceptance testing shall meet the concrete laboratory technician requirements of Practice C1077, including an examination requiring performance demonstration that is evaluated by an independent examiner.

NOTE 1—Certification equivalent to the minimum guidelines for ACI Concrete Laboratory Technician, Level I or ACI Concrete Strength Testing Technician will satisfy this requirement.

6. Apparatus

6.1 *Testing Machine*—The testing machine shall be of a type having sufficient capacity and capable of providing the rates of loading prescribed in 8.5.

6.1.1 Verify the accuracy of the testing machine in accordance with Practices E4, except that the verified loading range shall be as required in 6.4. Verification is required:

6.1.1.1 Within 13 months of the last calibration,

6.1.1.2 On original installation or immediately after relocation,

6.1.1.3 Immediately after making repairs or adjustments that affect the operation of the force applying system or the values displayed on the load indicating system, except for zero adjustments that compensate for the mass of bearing blocks or specimen, or both, or

6.1.1.4 Whenever there is reason to suspect the accuracy of the indicated loads.

6.1.2 *Design*—The design of the machine must include the following features:

6.1.2.1 The machine must be power operated and must apply the load continuously rather than intermittently, and without shock. If it has only one loading rate (meeting the requirements of 8.5), it must be provided with a supplemental means for loading at a rate suitable for verification. This supplemental means of loading may be power or hand operated.

6.1.2.2 The space provided for test specimens shall be large enough to accommodate, in a readable position, an elastic calibration device which is of sufficient capacity to cover the potential loading range of the testing machine and which complies with the requirements of Practice E74.

NOTE 2—The types of elastic calibration devices most generally available and most commonly used for this purpose are the circular proving ring or load cell.

6.1.3 *Accuracy*—The accuracy of the testing machine shall be in accordance with the following provisions:

6.1.3.1 The percentage of error for the loads within the proposed range of use of the testing machine shall not exceed ±1.0 % of the indicated load.

6.1.3.2 The accuracy of the testing machine shall be verified by applying five test loads in four approximately equal increments in ascending order. The difference between any two successive test loads shall not exceed one third of the difference between the maximum and minimum test loads.

6.1.3.3 The test load as indicated by the testing machine and the applied load computed from the readings of the verification device shall be recorded at each test point. Calculate the error, *E,* and the percentage of error, E_p, for each point from these data as follows:

$$E = A - B \tag{1}$$

$$E_p = 100(A - B)/B$$

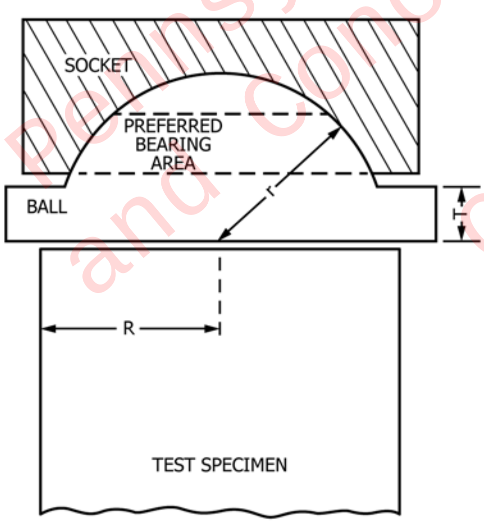
where:

A = load, kN [lbf] indicated by the machine being verified, and
B = applied load, kN [lbf] as determined by the calibrating device.

6.1.3.4 The report on the verification of a testing machine shall state within what loading range it was found to conform to specification requirements rather than reporting a blanket acceptance or rejection. In no case shall the loading range be stated as including loads below the value which is 100 times the smallest change of load estimable on the load-indicating mechanism of the testing machine or loads within that portion of the range below 10 % of the maximum range capacity.

6.1.3.5 In no case shall the loading range be stated as including loads outside the range of loads applied during the verification test.

6.1.3.6 The indicated load of a testing machine shall not be corrected either by calculation or by the use of a calibration diagram to obtain values within the required permissible variation.



$T \geq R - r$
r = radius of spherical portion of upper bearing block
R = nominal radius of specimen
T = thickness of upper bearing block extending beyond the sphere

FIG. 1 Schematic Sketch of Typical Upper Bearing Block

6.2 *Bearing Blocks*—The upper and lower bearing blocks shall conform to the following requirements:

6.2.1 Bearing blocks shall be steel with hardened bearing faces (Note 3).

6.2.2 Bearing faces shall have dimensions at least 3 % greater than the nominal diameter of the specimen.

6.2.3 Except for the inscribed concentric circles described in 6.2.4.7, the bearing faces shall not depart from a plane by more than 0.02 mm [0.001 in.] along any 150 mm [6 in.] length for bearing blocks with a diameter of 150 mm [6 in.] or larger, or by more than 0.02 mm [0.001 in.] in any direction of smaller bearing blocks. New bearing blocks shall be manufactured within one half of this tolerance.

NOTE 3—It is desirable that the bearing faces of bearing blocks have a Rockwell hardness at least 55 HRC as determined by Test Methods E18.

NOTE 4—Square bearing faces are permissible for the bearing blocks.

6.2.4 *Upper Bearing Block*—The upper bearing block shall conform to the following requirements:

6.2.4.1 The upper bearing block shall be spherically seated and the center of the sphere shall coincide with the center of the bearing face within ±5 % of the radius of the sphere.

6.2.4.2 The ball and the socket shall be designed so that the steel in the contact area does not permanently deform when loaded to the capacity of the testing machine.

NOTE 5—The preferred contact area is in the form of a ring (described as *preferred bearing area*) as shown in Fig. 1.

6.2.4.3 Provision shall be made for holding the upper bearing block in the socket. The design shall be such that the bearing face can be rotated and tilted at least 4° in any direction.

6.2.4.4 If the upper bearing block is a two-piece design composed of a spherical portion and a bearing plate, a mechanical means shall be provided to ensure that the spherical portion is fixed and centered on the bearing plate.

6.2.4.5 The diameter of the sphere shall be at least 75 % of the nominal diameter of the specimen. If the diameter of the sphere is smaller than the diameter of the specimen, the portion of the bearing face extending beyond the sphere shall have a thickness not less than the difference between the radius of the sphere and radius of the specimen (see Fig. 1). The least dimension of the bearing face shall be at least as great as the diameter of the sphere.

6.2.4.6 The dimensions of the bearing face of the upper bearing block shall not exceed the following values:

Nominal Diameter of Specimen, mm [in.]	Maximum Diameter of Round Bearing Face, mm [in.]	Maximum Dimensions of Square Bearing Face, mm [in.]
50 [2]	105 [4]	105 by 105 [4 by 4]
75 [3]	130 [5]	130 by 130 [5 by 5]
100 [4]	165 [6.5]	165 by 165 [6.5 by 6.5]
150 [6]	255 [10]	255 by 255 [10 by 10]
200 [8]	280 [11]	280 by 280 [11 by 11]

6.2.4.7 If the diameter of the bearing face of the upper bearing block exceeds the nominal diameter of the specimen by more than 13 mm [0.5 in.], concentric circles not more than 0.8 mm [0.03 in.] deep and not more than 1 mm [0.04 in.] wide shall be inscribed on the face of upper bearing block to facilitate proper centering.

6.2.4.8 At least every six months, or as specified by the manufacturer of the testing machine, clean and lubricate the curved surfaces of the socket and of the spherical portion of the upper bearing block. The lubricant shall be a petroleum-type oil such as conventional motor oil or as specified by the manufacturer of the testing machine.

NOTE 6—To ensure uniform seating, the upper bearing block is designed to tilt freely as it comes into contact with the top of the specimen. After contact, further rotation is undesirable. Friction between the socket and the spherical portion of the head provides restraint against further rotation during loading. Pressure-type greases can reduce the desired friction and permit undesired rotation of the spherical head and should not be used unless recommended by the manufacturer of the testing machine. Petroleum-type oil such as conventional motor oil has been shown to permit the necessary friction to develop.

6.2.5 *Lower Bearing Block*—The lower bearing block shall conform to the following requirements:

6.2.5.1 The lower bearing block shall be solid.

6.2.5.2 The top and bottom surfaces of the lower bearing block shall be parallel to each other.

6.2.5.3 The lower bearing block shall be at least 25 mm [1.0 in.] thick when new, and at least 22.5 mm [0.9 in.] thick after resurfacing.

6.2.5.4 The lower bearing block shall be fully supported by the platen of the testing machine or by any spacers used.

6.2.5.5 If the testing machine is designed that the platen itself is readily maintained in the specified surface condition, a lower bearing block is not required.

NOTE 7—The lower bearing block may be fastened to the platen of the testing machine.

NOTE 8—Inscribed concentric circles as described in 6.2.4.7 are optional on the lower bearing block.

6.3 *Spacers*—If spacers are used, the spacers shall be placed under the lower bearing block and shall conform to the following requirements:

6.3.1 Spacers shall be solid steel. One vertical opening located in the center of the spacer is permissible. The maximum diameter of the vertical opening is 19 mm [0.75 in.].

6.3.2 The top and bottom surfaces of the spacer shall be parallel to each other.

6.3.3 Spacers shall be fully supported by the platen of the test machine.

6.3.4 Spacers shall fully support the lower bearing block and any spacers above.

6.3.5 Spacers shall not be in direct contact with the specimen or the retainers of unbonded caps.

6.4 *Load Indication*—The testing machine shall be equipped with either a dial or digital load indicator.

6.4.1 The verified loading range shall not include loads less than 100 times the smallest change of load that can be read.

6.4.2 A means shall be provided that will record, or indicate until reset, the maximum load to an accuracy within 1.0 % of the load.

6.4.3 If the load is displayed on a dial, the graduated scale shall be readable to at least the nearest 0.1 % of the full scale load (Note 9). The dial shall be readable within 1.0 % of the indicated load at any given load level within the loading range. The dial pointer shall be of sufficient length to reach the graduation marks. The width of the end of the pointer shall not exceed the clear distance between the smallest graduations. The scale shall be provided with a labeled graduation line load corresponding to zero load. Each dial shall be equipped with a zero adjustment located outside the dial case and accessible from the front of the machine while observing the zero mark and dial pointer.

NOTE 9—Readability is considered to be 0.5 mm [0.02 in.] along the arc described by the end of the pointer. If the spacing is between 1 and 2 mm [0.04 and 0.08 in.], one half of a scale interval is considered readable. If the spacing is between 2 and 3 mm [0.08 and 0.12 in.], one third of a scale interval is considered readable. If the spacing is 3 mm [0.12 in.] or more, one fourth of a scale interval is considered readable.

6.4.4 If the load is displayed in digital form, the numbers must be large enough to be read. The numerical increment shall not exceed 0.1 % of the full scale load of a given loading range. Provision shall be made for adjusting the display to indicate a value of zero when no load is applied to the specimen.

6.5 Documentation of the calibration and maintenance of the testing machine shall be in accordance with Practice C1077.

7. Specimens

7.1 Specimens shall not be tested if any individual diameter of a cylinder differs from any other diameter of the same cylinder by more than 2 %.

NOTE 10—This may occur when single use molds are damaged or deformed during shipment, when flexible single use molds are deformed during molding, or when a core drill deflects or shifts during drilling.

