



# Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)<sup>1</sup>

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

## 2. Referenced Documents

2.1 *ASTM Standards:*<sup>2</sup>

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

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

C617/C617M Practice for Capping Cylindrical Concrete Specimens

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

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

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<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

## 3. Significance and Use

3.1 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.

3.2 The measured modulus of rupture generally increases as the specimen size decreases<sup>3,4,5</sup> and it has been shown that the variability of individual test results increases as the specimen size decreases.<sup>3,4</sup>

3.3 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. Apparatus

4.1 *Testing Machine*—The testing machine shall conform to the requirements of the sections on Basis of Verification, Corrections, and Time Interval Between Verifications of Practices E4. 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

<sup>3</sup> 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.

<sup>4</sup> 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.

<sup>5</sup> 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.

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.

**4.2 Loading Apparatus**—The third point loading method shall be used in making flexure tests of concrete employing bearing blocks that will ensure that forces applied to the beam will be perpendicular to the face of the specimen and applied without eccentricity. A diagram of an apparatus that accomplishes this purpose is shown in Fig. 1.

**4.2.1** All apparatus for making flexure tests of concrete shall be capable of maintaining the specified span length and distances between load-applying blocks and support blocks constant within  $\pm 1.0$  mm [ $\pm 0.05$  in.].

**4.2.2** The ratio of the horizontal distance between the point of application of the load and the point of application of the nearest reaction to the depth of the beam shall be  $1.0 \pm 0.03$ .

**4.2.3** If an apparatus similar to that illustrated in Fig. 1 is used: the load-applying and support blocks shall not be more than 65 mm [2.50 in.] high, measured from the center or the axis of pivot, and should extend entirely across or beyond the full width of the specimen. Each case-hardened bearing 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 [ $45^\circ$ ]. The load-applying 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 pivot rod or ball. The uppermost bearing plate and center point ball in Fig. 1 may be omitted

when a spherically seated bearing block is used, provided one rod and one ball are used as pivots for the upper load-applying blocks.

## 5. Test Specimens

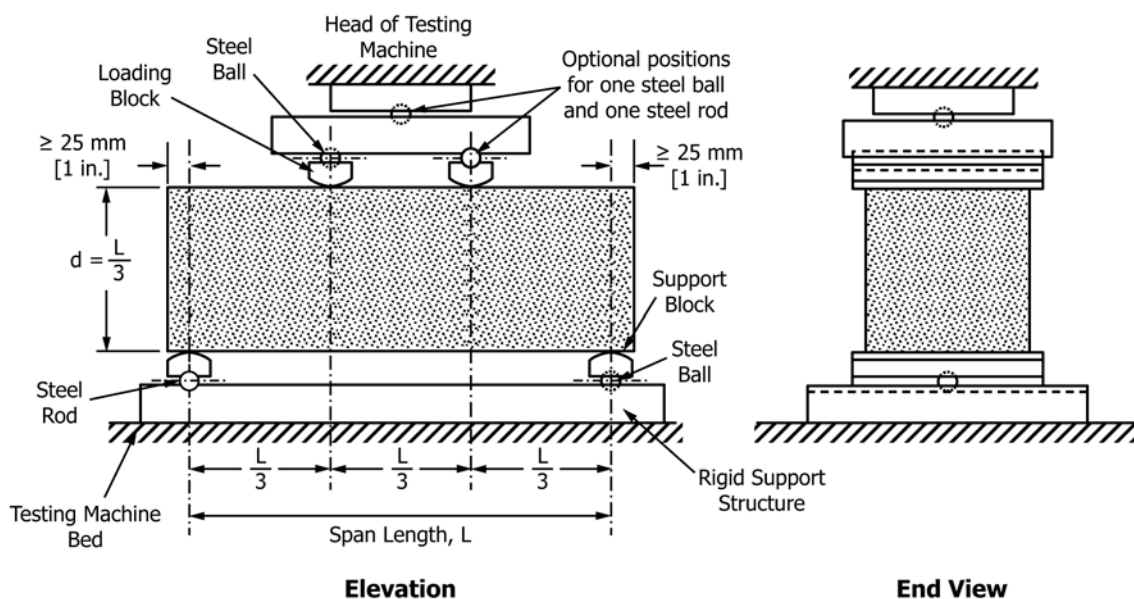
**5.1** The test specimen shall conform to all requirements of Test Method C42/C42M or Practices C31/C31M or C192/C192M applicable to beam specimens and shall have a test span within 2 % of being three times its depth as tested. The sides of the specimen shall be at right angles with the top and bottom.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

**5.2** 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.<sup>3,4</sup> (Note 1).

NOTE 1—The strength ratio for beams of different sizes depends primarily on the maximum size of aggregate.<sup>5</sup> Experimental data obtained in two different studies have shown that for maximum aggregate size between 19.0 and 25.0 mm [ $\frac{3}{4}$  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<sup>3</sup> and for maximum aggregate size between 9.5 and 37.5 mm [ $\frac{3}{8}$  and  $1\frac{1}{2}$  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.<sup>4</sup>

**5.3** The specifier of tests shall specify the specimen size and number of specimens to be tested to obtain an average test result (Note 2). The same specimen size shall be used for qualification and acceptance testing.

NOTE 2—It has been shown that the variability of individual test results increases as the specimen size decreases.<sup>3,4</sup>



NOTE 1—This apparatus may be used inverted. If the testing machine applies force through a spherically seated head, the center pivot may be omitted, provided one load-applying block pivots on a rod and the other on a ball.

FIG. 1 Schematic of a Suitable Apparatus for Flexure Test of Concrete by Third-Point Loading Method

## 6. Procedure

6.1 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