7.2 Prior to testing, neither end of test specimens shall depart from perpendicularity to the axis by more than 0.5° (approximately equivalent to 1 mm in 100 mm [0.12 in. in 12 in.]). The ends of compression test specimens that are not plane within 0.050 mm [0.002 in.] shall be sawed or ground to meet that tolerance, or capped in accordance with either Practice C617/C617M or, when permitted, Practice C1231/C1231M. The diameter used for calculating the cross-sectional area of the test specimen shall be determined to the nearest 0.25 mm [0.01 in.] by averaging two diameters measured at right angles to each other at about midheight of the specimen.

7.3 The number of individual cylinders measured for determination of average diameter is not prohibited from being reduced to one for each ten specimens or three specimens per day, whichever is greater, if all cylinders are known to have been made from a single lot of reusable or single-use molds which consistently produce specimens with average diameters within a range of 0.5 mm [0.02 in.]. When the average diameters do not fall within the range of 0.5 mm [0.02 in.] or when the cylinders are not made from a single lot of molds, each cylinder tested must be measured and the value used in calculation of the unit compressive strength of that specimen. When the diameters are measured at the reduced frequency, the cross-sectional areas of all cylinders tested on that day shall be computed from the average of the diameters of the three or more cylinders representing the group tested that day.

7.4 If the purchaser of the testing services or the specifier of the tests requests measurement of the specimen density, determine the specimen density before capping by either 7.4.1

(specimen dimension method) or 7.4.2 (submerged weighing method). For either method, use a balance or scale that is accurate to within 0.3 % of the mass being measured.

7.4.1 Remove any surface moisture with a towel and measure the mass of the specimen. Measure the length of the specimen to the nearest 1 mm [0.05 in.] at three locations spaced evenly around the circumference. Compute the average length and record to the nearest 1 mm [0.05 in.].

7.4.2 Remove any surface moisture with a towel and determine the mass of the specimen in air. Submerge the specimen in water at a temperature of 23.0 ± 2.0°C [73.5 ± 3.5°F] for 15 ± 5 sec. Then, determine the apparent mass of the specimen while submerged under water.

7.5 When density determination is not required and the length to diameter ratio is less than 1.8 or more than 2.2, measure the length of the specimen to the nearest 0.05 D.

8. Procedure

8.1 Compression tests of moist-cured specimens shall be made as soon as practicable after removal from moist storage.

8.2 Test specimens shall be kept moist by any convenient method during the period between removal from moist storage and testing. They shall be tested in the moist condition.

8.3 Tolerances for specimen ages are as follows:

Test Age[A]	Permissible Tolerance
24 h	±0.5 h
3 days	±2 h
7 days	±6 h
28 days	±20 h
90 days	±2 days

[A]For test ages not listed, the test age tolerance is ±2.0% of the specified age.

8.3.1 Unless otherwise specified by the specifier of tests, for this test method the test age shall start at the beginning of casting specimens.

8.4 *Placing the Specimen*—Place the lower bearing block, with the hardened face up, on the table or platen of the testing machine. Wipe clean the bearing faces of the upper and lower bearing blocks, spacers if used, and of the specimen. If using unbonded caps, wipe clean the bearing surfaces of the retainers and center the unbonded caps on the specimen. Place the specimen on the lower bearing block and align the axis of the specimen with the center of thrust of the upper bearing block.

NOTE 11—Although the lower bearing block may have inscribed concentric circles to assist with centering the specimen, final alignment is made with reference to the upper bearing block.

8.4.1 *Zero Verification and Block Seating*—Prior to testing the specimen, verify that the load indicator is set to zero. In cases where the indicator is not properly set to zero, adjust the indicator (Note 12). After placing the specimen in the machine but prior to applying the load on the specimen, tilt the movable portion of the spherically seated block gently by hand so that the bearing face appears to be parallel to the top of the test specimen.

NOTE 12—The technique used to verify and adjust load indicator to zero will vary depending on the machine manufacturer. Consult your owner's manual or compression machine calibrator for the proper technique.

8.4.2 *Verification of Alignment When Using Unbonded Caps*—If using unbonded caps, verify the alignment of the specimen after application of load, but before reaching 10 % of the anticipated specimen strength. Check to see that the axis of the cylinder does not depart from vertical by more than 0.5° (Note 13) and that the ends of the cylinder are centered within the retaining rings. If the cylinder alignment does not meet these requirements, release the load, and carefully recenter the specimen. Reapply load and recheck specimen centering and alignment. A pause in load application to check cylinder alignment is permissible.

NOTE 13—An angle of 0.5° is equal to a slope of approximately 1 mm in 100 mm [⅛ inches in 12 inches]

8.5 *Rate of Loading*—Apply the load continuously and without shock.

8.5.1 The load shall be applied at a rate of movement (platen to crosshead measurement) corresponding to a stress rate on the specimen of 0.25 ± 0.05 MPa/s [35 ± 7 psi/s] (see Note 14). The designated rate of movement shall be maintained at least during the latter half of the anticipated loading phase.

NOTE 14—For a screw-driven or displacement-controlled testing machine, preliminary testing will be necessary to establish the required rate of movement to achieve the specified stress rate. The required rate of movement will depend on the size of the test specimen, the elastic modulus of the concrete, and the stiffness of the testing machine.

8.5.2 During application of the first half of the anticipated loading phase, a higher rate of loading shall be permitted. The higher loading rate shall be applied in a controlled manner so that the specimen is not subjected to shock loading.

8.5.3 Make no adjustment in the rate of movement (platen to crosshead) as the ultimate load is being approached and the stress rate decreases due to cracking in the specimen.

8.6 Apply the compressive load until the load indicator shows that the load is decreasing steadily and the specimen displays a well-defined fracture pattern (Types 1 to 4 in Fig. 2). For a testing machine equipped with a specimen break detector, automatic shut-off of the testing machine is prohibited until the load has dropped to a value that is less than 95 % of the peak load. When testing with unbonded caps, a corner fracture similar to a Type 5 or 6 pattern shown in Fig. 2 may occur before the ultimate capacity of the specimen has been attained. Continue compressing the specimen until the user is certain that the ultimate capacity has been attained. Record the maximum load carried by the specimen during the test, and note the type of fracture pattern according to Fig. 2. If the fracture pattern is not one of the typical patterns shown in Fig. 2, sketch and describe briefly the fracture pattern. If the measured strength is lower than expected, examine the fractured concrete and note the presence of large air voids, evidence of segregation, whether fractures pass predominantly around or through the coarse aggregate particles, and verify end preparations were in accordance with Practice C617/C617M or Practice C1231/C1231M.

9. Calculation

9.1 Calculate the compressive strength of the specimen as follows:

SI units:

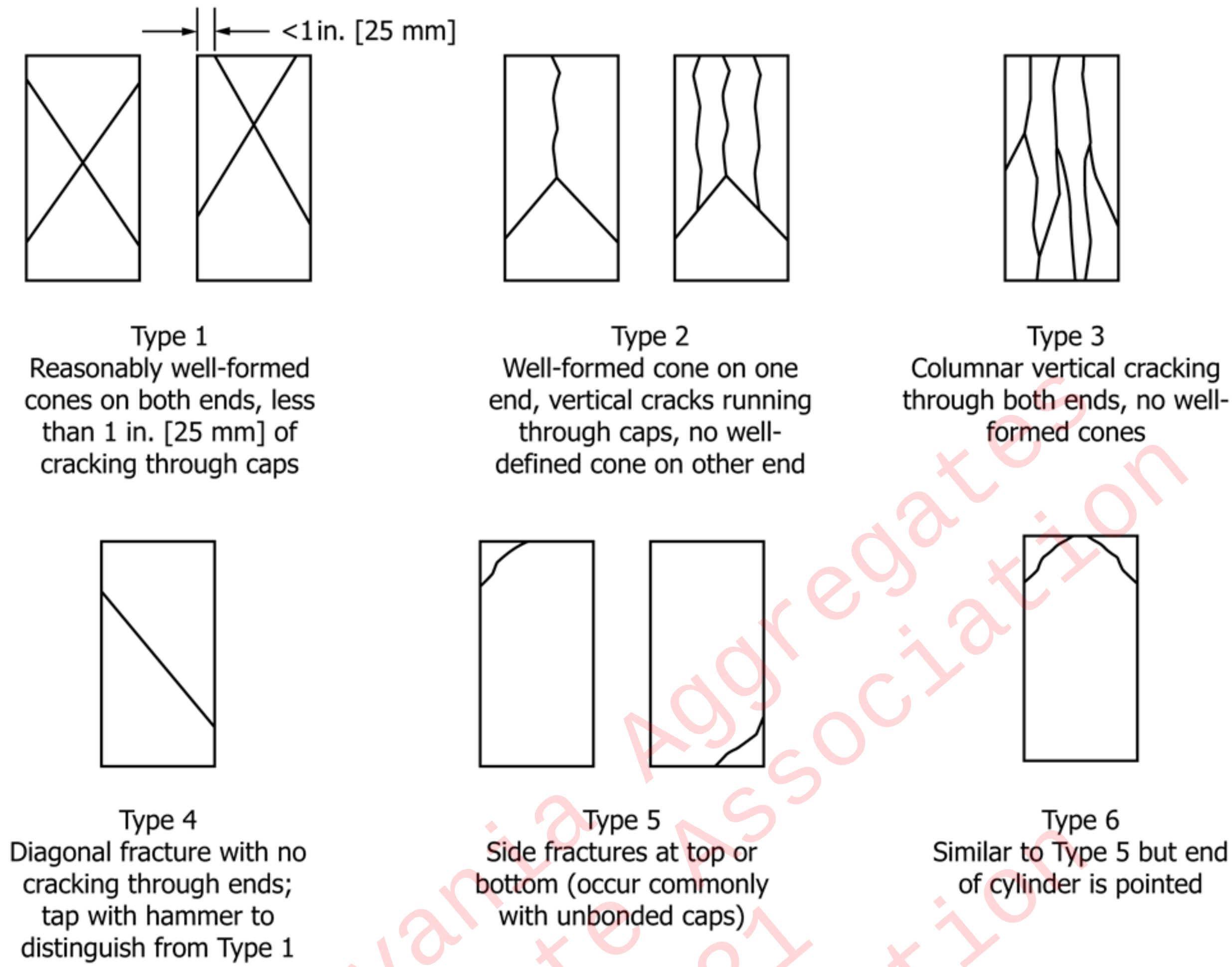


FIG. 2 Schematic of Typical Fracture Patterns

$$f_{cm} = \frac{4000 P_{max}}{\pi D^2} \quad (2)$$

Inch-pound units:

$$f_{cm} = \frac{4 P_{max}}{\pi D^2} \quad (3)$$

where:

f_{cm} = compressive strength, MPa [psi],
P_{max} = maximum load, kN [lbf], and
D = average measured diameter, mm [in.].

9.2 If the specimen length to diameter ratio is 1.75 or less, correct the result obtained in 9.1 by multiplying by the appropriate correction factor shown in the following table:

L/D:	1.75	1.50	1.25	1.00
Factor:	0.98	0.96	0.93	0.87

Use interpolation to determine correction factors for L/D values between those given in the table.

NOTE 15—Correction factors depend on various conditions such as moisture condition, strength level, and elastic modulus. Average values are given in the table. These correction factors apply to low-density concrete weighing between 1600 and 1920 kg/m^3 [100 and 120 lb/ft^3] and to normal-density concrete. They are applicable to concrete dry or soaked at the time of loading and for nominal concrete strengths from 14 to 42 MPa [2000 to 6000 psi]. For strengths higher than 42 MPa [6000 psi] correction factors may be larger than the values listed above[3].

9.3 If required, calculate the specimen density to the nearest 10 kg/m^3 [1 lb/ft^3] using the applicable method.

9.3.1 If specimen density is determined based on specimen dimensions, calculate specimen density as follows:

SI units:

$$\rho_s = \frac{4 \times 10^9 \times W}{L \times D^2 \times \pi} \quad (4)$$

Inch-pound units:

$$\left[\rho_s = \frac{6912 \times W}{L \times D^2 \times \pi} \right] \quad (5)$$

where:

ρ_s = specimen density, kg/m^3 [lb/ft^3],
W = mass of specimen in air, kg [lb],
L = average measured length, mm [in.], and
D = average measured diameter, mm [in.].

9.3.2 If the specimen density is based on submerged weighing, calculate the specimen density as follows:

[3] Bartlett, F.M. and MacGregor, J.G., "Effect of Core Length-to-Diameter Ratio on Concrete Core Strength," *ACI Materials Journal*, Vol 91, No. 4, July-August, 1994, pp. 339–348.

$$\rho_s = \frac{W \times \gamma_w}{W - W_s} \quad (6)$$

where:

ρ_s = specimen density, kg/m^3 [lb/ft^3],
W = mass of specimen in air, kg [lb],
W_s = apparent mass of submerged specimen, kg [lb], and
γ_w = density of water at 23°C [73.5°F] = 997.5 kg/m^3 [62.27 lb/ft^3].

10. Report

10.1 Report the following information:

10.1.1 Identification number,

10.1.2 Average measured diameter (and measured length, if outside the range of 1.8 *D* to 2.2 *D*), in millimetres [inches],

10.1.3 Cross-sectional area, in square millimetres [square inches],

10.1.4 Maximum load, in kilonewtons [pounds-force],

10.1.5 Compressive strength rounded to the nearest 0.1 MPa [10 psi],

10.1.6 If the average of two or more companion cylinders tested at the same age is reported, calculate the average compressive strength using the unrounded individual compressive strength values. Report the average compressive-strength rounded to the nearest 0.1 MPa [10 psi].

10.1.7 Type of fracture (see Fig. 2),

10.1.8 Defects in either specimen or caps,

10.1.9 Age of specimen at time of testing. Report age in days for ages three days or greater, report age in hours if the age is less than three days,

NOTE 16—If software limitations prevent reporting the specimen age in hours, the age of the specimen in hours may be included in a note in the report.

10.1.10 If determined, the density to the nearest 10 kg/m^3 [1 lb/ft^3].

11. Precision and Bias

11.1 *Precision*

11.1.1 *Single-Operator Precision*—The following table provides the single-operator precision of tests of 150 by 300 mm [6 by 12 in.] and 100 by 200 mm [4 by 8 in.] cylinders made from a well-mixed sample of concrete under laboratory conditions and under field conditions (see 11.1.2).

	Coefficient of Variation[4]	Acceptable Range[4] of Individual Cylinder Strengths	
		2 cylinders	3 cylinders
150 by 300 mm [6 by 12 in.]			
Laboratory conditions	2.4 %	6.6 %	7.8 %
Field conditions	2.9 %	8.0 %	9.5 %
100 by 200 mm [4 by 8 in.]			
Laboratory conditions	3.2 %	9.0 %	10.6 %

[4] These numbers represent respectively the (1s %) and (d2s %) limits as described in Practice C670.

11.1.2 The single-operator coefficient of variation represents the expected variation of measured strength of companion cylinders prepared from the same sample of concrete and tested by one laboratory at the same age. The values given for the single-operator coefficient of variation of 150 by 300 mm [6 by 12 in.] cylinders are applicable for compressive strengths between 15 to 55 MPa [2000 to 8000 psi] and those for 100 by 200 mm [4 by 8 in.] cylinders are applicable for compressive strengths between 17 to 32 MPa [2500 and 4700 psi]. The single-operator coefficients of variation for 150 by 300 mm [6 by 12 in.] cylinders are derived from CCRL concrete proficiency sample data for laboratory conditions and a collection of 1265 test reports from 225 commercial testing laboratories in 1978.[5] The single-operator coefficient of variation of 100 by 200 mm [4 by 8 in.] cylinders are derived from CCRL concrete proficiency sample data for laboratory conditions.

11.1.3 *Multilaboratory Precision*—The multi-laboratory coefficient of variation for compressive strength test results of 150 by 300 mm [6 by 12 in.] cylinders has been found to be 5.0 %[4]; therefore, the results of properly conducted tests by two laboratories on specimens prepared from the same sample of concrete are not expected to differ by more than 14 %[4] of the average (see Note 17). A strength test result is the average of two cylinders tested at the same age.

NOTE 17—The multilaboratory precision does not include variations associated with different operators preparing test specimens from split or independent samples of concrete. These variations are expected to increase the multilaboratory coefficient of variation.

11.1.4 The multilaboratory data were obtained from six separate organized strength testing round robin programs where 150 by 300 mm [6 by 12 in.] cylindrical specimens were prepared at a single location and tested by different laboratories. The range of average strength from these programs was 17.0 to 90 MPa [2500 to 13 000 psi].

NOTE 18—Subcommittee C09.61 will continue to examine recent concrete proficiency sample data and field test data and make revisions to precisions statements when data indicate that they can be extended to cover a wider range of strengths and specimen sizes.

11.2 *Bias*—Since there is no accepted reference material, no statement on bias is being made.

12. Keywords

12.1 concrete core; concrete cylinder; concrete specimen; concrete strength; compressive strength; core; cylinder; drilled core; strength

[5] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:C09-1006. Contact ASTM Customer Service at service@astm.org.

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this standard since the last issue (C39/C39M–17b) that may impact the use of this standard. (Approved Jan. 1, 2018)

(1) Added Practice C943 to Referenced Documents and Practice C943 as a source of specimens.

(2) Revised 8.3.

Designation: C78/C78M – 18

Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)[1]

This standard is issued under the fixed designation C78/C78M; 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 the flexural strength of concrete by the use of a simple beam with third-point loading.

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

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

C125 Terminology Relating to Concrete and Concrete Aggregates

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

C293/C293M Test Method for Flexural Strength of Concrete (Using Simple Beam With Center-Point Loading)

C617/C617M Practice for Capping Cylindrical Concrete Specimens

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

C1077 Practice for Agencies Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Testing Agency Evaluation

E4 Practices for Force Verification of Testing Machines

E6 Terminology Relating to Methods of Mechanical Testing

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in this test method, refer to Terminology C125 and Terminology E6.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *flexural strength*—maximum resistance of a specimen subjected to bending.

3.2.1.1 *Discussion*—In this test method, *flexural strength* is reported as the *modulus of rupture*.

3.2.2 *flexural testing apparatus*—fixture used to apply force to the beam specimen and consists of loading and support blocks.

3.2.3 *loading block*—component of the testing apparatus in the shape of a portion of a cylinder that is used to apply a force to the beam specimen.

3.2.4 *modulus of rupture*—calculated stress, assuming linear-elastic behavior, in the tensile face of a beam specimen at the maximum bending moment during a standard test method.

3.2.5 *span length*—distance between lines of support, or reaction, for the beam specimen, and it is equal to three times the nominal depth of the beam.

3.2.5.1 *Discussion*—For example, for a 100 mm [4 in.] nominal depth beam, the span length is 300 mm [12 in.] and for a 150 mm [6 in.] nominal depth beam, the span length is 450 mm [18 in.]. See 3.2.6.1, for discussion of *reaction block*.

[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.

Current edition approved Jan. 1, 2018. Published February 2018. Originally approved in 1930. Last previous edition approved in 2016 as C78/C78M – 16. DOI: 10.1520/C0078_C0078M-18.

[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.

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

3.2.6 *support block*—component of the testing apparatus in the shape of a portion of a cylinder that is used to provide a reaction to the force applied to the beam specimen.

3.2.6.1 *Discussion*—If the testing apparatus applies force to the top of the beam, this block supports the beam. If the testing apparatus applies force to the bottom of the beam, the support block may be considered a reaction block because it provides a line of reaction at the top of the beam and does not support the beam.

3.2.7 *testing machine*—mechanical device for applying force to a specimen.

4. Significance and Use

4.1 This test method is used to determine the flexural strength of specimens prepared and cured in accordance with Test Methods C42/C42M or Practices C31/C31M or C192/C192M. Results are calculated and reported as the modulus of rupture. For the same specimen size, the strength determined will vary if there are differences in specimen preparation, curing procedure, moisture condition at time of testing, and whether the beam was molded or sawed to size.

4.2 The measured modulus of rupture generally increases as the specimen size decreases.[3,4,5]

4.3 The results of this test method may be used to determine compliance with specifications or as a basis for mixture proportioning, evaluating uniformity of mixing, and checking placement operations by using sawed beams. It is used primarily in testing concrete for the construction of slabs and pavements.

4.4 For identical test specimens, the modulus of rupture obtained by this test method will, on average, be lower than that obtained by Test Method C293/C293M.

5. Apparatus

5.1 *Testing Machine*—Hand operated testing machines having pumps that do not provide a continuous loading in one stroke are not permitted. Motorized pumps or hand operated positive displacement pumps having sufficient volume in one continuous stroke to complete a test without requiring replenishment are permitted and shall be capable of applying loads at a uniform rate without shock or interruption. The testing machine shall be equipped with a means of recording or holding the peak value that will indicate the maximum load, to within 1 % accuracy, applied to the specimen during a test.

5.1.1 *Verification:*

5.1.1.1 The testing machine shall conform to the requirements of the sections on Basis of Verification, Corrections, and Time Interval Between Verifications of Practice E4.

5.1.1.2 Verify the accuracy of the testing machine in accordance with Practice E4, except that the verified loading range shall be as required for flexural testing. Verification is required:

(1) Within 13 months of the last verification,

(2) On original installation,

(3) After relocation,

(4) After making repairs or adjustments that affect the operation of the force applying system or the values displayed on the load indicator, except for zero adjustments that compensate for the weight of loading or support blocks or specimen, or both, or

(5) Whenever there is reason to suspect the accuracy of the indicated forces.

5.2 *Flexural Testing Apparatus*—The third point loading method shall be used to determine the flexural strength of concrete. The loading blocks and support blocks shall be designed so that forces applied to the beam will be along lines perpendicular to the side faces of the beam and applied without eccentricity. A diagram of the flexural testing apparatus is shown in Fig. 1.

NOTE 1—The flexural testing apparatus shown in Fig. 1 may be used inverted. In this case, the loading blocks will be at the bottom of the beam, while the reaction blocks will be at the top of the beam.

5.2.1 The flexural testing apparatus shall be capable of maintaining the span length and distance between the lines of loading within ±1.0 mm [±0.05 in.] of the specified values.

5.2.2 The ratio of the horizontal distance between the line of application of the force and the line of the nearest reaction to the depth of the beam shall be 1.0 ± 0.03.

5.2.3 The loading blocks and support blocks shall not be more than 65 mm [2.50 in.] high, measured from the center or the axis of the ball or the axis of the rod and shall extend entirely across or beyond the full width of the specimen. Each case, the block surface in contact with the specimen shall not depart from a plane by more than 0.05 mm [0.002 in.] and shall be a portion of a cylinder, the axis of which is coincidental with either the axis of the rod or center of the ball, whichever the block is pivoted upon. The angle subtended by the curved surface of each block shall be at least 0.80 rad [45°].

5.2.4 At least every six months or as specified by the manufacturer of the flexural testing apparatus, clean and lubricate metal-to-metal contact surfaces, such as internal concave surfaces and steel balls and rods of the loading blocks and support blocks (Fig. 1). The lubricant shall be a petroleum-type oil, such as conventional motor oil, or as specified by the manufacturer of the apparatus.

5.2.5 The support blocks shall be free to rotate.

5.2.6 The loading blocks and support blocks shall be maintained in a vertical position and in contact with the rod or ball by means of spring-loaded screws that hold them in contact with the rod or ball. The uppermost bearing plate and center point ball in Fig. 1 may be omitted if the testing machine has a spherically seated bearing block, provided one rod and one ball are used as pivots for the upper loading blocks.

[3] Tanesi, J; Ardani, A. Leavitt, J. "Reducing the Specimen Size of Concrete Flexural Strength Test (AASHTO T97) for Safety and Ease of Handling," *Transportation Research Record: Journal of the Transportation Research Board*, No. 2342, Transportation Research Board of National Academies, Washington, D.C., 2013.

[4] Carrasquillo, P.M. and Carrasquillo, R. L "Improved Concrete Quality Control Procedures Using Third Point Loading", *Research Report 119-1F*, Project 3-9-87-1119, Center For Transportation Research, The University of Texas at Austin, November 1987.

[5] Bazant, Z. and Novak, D. "Proposal for Standard Test of Modulus of Rupture of Concrete with its Size Dependence," *ACI Materials Journal*, January-February 2001.

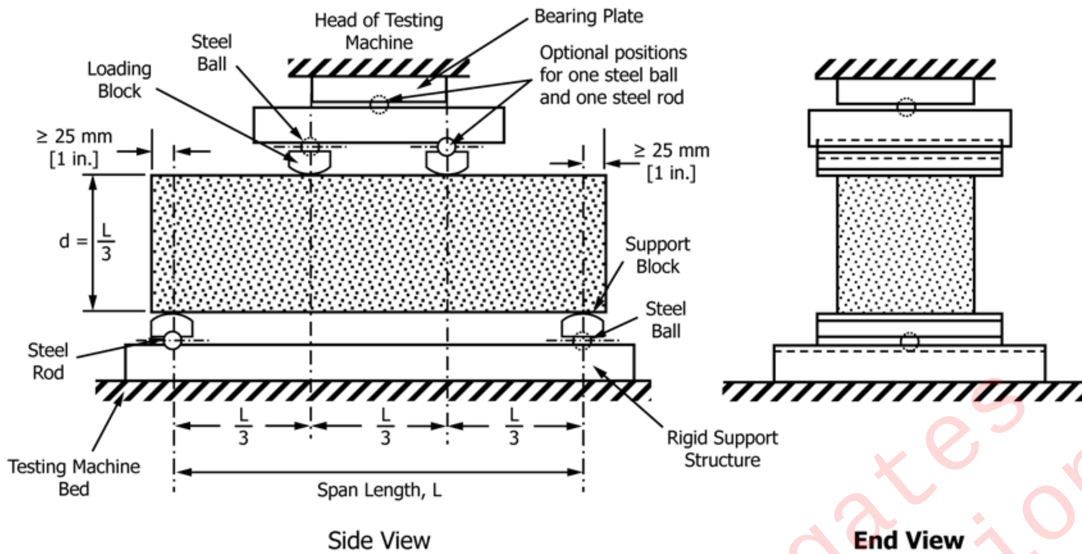


FIG. 1 Schematic of Flexural Testing Apparatus for Third-Point Loading Method

6. Test Specimens

6.1 The test specimen shall conform to all requirements of Test Method C42/C42M or Practices C31/C31M or C192/C192M applicable to beam specimens and shall have a test span within 2 % of being three times its depth as tested. The sides of the specimen shall be at right angles with the top and bottom. All surfaces shall be smooth and free of scars, indentations, holes, or inscribed identification marks.

6.2 Provided the smaller cross-sectional dimension of the beam is at least three times the nominal maximum size of the coarse aggregate, the modulus of rupture can be determined using different specimen sizes. However, measured modulus of rupture generally increases as specimen size decreases.[3,4] (Note 2).

NOTE 2—The strength ratio for beams of different sizes depends primarily on the maximum size of aggregate.[5] Experimental data obtained in two different studies have shown that for maximum aggregate size between 19.0 and 25.0 mm [¾ and 1 in.], the ratio between the modulus of rupture determined with a 150 by 150 mm [6 by 6 in.] and a 100 by 100 mm [4 by 4 in.] may vary from 0.90 to 1.07[3] and for maximum aggregate size between 9.5 and 37.5 mm [⅜ and 1½ in.], the ratio between the modulus of rupture determined with a 150 by 150 mm [6 by 6 in.] and a 115 by 115 mm [4.5 by 4.5 in.] may vary from 0.86 to 1.00.[4]

6.3 The specifier of tests shall specify the specimen size and number of specimens to be tested to obtain an average test result. The same specimen size shall be used for qualification and acceptance testing.

7. Procedure

7.1 Moist-cured specimens shall be kept moist during the period between removal from moist storage and testing.

NOTE 3—Surface drying of the specimen results in a reduction in the measured flexural strength.

NOTE 4—Methods for keeping the specimen moist include wrapping in moist fabric or matting and keeping specimens under lime water in containers near the flexural testing machine until time of testing.

7.2 For molded specimens, turn the test specimen on its side with respect to its position as molded and center it on the support blocks. When using sawed specimens, position the specimen so that the tension face corresponds to the top or bottom of the specimen as cut from the parent material. Center the loading blocks in relation to the applied force. Bring the loading blocks in contact with the surface of the specimen at the third points and apply a force of between 3 and 6 % of the estimated ultimate force. Using 0.10 mm [0.004 in.] and 0.40 mm [0.015 in.] leaf-type feeler gages, determine whether any gap between the specimen and the loading or support blocks is greater or less than each of the gages over a length of 25 mm [1 in.] or more. Grind, cap, or use leather shims on the specimen contact surface to eliminate any gap in excess of 0.10 mm [0.004 in.] in width. Leather shims shall be of uniform 6 mm [0.25 in.] thickness, 25 to 50 mm [1.0 to 2.0 in.] width, and shall extend across the full width of the specimen. Gaps in excess of 0.40 mm [0.015 in.] shall be eliminated only by capping or grinding. Grinding of lateral surfaces shall be minimized because grinding may change the physical characteristics of the specimens. Capping shall be in accordance with the applicable sections of Practice C617/C617M.

7.3 Load the specimen continuously and without shock. The load shall be applied at a constant rate to the breaking point. Apply the load at a rate that constantly increases the maximum stress on the tension face between 0.9 and 1.2 MPa/min [125 and 175 psi/min] until rupture occurs. The loading rate is calculated using the following equation:

$$r = \frac{Sbd^2}{L} \quad (1)$$

where:

r = loading rate, N/min [lb/min],
S = rate of increase in maximum stress on the tension face, MPa/min [psi/min],
b = average width of the specimen as oriented for testing, mm [in.],
d = average depth of the specimen as oriented for testing, mm [in.], and

L = span length, mm [in.].

8. Measurement of Specimens After Test

8.1 To determine the dimensions of the specimen cross section for use in calculating modulus of rupture, take measurements across one of the fractured faces after testing. The width and depth are measured with the specimen as oriented for testing. For each dimension, take one measurement at each edge and one at the center of the cross section. Use the three measurements for each direction to determine the average width and the average depth. Take all measurements to the nearest 1 mm [0.05 in.]. If the fracture occurs at a capped section, include the cap thickness in the measurement.

9. Calculation

9.1 If the fracture initiates in the tension surface within the middle third of the span length, calculate the modulus of rupture as follows:

$$R = \frac{PL}{bd^2} \quad (2)$$

where:

R = modulus of rupture, MPa [psi],
P = maximum applied load indicated by the testing machine, N [lbf],
L = span length, mm [in.],
b = average width of specimen, mm [in.], at the fracture, and
d = average depth of specimen, mm [in.], at the fracture.

NOTE 5—The weight of the beam is not included in the above calculation.

9.2 If the fracture occurs in the tension surface outside of the middle third of the span length by not more than 5 % of the span length, calculate the modulus of rupture as follows:

$$R = \frac{3Pa}{bd^2} \quad (3)$$

where:

a = average distance between line of fracture and the nearest support measured on the tension surface of the beam, mm [in.].

NOTE 6—The weight of the beam is not included in the above calculation.

9.3 If the fracture occurs in the tension surface outside of the middle third of the span length by more than 5 % of the span length, discard the results of the test.

10. Report

10.1 Report the following information:
10.1.1 Identification number,
10.1.2 Average width to the nearest 1 mm [0.05 in.],
10.1.3 Average depth to the nearest 1 mm [0.05 in.],
10.1.4 Span length in mm [in.],
10.1.5 Maximum applied load in N [lbf],
10.1.6 Modulus of rupture calculated to the nearest 0.05 MPa [5 psi],
10.1.7 Curing history and apparent moisture condition of the specimens at the time of test,
10.1.8 If specimens were capped, ground, or if leather shims were used,
10.1.9 Whether sawed or molded and defects in specimens, and
10.1.10 Age of specimens.

11. Precision and Bias

11.1 *Precision:*

11.1.1 *Single-Operator Precision*—The single operator standard deviation for test determinations has been found to be 0.25 MPa [37 psi] and to be independent of the beam sizes used in the interlaboratory study (ILS) (Note 7). Therefore, the modulus of rupture from two properly conducted tests by the same operator on specimens of the same material (same batch of concrete), using the same size specimen (100-mm [4-in.] or 150-mm [6-in.] deep beams), is not expected to differ by more than 0.72 MPa [104 psi].[6]

11.1.2 *Multi-Laboratory Precision*—The multilaboratory coefficient of variation for test determinations has been found to be as shown in the third column of Table 1. The coefficient of variation was found to be similar for both specimen sizes used in the ILS for modulus of rupture between 4.2 and 5.5 MPa [600 and 800 psi]. A higher multilaboratory coefficient of variation was observed for 100-mm [4-in.] deep beams for modulus of rupture near 6.9 MPa [1000 psi]. Therefore, the modulus of rupture from two properly conducted tests by two different laboratories on specimens of the same material (same batch of concrete) and beam size are not expected to differ from each other by more than the value in the fourth column of Table 1. The acceptable difference between two test determinations is expressed as a percentage of their average.

NOTE 7—The precision of this test method was determined from an interlaboratory study conducted in 2016. The study involved three concrete mixtures with modulus of rupture values of approximately 4.1 MPa [600 psi], 5.5 MPa [800 psi] and 6.9 MPa [1000 psi]. Two beam sizes were used: 100 by 100 by 355 mm [4 by 4 by 14 in.] and 150 by 150 by 533 mm [6 by 6 by 21 in.]. Three test determinations were conducted for each combination of specimen size and concrete mixture. The number of laboratories used for determining the precision varied from 10 to 17 depending on the concrete mixture and beam size. The data used to develop the precision statement were obtained using the inch-pound

[6] This number represents the difference limit (d2s) as described in Practice C670.

TABLE 1 Multilaboratory Precision

Beam Depth, in. [mm]	Modulus of Rupture, psi [MPa]	Coefficient of Variation	Acceptable Difference Between Two Test Determinations (percentage of their average)[A]
100 mm [4 in.]	4.1 to 5.5 MPa [600 to 800 psi]	6.1 %	17.1 %
100 mm [4 in.]	6.9 MPa [1000 psi]	11.4 %	31.8 %
150 mm [6 in.]	4.1 to 6.9 MPa [600 to 1000 psi]	6.9 %	19.3 %

[A] These numbers represent the difference limit (d2s%) as described in Practice C670.

version of this test method. The precision indexes shown in SI units are exact conversions of the values in inch-pound units. Supporting data have been filed at ASTM Headquarters and may be obtained by requesting Research Report RR:C09-1050.[7]

NOTE 8—The results for each test condition (specimen size and concrete strength) include data from 3 to 5 laboratories that used hand operated testing machines with paper charts for reading the ultimate force. For the 100-mm [4-in.] deep beams, these machines resulted in higher single-operator variability in mixtures with strengths between 4.1 to 5.5 MPa [600 and 800 psi], as well as higher multilaboratory variability in all mixtures. For the 150-mm [6-in.] deep beams, these machines resulted in higher variability only for the mixture with flexural strength of approximately 6.9 MPa [1000 psi]. Refer to Research Report RR:C09-1050 (Appendix J) for a discussion of possible reasons why these machines may have resulted in higher variability.

[7] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:C09-1050. Contact ASTM Customer Service at service@astm.org.

11.2 *Bias*—Because there is no accepted standard for determining bias in this test method, no statement on bias is made.

12. Keywords

12.1 beams; concrete; flexural strength testing; modulus of rupture

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C78/C78M – 16, that may impact the use of this test method. (Approved Jan. 1, 2018.)

(1) Revised Sections 2 and 7.2.
(2) Added Sections 3 and 4.4.
(3) Revised 5.1.
(4) Added 5.1.1.
(5) Revised 5.2 and its subsections.
(6) Revised Fig. 1.
(7) Added Note 1.
(8) Deleted existing Notes 2, 7, and 8.
(9) Revised 4.2, 6.3, and 11.1.
(10) Added Table 1 and Notes 7 and 8.
(11) Added 5.2.4.

INTERNATIONAL

Designation: C617/C617M − 15

Standard Practice for Capping Cylindrical Concrete Specimens[1]

This standard is issued under the fixed designation C617/C617M; 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 practice covers apparatus, materials, and procedures for capping freshly molded concrete cylinders with neat cement and hardened cylinders and drilled concrete cores with high-strength gypsum paste or sulfur mortar.

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 and health practices and determine the applicability of regulatory limitations prior to use.* For specific precaution statements see 4.3.1 and 6.2.4.1.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C109/C109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)

C150 Specification for Portland Cement

C472 Test Methods for Physical Testing of Gypsum, Gypsum Plasters and Gypsum Concrete

C595 Specification for Blended Hydraulic Cements

C1231/C1231M Practice for Use of Unbonded Caps in Determination of Compressive Strength of Hardened Concrete Cylinders

2.2 *ANSI Standard:*[3]

B46.1 Standard for Surface Texture (Surface, Roughness, Waviness and Lay)

3. Significance and Use

3.1 This practice describes procedures for providing plane surfaces on the ends of freshly molded concrete cylinders, hardened cylinders, or drilled concrete cores when the end surfaces do not conform with the planeness and perpendicularity requirements of applicable standards. Practice C1231/C1231M describes alternative procedures using unbonded caps or pad caps.

4. Capping Equipment

4.1 *Capping Plates*—Neat cement caps and high-strength gypsum-paste caps shall be formed against a glass plate at least 6 mm [¼ in.] thick, a machined metal plate at least 11 mm [0.45 in.] thick, or a polished plate of granite or diabase at least 75 mm [3 in.] thick. Sulfur mortar caps shall be formed against similar metal or stone plates except that the recessed area which receives molten sulfur shall not be deeper than 12 mm [½ in.]. In all cases, plates shall be at least 25 mm [1 in.] greater in diameter than the test specimen and the working surfaces shall not depart from a plane by more than 0.05 mm [0.002 in.] in 150 mm [6 in.]. The surface roughness of newly finished metal plates shall not exceed that set forth in Table 4 of American National Standard B46.1, or 3.2 µm [125 µin.] for any type of surface and direction of lay. The surface, when new, shall be free of gouges, grooves, or indentations beyond those caused by the finishing operation. Metal plates that have been in use shall be free of gouges, grooves, and indentations greater than 0.25 mm [0.010 in.] deep or greater than 30 mm^2 [0.05 $in.^2$] in surface area.

NOTE 1—A Rockwell hardness of 48 HRC is suggested for capping plates of devices used to form sulfur mortar caps.

4.2 *Alignment Devices*—Suitable alignment devices, such as guide bars or bull's-eye levels, shall be used in conjunction with capping plates to ensure that no single cap will depart from perpendicularity to the axis of a cylindrical specimen by

[1] This practice 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.

Current edition approved April 1, 2015. Published May 2015. Originally approved in 1968. Last previous edition approved in 2012 as C617/C617M – 12. DOI: 10.1520/C0617_C0617M-15.

[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 American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

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

more than 0.5° (See Note 2). The same requirement is applicable to the relationship between the axis of the alignment device and the surface of a capping plate when guide bars are used. In addition, the location of each bar with respect to its plate must be such that no cap will be off-centered on a test specimen by more than 2 mm [1⁄16 in.].

NOTE 2—A deviation from perpendicularity of 0.5° is equal to a slope of approximately 1 mm in 100 mm [1⁄8 in. in 12 in.].

4.3 *Melting Pots for Sulfur Mortars*—Pots used for melting sulfur mortars shall be equipped with automatic temperature controls and shall be made of metal or lined with a material that is nonreactive with molten sulfur.

4.3.1 **Warning**—Melting pots equipped with peripheral heating will ensure against accidents during reheating of cooled sulfur mixture that have a crusted-over surface. When using melting pots not so equipped, a build-up of pressure under the hardened surface crust on subsequent reheating may be avoided by use of a metal rod that contacts the bottom of the pot and projects above the surface of the fluid sulfur mix as it cools. The rod should be of sufficient size to conduct enough heat to the top on reheating to melt a ring around the rod first and thus avoid the development of pressure. A large metal ladle can be substituted for the rod.

4.3.1.1 Use sulfur melting pots in a hood to exhaust the fumes to outdoors. Heating over an open flame is dangerous because the flash point of sulfur is approximately 207°C [405°F] and the mixture can ignite due to overheating. If the mixture starts to burn, covering will snuff out the flame. Recharge the pot with fresh material after the flame has been extinguished.

5. Capping Materials

5.1 The strength of the capping material and the thickness of the caps shall conform to the requirements of Table 1.

5.1.1 If sulfur mortar, high strength gypsum paste and other materials except neat cement paste are to be used to test concrete with a strength greater than 50 MPa [7000 psi] and their compressive strength is less than the cylinder compressive strength, the manufacturer or the user of the material must provide documentation:

5.1.1.1 That the average strength of 15 cylinders capped with the material is not less than 98 % of the average strength of 15 companion cylinders capped with neat cement paste or 15 cylinders ground plane to within 0.05 mm [0.002 in.].

TABLE 1 Compressive Strength and Maximum Thickness of Capping Materials

Cylinder Compressive Strength MPa [psi]	Minimum Strength of Capping Material	Maximum Average Thickness of Cap	Maximum Thickness Any Part of Cap
3.5 to 50 MPa [500 to 7000 psi]	35 MPa [5000 psi] or cylinder strength whichever is greater	6 mm [1⁄4 in.]	8 mm [5⁄16 in.]
greater than 50 MPa [7000 psi]	Compressive strength not less than cylinder strength, except as provided in 5.1.1	3 mm [1⁄8 in.]	5 mm [3⁄16 in.]

5.1.1.2 That the standard deviation of the strengths of the capped cylinders is not greater than 1.57 times that of the standard deviation of the reference cylinders.

5.1.1.3 That the cap thickness requirements were met in the qualification tests, and

5.1.1.4 Of the hardening time of the caps used in the qualification tests.

5.1.2 Additionally, the qualification test report must include the compressive strength of 50 mm [2 in.] cubes of the material qualified and of neat cement paste cubes, if used. Capping materials conforming to these requirements is permitted to be used for cylinders with strengths up to 20 % greater than the concrete tested in these qualification tests. The manufacturer must requalify lots of material manufactured on an annual basis or whenever there is a change in the formulation or the raw materials. The user of the material must retain a copy of the qualification results, and the dates of manufacture of material qualified and of the material currently being used.

NOTE 3—Table 2 is an example of a report of test results to qualify a capping material.

5.1.3 The compressive strength of capping materials shall be determined by testing 50 mm [2 in.] cubes following the procedure described in Test Method C109/C109M. Except for sulfur mortars, molding procedures shall be as in Test Method C109/C109M unless other procedures are required to eliminate large entrapped air voids. See Test Methods C472 for alternative compaction procedures. Cure cubes in the same environment for the same length of time as the material used to cap specimens.

5.1.4 The strength of the capping material shall be determined on receipt of a new lot and at intervals not exceeding three months. If a given lot of the capping material fails to conform to the strength requirements, it shall not be used, and strength tests of the replacement material shall be made weekly until four consecutive determinations conform to specification requirements.

5.2 *Neat Hydraulic Cement Paste:*

5.2.1 Make qualification tests of the neat hydraulic cement paste prior to use for capping to establish the effects of water-cement ratio and age on compressive strength of 50 mm [2 in.] cubes.

NOTE 4—The cements used generally conform to Specification C150 Types I, II or III; however, Specification C595 blended cements, calcium aluminate or other hydraulic cements producing acceptable strength may be used.

5.2.2 Mix the neat cement paste to the desired consistency at a water-cement ratio equal to or less than that required to produce the required strength, generally 2 to 4 h before the paste is to be used (Note 5). Remix as necessary to maintain acceptable consistency (Note 6). Some retempering of the paste is acceptable if the required water-cement ratio is not exceeded. Optimum consistency is generally produced at water-cement ratios of 0.32 to 0.36 by mass for Type I and Type II cements and 0.35 to 0.39 by mass for Type III cements.

NOTE 5—Freshly mixed pastes tend to bleed, shrink, and make unacceptable caps. The 2 to 4 h period is generally appropriate for portland cements.

TABLE 2 Example of Report of Qualification of a Capping Material

NOTE 1—Manufacturer: Testing Supplies Co.
Capping Material: Super Strong AAA-Sulfur mortar
Lot: 12a45 Date Tested: 11/3/XX
Signed by:_____________________________ (testing agency and responsible official)

Item	Capping Material	Control Cylinders	Ratio Cap/Control	Criteria	Pass/Fail
	Concrete Cylinder Test Data				
Type of capping material	Sulfur	Ground			
Average Concrete Strength, psi	11 061	11 008	1.005	>0.98	Pass
Standard Deviation, psi	376	250	1.504	≤1.57	Pass
Number of cylinders tested	15	15			
Cap age when cylinders tested	7 days	na			
	Capping Material Test Data				
Average cap thickness, in.	0.11	na			
Compressive strength of 2 in. cubes, psi	12 195				
Cube age when tested.	7 days				
Maximum concrete strength qualified, psi				1.2 Av. Str = 13 273[A]	

[A] Nominally a specified strength of 11 000 psi and perhaps somewhat higher.

NOTE 6—The required consistency of the paste is determined by the appearance of the cap when it is stripped. Fluid paste results in streaks in the cap. Stiff paste results in thick caps.

5.3 *High-Strength Gypsum Cement Paste:*

5.3.1 No fillers or extenders may be added to neat high-strength gypsum cement paste subsequent to the manufacture of the cement. (Note 7) Qualification tests shall be made to determine the effects of water-cement ratio and age on compressive strength of 50 mm [2 in.] cubes. Retarders may be used to extend working time, but their effects on required water-cement ratio and strength must be determined. (Note 8)

NOTE 7—Low-strength molding plaster, plaster of paris, or mixtures of plaster of paris and portland cement are unsuitable for capping.

NOTE 8—The water-gypsum cement ratio should be between 0.26 and 0.30. Use of low water-cement ratios and vigorous mixing will usually permit development of 35 MPa [5000 psi] at ages of 1 or 2 h. Higher water-gypsum cement ratios extend working time, but reduce strength.

5.3.2 Mix the neat gypsum cement paste at the desired water-cement ratio and use it promptly since it sets rapidly.

5.4 *Sulfur Mortar:*

5.4.1 Proprietary or laboratory prepared sulfur mortars are permitted if allowed to harden a minimum of 2 h before testing concrete with strength less than 35 MPa [5000 psi]. For concrete strengths of 35 MPa [5000 psi] or greater, sulfur mortar caps must be allowed to harden at least 16 h before testing, unless a shorter time has been shown to be suitable as specified in 5.1.1.

5.4.2 *Determination of Compressive Strength*—Prepare test specimens using a cube mold and base plate conforming to the requirements of Test Method C109/C109M and a metal cover plate conforming in principle to the design shown in Fig. 1 (Note 9). Bring the various parts of the apparatus to a temperature of 20 to 30°C [68 to 86°F], lightly coat the surfaces that will be in contact with the sulfur mortar with mineral oil, and assemble near the melting pot. Bring the temperature of the molten-sulfur mortar in the pot within a range of 130 to 145°C [265 to 290°F], stir thoroughly, and begin casting cubes. Using a ladle, or other suitable pouring device, quickly fill each of the three compartments until the molten material reaches the top of the filling hole. Allow sufficient time for maximum shrinkage, due to cooling, and solidification to occur (approximately 15 min) and refill each hole with molten material (Note 10). After solidification is complete, remove the cubes from the mold without breaking off the knob formed by the filling hole in the cover plate. Remove oil, sharp edges, and fins from the cubes and check the planeness of the bearing surfaces in the manner described in Test Method C109/C109M. After storage at room temperature to the desired age, but not less than 2 h, test cubes in compression following the procedure described in Test Method C109/C109M, and calculate the compressive strength.

NOTE 9—If desired, a 3-mm [⅛ in.] thick plate of thermosetting plastic (such as phenol formaldehyde), provided with three appropriately spaced filling holes, may be inserted between the cover plate and the mold to slow the rate of cooling of test specimens.

NOTE 10—The second filling helps to prevent the formation of a large void or shrinkage pipe in the body of a cube. However, such defects may occur no matter how much care is exercised, and it therefore is advisable to inspect the interior of tested sulfur mortar cubes for homogeneity whenever the strength values obtained are significantly lower than anticipated.

6. Capping Procedures

6.1 *Freshly Molded Cylinders*—Use only neat portland cement pastes (Note 11) to cap freshly molded cylinders. Make caps as thin as practicable. Do not apply the neat paste to the exposed end until the concrete has ceased settling in the molds, generally from 2 to 4 h after molding. During the molding of the cylinder, strike off the upper end even with or slightly below the plane of the rim of the mold. Remove free water and laitance from the top of the specimen immediately before capping. Form the cap by placing a conical mound of paste on the specimen and then gently pressing a freshly oiled capping plate on the conical mound until the plate contacts the rim of the mold. A very slight twisting motion may be required to extrude excess paste and minimize air voids in the paste. The capping plate must not rock during this operation. Carefully cover the capping plate and mold with a double layer of damp burlap and a polyethylene sheet to prevent drying. Removal of

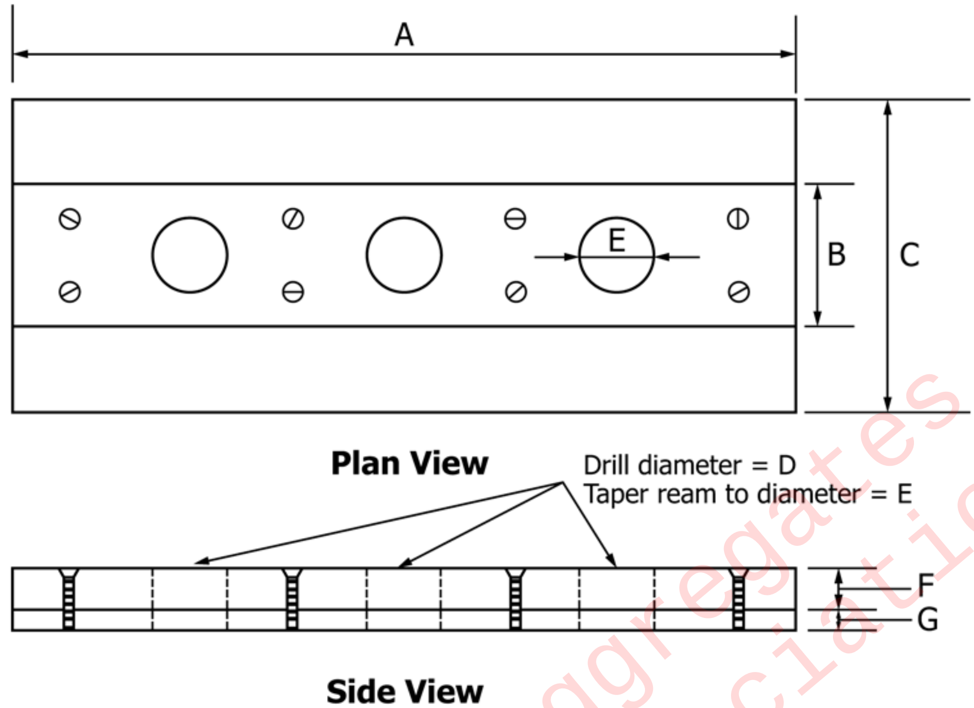


TABLE 1 Table of Dimensions

Label	A	B	C	D	E	F	G
Dimension, mm [in.]	255 [10]	45 [1¾]	100 [4]	22 [⅞]	24 [15⁄16]	12 [½]	6 [¼]

FIG. 1 Sketch of Cover Plate for 50-mm [2-in.] Cube Mold

the capping plate after hardening may be accomplished by tapping the edge with a rawhide hammer in a direction parallel to the plane of the cap.

NOTE 11—Type I neat cement caps generally require at least 6 days to develop acceptable strength and Type III neat cement caps at least 2 days. Dry concrete specimens will absorb water from freshly mixed neat cement paste and produce unsatisfactory caps. Neat cement paste caps will shrink and crack on drying and, therefore, should be used only for specimens that are to be moist cured continuously until time of testing.

NOTE 12—High-strength gypsum caps soften and deteriorate on contact with water and cannot be used on freshly mixed concrete or stored in a moist room for more than very brief periods.

6.2 *Hardened Concrete Specimens:*

6.2.1 *General*—If an end of a specimen has a coating or deposit of oily or waxy materials that would interfere with the bond of the cap, remove such coatings or deposits. If necessary, the ends of a specimen may be slightly roughened with a steel file or wire brush to produce proper adhesion of the cap. If desired, capping plates may be coated with a thin layer of mineral oil or grease to prevent the capping material from adhering to the surface of the plate.

6.2.2 *End Condition*—The distance of any point on an uncapped end from a plane that passes through the highest point of the end surface and is perpendicular to the axis of the cylinder shall not exceed 3 mm [⅛ in.] (Note 13). If the end exceeds this limit, the end of the cylinder shall be cut, lapped or ground prior to capping.

NOTE 13—This provision is to control the difference between the thickest and thinnest parts of a cap. The distance may be checked using a square with one blade touching the cylinder parallel to the cylinder axis and the other blade touching the highest point on the end of the cylinder. The distance between the blade of the square and the lowest point on the end of the cylinder is measured.

6.2.3 *Capping with High-Strength Gypsum Paste or Neat Cement Paste*—Mix the paste as described in 5.2 and 5.3. Do not exceed the water-cement ratio determined in qualification tests. Form the caps as described in 6.1 using capping plates described in 4.1 to achieve the alignment required in 4.2 (Note 14). Generally, capping plates may be removed within 45 min with gypsum cement pastes and after 12 h with neat cement paste, without visibly damaging the cap.

NOTE 14—A number of methods have been used to obtain the desired perpendicularity of the cap to the axis of the cylinder. A mound of paste can be placed on a capping plate and the specimen lowered into it. A bull's-eye level on the top of the cylinder helps obtain alignment. A mound of paste can be placed on top of the cylinder and a capping plate pressed into it, again using the bull's-eye level. A better system is to make a half-height mold with a vertical split so that it can be slipped over the hardened cylinder. A clamp is used to position the mold and to ensure the required cap thickness. The mound of paste can then be placed either on a capping plate or on top of the cylinder and pressed until the plate contacts the mold. As Noted earlier, very stiff paste may require excessive pressure and produce thick or defective caps.

6.2.4 *Capping with Sulfur Mortar*—Prepare sulfur mortar for use by heating to a temperature between 130 to 145°C [265 to 290°F] as determined by an all-metal thermometer inserted near the center of the mass. Check the temperature at approximately hourly intervals during capping. Empty the pot and recharge with fresh material at intervals to ensure that the oldest material in the pot has not been used more than five times. When capping concrete cylinders with a compressive strength of 35 MPa [5000 psi] or greater, it is not permitted to reuse compound recovered from the capping operation or old caps. Fresh sulfur mortar must be dry at the time it is placed in the pot as dampness may cause foaming. Keep water away from molten sulfur mortar for the same reason. The capping plate or device should be warmed before use to slow the rate of hardening and permit the production of thin caps. Oil the capping plate lightly and stir the molten sulfur mortar immediately prior to pouring each cap. The ends of moist cured specimens shall be dry enough at the time of capping to preclude the formation of steam or foam pockets under or in the cap larger than 6 mm [¼ in.] in diameter. Replace caps with steam pockets or voids larger than 6 mm [¼ in.] (Note 15). To ensure that the cap is bonded to the surface of the specimen, the end of the specimen shall not be oiled prior to the application of the cap. When using a vertical device, pour the mortar onto the surface of the capping plate, lift the cylinder above the plate and contact the cylinder sides with the guides, slide the cylinder down the guides onto the capping plate while keeping constant contact with the alignment guides. The cylinder end should continue to rest on the capping plate with cylinder sides in positive contact with the alignment guides until the mortar has hardened. Use sufficient material to cover the cylinder end after the sulfur mortar solidifies.

NOTE 15—Periodically, the sulfur mortar cap should be examined after testing for air or steam pockets in the cap. Before testing, the cap can be tapped with a coin or rubbed with a light metal implement to see if a hollow sound can be detected. Caps with hollow areas should be removed and recapped.

6.2.4.1 **Warning—**Hydrogen sulfide gas may be produced during capping when sulfur mortar is contaminated with organic materials such as paraffin or oil. The gas is colorless and has a notoriously bad odor of rotten eggs; however, the odor should not be relied upon as a warning sign, since the sensitivity to the odor disappears rapidly on exposure. High concentrations are lethal and less concentrated dosages may produce nausea, stomach distress, dizziness, headache, or irritation of the eyes. For this and other reasons, the melting pot must be located under a hood with an exhaust fan and that capping area must be well ventilated.

6.2.5 *Daily Check:*

6.2.5.1 During each day's capping operation, check the planeness of the caps prior to compression testing on at least three specimens, selected at random, representing the start, middle, and end of the run. Check planeness with a straightedge and feeler gage, making a minimum of three measurements on different diameters to ensure that the surface of the caps do not depart from a plane by more than 0.05 mm [0.002 in.]. Check also for hollow areas (Note 15). Record the results of these determinations in the quality control documentation for the laboratory. If caps fail to satisfy the planeness requirement or have hollow areas, remove and reapply the caps.

6.2.5.2 During each day's compressive strength testing operation, check the thickness of caps on at least three specimens, selected at random, from the start, middle, and end of that day's operation. After completing the compression test, recover at least six pieces of capping material from the top of the selected specimen (Note 16). The pieces shall be selected at random and be distributed over the entire area of the cap. The selected pieces shall have debonded completely from the concrete. Measure and record the thicknesses of the pieces to the nearest 0.2 mm [0.01 in.] using a micrometer, caliper or other thickness measurement device. Compare the average and maximum thicknesses with the values in Table 1. Record the results of the thickness determinations in the quality control documentation for the laboratory.

NOTE 16—Caps may be removed by using a hammer and sharp chisel. Place the chisel tip at the bond line and nearly parallel with the plane of the cap so as to create a wedging action when the chisel is struck with the hammer. Recovery of the entire cap may be simplified by placing duct tape over the cap prior to attempting its removal. The tape will keep the pieces of capping material from being dispersed during removal and will simplify the selection of pieces uniformly distributed over the cap area.

7. Protection of Specimens After Capping

7.1 Maintain moist cured specimens in a moist condition between the completion of capping and the time of testing by returning them to moist storage or wrapping them with a double layer of wet burlap. Do not store specimens with high-strength gypsum paste caps immersed in water or for more than 4 h in a moist room. Protect gypsum paste caps from dripping water.

7.2 Do not test capped specimens before the capping material has sufficient time to develop the strength required in 5.1.

8. Keywords

8.1 capping; concrete; compressive strength; cores; cylinders; gypsum cement paste; neat hydraulic cement paste; sulfur mortar

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this practice since the last issue, C617/C617M – 12, that may impact the use of this practice. (Approved April 1, 2015.)

(1) Revised 5.4.2 and 6.2.4.

Designation: C1231/C1231M – 15

Standard Practice for Use of Unbonded Caps in Determination of Compressive Strength of Hardened Cylindrical Concrete Specimens[1]

This standard is issued under the fixed designation C1231/C1231M; 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 practice covers requirements for a capping system using unbonded caps for testing concrete cylinders molded in accordance with Practice C31/C31M or C192/C192M, or cores obtained in accordance with Test Method C42/C42M. *Unbonded neoprene caps of a defined hardness are permitted to be used for testing for a specified maximum number of reuses without qualification testing up to a certain concrete compressive strength level. Above that strength, level neoprene caps will require qualification testing. Qualification testing is required for all elastomeric materials other than neoprene regardless of the concrete strength.*

1.2 Unbonded caps are not to be used for acceptance testing of concrete with compressive strength below 10 MPa [1500 psi] or above 80 MPa [12 000 psi].

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 non-conformance with the standard.

1.4 *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.* (**Warning—** Concrete specimens tested with unbonded caps rupture more violently than comparable specimens tested with bonded caps. The safety precautions given in the Manual of Aggregate and Concrete Testing are recommended.[2])

2. Referenced Documents

2.1 *ASTM Standards:*[3]

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

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

C617 Practice for Capping Cylindrical Concrete Specimens

D2000 Classification System for Rubber Products in Automotive Applications

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *pad, n*—an unbonded elastomeric pad.

3.1.2 *unbonded cap, n*—a metal retainer and an elastomeric pad.

4. Significance and Use

4.1 This practice provides for using an unbonded capping system in testing hardened concrete cylinders made in accordance with Practices C31/C31M or C192/C192M, or cores obtained in accordance with Test Method C42/C42M in lieu of the capping systems described in Practice C617.

4.2 The elastomeric pads deform in initial loading to conform to the contour of the ends of the test specimens and are restrained from excessive lateral spreading by plates and metal rings to provide a uniform distribution of load from the bearing blocks of the testing machine to the ends of the concrete or mortar specimens.

[1] This practice 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.

Current edition approved Dec. 1, 2015. Published February 2016. Originally approved in 1993. Last previous edition approved in 2014 as C1231/C1231M – 14. DOI: 10.1520/C1231_C1231M-15.

[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.

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

5. Materials and Apparatus

5.1 Materials and equipment necessary to produce ends of the reference specimens that conform to planeness requirements of Test Method C39/C39M and the requirements of Practice C617. This may include grinding equipment or capping materials and equipment to produce neat cement paste, high strength gypsum plaster, or sulfur mortar caps.

5.2 *Elastomeric Pads:*

5.2.1 Pads shall be 13 ± 2 mm [½ ± 1⁄16 in.] thick and the diameter shall not be more than 2 mm [1⁄16 in.] smaller than the inside diameter of the retaining ring.

5.2.2 Pads shall be made from polychloroprene (neoprene) meeting the requirements of Classification D2000 as follows:

Shore A Durometer	Classification D2000 Line Call-Out
50	M2BC514
60	M2BC614
70	M2BC714

The tolerance on Shore A durometer hardness is ±5. Table 1 provides requirements for use of caps made from material meeting the requirements of Classification D2000, above.

5.2.3 Other elastomeric materials that meet the performance requirements of qualification tests in Section 8 are permitted.

5.2.4 Elastomeric pads shall be supplied with the following information:

5.2.4.1 The manufacturer's or supplier's name,

5.2.4.2 The Shore A hardness, and

5.2.4.3 The applicable range of concrete compressive strength from Table 1 or from qualification testing.

5.2.5 The user shall maintain a record indicating the date the pads are placed in service, the pad durometer, and the number of uses to which they have been subjected.

5.3 *Retainers* are a pair of metal fixtures used to provide support for and alignment of the neoprene pads and the test specimen ends (Note 1 and Fig. 1). Each retainer (upper and lower) includes a (retaining) ring that is welded to or manufactured integrally with a base plate. The height of the retaining ring shall be 25 ± 3 mm [1.0 ± 0.1 in.]. The inside diameter of the retaining ring shall not be less than 102% or greater than 107% of the diameter of the specimen. For test specimens having nominal diameters of 100 mm [4 in.] or less, the thickness of the retaining ring shall be at least 9 mm [0.35 in.] and the thickness of the baseplate shall be at least 8 mm [0.30 in.]. For test specimens having nominal diameters greater than 100 mm [4 in.], the thickness of the retaining ring and baseplate shall be at least 12 mm [0.47 in.]. The surface of the baseplate that contacts the bearing block of the testing machine shall be plane to within 0.05 mm [0.002 in.]. The bearing surfaces of the retainers shall not have gouges, grooves, protrusions, or indentations greater than 0.25 mm [0.010 in.] deep or greater than 32 mm^2 [0.05 in.^{2}] in surface area.

NOTE 1—Retainers made from steel and some aluminum alloys have been found acceptable.

TABLE 1 Requirements for Use of Polychloroprene(Neoprene) Pads

Compressive Strength,[A] MPa [psi]	Shore A Durometer Hardness	Qualification Tests Required	Maximum Reuses
Less than 10 [1 500]		Not permitted	
10 to 40 [1 500 to 6 000]	50	None	100
17 to 50 [2 500 to 7 000]	60	None	100
28 to 50 [4 000 to 7 000]	70	None	100
50 to 80 [7 000 to 12 000]	70	Required	50
Greater than 80 [12 000]		Not permitted	

[A] Compressive strength of concrete at age of testing as specified in Contract Documents. For acceptance testing, it is the specified compressive strength f_c' .

6. Test Specimens

6.1 Specimens shall be cylinders made in accordance with Practices C31/C31M or C192/C192M, or cores obtained in accordance with Test Method C42/C42M.

6.2 Depressions under a straight edge measured with a round wire gage across any diameter shall not exceed 5 mm [0.20 in.]. If the specimen ends do not meet this tolerance, the specimen shall not be tested unless irregularities are corrected by sawing or grinding.

7. Procedure

7.1 Unbonded caps are permitted to be used on one or both ends of a test specimen in lieu of a cap or caps meeting Practice C617, provided the caps meet the requirements of Section 5. Pad hardness shall be in accordance with Table 1.

NOTE 2—The specified strength in the contract documents is for various stages of construction. This may include strength test requirements for formwork removal or release of prestress in addition to the test requirements for verification of specified compressive strength. Therefore, pad selection is based on the strength requirement for the designated stage of construction.

7.2 Replace pads that do not meet the dimensional requirements of 5.2 or that exceed the maximum reuse limits of Table 1. Insert pad in the retainer before it is placed on the specimen.

NOTE 3—Some manufacturers recommend dusting the pads and the ends of the specimens with corn starch or talcum powder prior to testing.

7.3 Complete the load application, testing, calculation, and reporting of results in accordance with Test Method C39/C39M.

NOTE 4—Some users have reported damage to testing machines from the sudden release of energy stored in the elastomeric pads.

NOTE 5—Occasionally, specimens tested with unbonded caps may develop early cracking, but continue to carry increasing load. For this reason Test Method C39/C39M requires test specimens to be loaded until it is certain that they have been compressed beyond their ultimate capacity.

8. Qualification of Unbonded Capping Systems and Verification of Reuse of Pads

8.1 Table 1 specifies the conditions under which polychloroprene (neoprene) unbonded pads must be qualified under this section depending on the concrete strength and the Shore A hardness. Unbonded pads made of other elastomeric materials must be qualified using the procedures in this section.

8.2 When qualification tests are required they must be made by either the supplier or user of the unbonded pads. The user of the pads must retain a copy of the current qualification test report to demonstrate compliance with this practice. See X1.1.

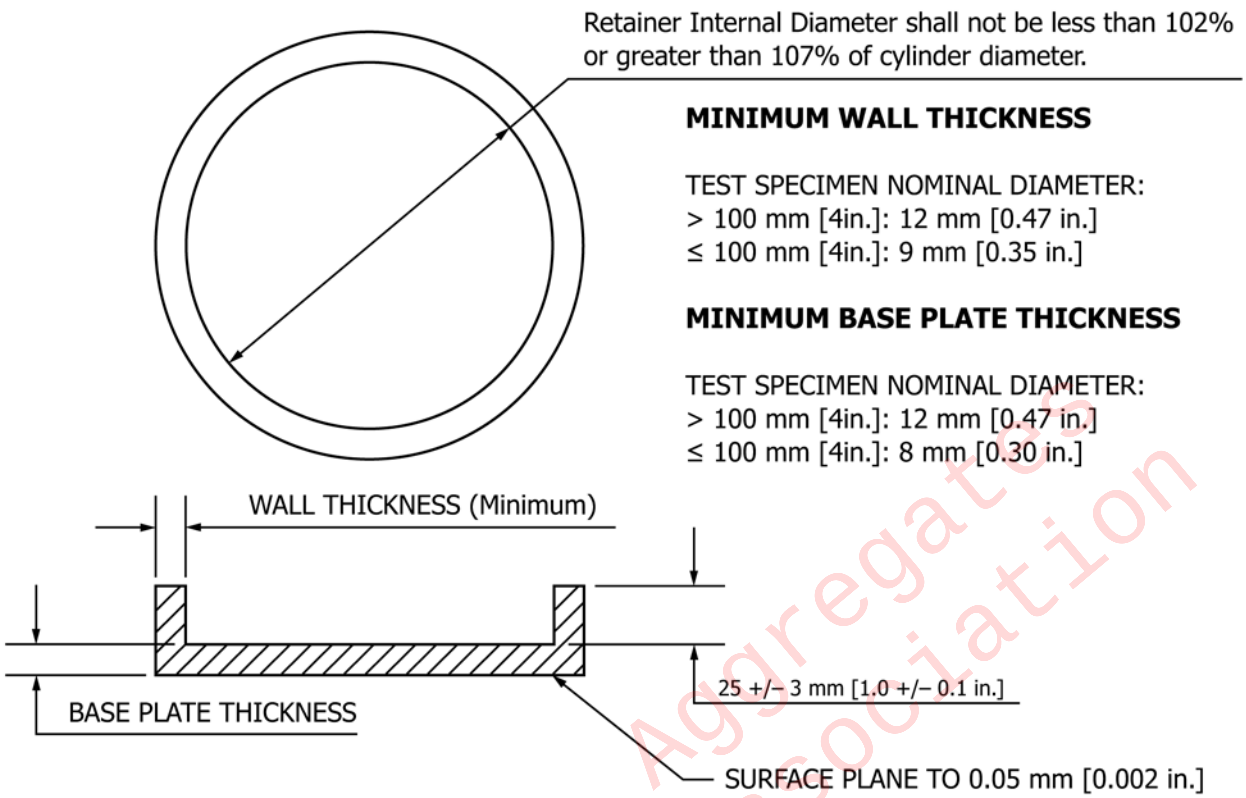


FIG. 1 Example of Retaining Ring and Base Plate

8.3 The compressive strength of molded cylinders tested with unbonded caps shall be compared with that of companion cylinders tested with ends ground or capped to meet requirements of Test Method C39/C39M and Practice C617.

8.4 To be acceptable, tests must demonstrate that at a 95 % confidence level ($\alpha = 0.05$), the average strength obtained using unbonded caps is not less than 98 % of the average strength of companion cylinders capped or ground in accordance with 8.3.

8.4.1 When required, qualification tests in accordance with 8.5 shall be made on initial use of an unbonded cap at both the highest and lowest strength levels anticipated to establish an acceptable range of cylinder strength for use. In practice individual cylinders shall not have strengths more than 10 % greater than the high strength level or more than 10 % less than the low strength level qualified or specified in Table 1. Qualification tests shall be repeated whenever there is a change in the design or dimensions of the retaining rings, or when there is a change in pad composition or thickness, or the Shore A hardness changes by more than five units. Initial qualification tests shall include verification that after the specified maximum number of reuses the pads meet the requirements of 8.4.

8.4.2 When tests are made to establish a permissible number of reuses exceeding those in Table 1, only those tests or reuses which are within 14 MPa [2000 psi] of the highest strength level to be qualified will be included in the reuse count. Laboratories must maintain records of the number of times pads are reused.

NOTE 6—Pad life depends on the hardness and type of pad material, the strength of the concrete, the difference between the outside diameter of the cylinder and the inside diameter of the retaining ring, the unevenness and roughness of the ends of the cylinder, and other factors. Based on available information, scuffing or abrasion of the perimeter of the pad is normal, provided it does not reduce the thickness of the pad around the perimeter.

8.5 *Specimen Preparation for Qualification and Pad Reuse Testing:*

8.5.1 Pairs of individual cylinders shall be made from a sample of concrete and cured as nearly alike as possible: one cylinder per pair is to be tested after grinding or capping in accordance with 8.3 and the other is to be tested using the unbonded cap system.

8.5.2 A minimum of 10 pairs of cylinders shall be made at both the highest and lowest strength levels desired or anticipated (Note 7). The "strength level" is the average of the strengths of the 20 or more cylinders whose strengths are within a range of 7 MPa [1000 psi] (Note 8). More than one pair of cylinders can be made from a single concrete sample, but cylinders must come from a minimum of two samples made on different days for each concrete strength level (Note 9).

NOTE 7—If the Practice C617 capped and unbonded capped specimens produce equal strengths, the number of pairs of cylinders that will be needed to demonstrate compliance will range from 9 to more than 60 depending on the variability of test results. If the two capping systems produce equal strengths, about 10 % of laboratories will require more than 60 tests and 10 % of the laboratories will require 9 tests to demonstrate statistical compliance.

NOTE 8—Note that the range of strengths permitted in qualification testing to define the strength level is 7 MPa [1000 psi], but that in counting number of reuses only cylinders within a range of 14 MPa [2000 psi] are included in the reuse count.

NOTE 9—Cylinders for qualification tests can be from pairs of cylinders tested in routine laboratory operations and, in most instances, special trial batches should not be required for qualification tests.

9. Calculation

9.1 For each strength level, compute the difference in strength for each pair of cylinders, and compute the average strength of the cylinders with reference caps and the average strength of the cylinders with unbonded caps, as follows:

$$d_i = x_{pi} - x_{si} \quad (1)$$

$$\bar{x}_s = (x_{s1} + x_{s2} + x_{s3} \ldots + x_{sn})/n$$

$$\bar{x}_p = (x_{p1} + x_{p2} + x_{p3} \ldots + x_{pn})/n$$

where:

d_i = difference in strength of a pair of cylinders computed as the strength of unbonded capped cylinder minus the strength of the cylinder prepared according to Practice C617 (may be positive or negative),
x_{pi} = cylinder strength using unbonded cap,
x_{si} = cylinder strength using Practice C617,
n = number of pairs of cylinders tested for the strength level,
$\bar{x}_s$ = average strength of Practice C617 capped cylinders for a strength level, and
$\bar{x}_p$ = average strength of unbonded cap cylinders for a strength level.

9.2 Compute the average difference, $\bar{d}$, and standard deviation of the difference, s_d, for each strength level, as follows:

$$\bar{d} = (d_1 + d_2 \ldots + d_n)/n \quad (2)$$

$$s_d = \left[\sum (d_i - \bar{d})^2/(n-1)\right]^{1/2}$$

9.3 To comply with this practice the following relationship must be satisfied:

$$\bar{x}_p \geq 0.98\,\bar{x}_s + (ts_d)/(n)^{1/2} \quad (3)$$

where t is the value of "students t" for $(n-1)$ pairs at $\alpha = 0.05$ from the following table:

$(n-1)$	$t(\alpha = 0.05)^A$
9	1.833
14	1.761
19	1.729
100	1.662

^{A} Use linear interpolation for other values of $(n-1)$ or refer to appropriate statistical tables.

10. Keywords

10.1 cap; compressive strength; concrete; concrete test; elastomeric; neoprene; pad cap; rubber; unbonded cap

APPENDIX

(Nonmandatory Information)

X1. SAMPLE REPORT AND CALCULATION

X1.1 Sample Report

X1.1.1 *Pad Material*—Lot 3742, Shore A = 52, Thickness 13 mm [0.51 in.].

X1.1.2 *Retaining Ring*—Set A manufactured 1–87.

X1.1.3 Concrete Cylinders: Job 1207, Nos. 1–10, January 2 to 5, 1987.

X1.1.4 *Sulfur Mortar*—Lot 3420. Compressive Strength of 48.2 MPa [6985 psi].

X1.1.5 All Tests 28 days age.

X1.2 Summary

xs = 25.35 MPa [3679 psi],
xp = 25.26 MPa [3663 psi],
sd = 0.328 MPa [46.06 psi],
n = 10, and
t = 1.833.

Cylinder Pair		Neoprene Pad			Sulfur Cap			Difference, d
		MPa	psi		MPa	psi	MPa	psi
1		24.9	3605		24.7	3580	0.20	25
2		24.9	3605		25.4	3690	-0.50	-85
3		24.7	3585		24.7	3595	0.00	-10
4		24.6	3570		25.0	3625	-0.40	-55
5		25.0	3625		25.1	3640	-0.10	-15
6		25.2	3660		25.8	3740	-0.60	-80
7		25.9	3750		25.6	3720	0.30	30
8		25.7	3725		25.6	3720	0.10	5
9		25.5	3700		25.7	3725	-020	-25
10		26.2	3805		25.9	3755	0.30	50
Average	xp	25.26	3663	xs	25.35	3679	d -0.090	-16
Std. Dev.							sd 0.328	46.06

X1.3 Calculation

X1.3.1 Using Eq 3 in 9.3:
SI Units:

$$25.26 \geq = (0.98)(25.35) + (1.833)(0.328)/(10)^{1/2}$$
$$25.26 > 25.03\ (\textit{System Qualifies})$$

Inch-Pound Units:

$$3663 \geq = (0.98)(3679) + (1.833)(46.06)/(10)^{1/2}$$
$$3663 > 3632\ (\textit{system qualifies at } 3670\ psi)$$

X1.4 Keywords

X1.4.1 caps; capping cylinders; compressive strength; pads; strength; unbonded capping system

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this standard since the last issue (C1231/C1231M – 14) that may impact the use of this standard. (Approved Dec. 1, 2015.)

(1) Deleted Note 2 and renumbered subsequent notes.
(2) Revised the following sections to reflect testing of cores in addition to concrete cylinders: Title, 1.1, 1.4, 4.1, 4.2, 5.1, 5.3, 6.1, 6.2, 7.1, 7.2, Note 3, and Note 5.
(3) Added Test Method C42/C42M as a referenced document in 2.1.
(4) Revised retainer requirements in 5.3 and Fig. 1.
(5) Removed perpendicularity and diameter check from 6.1.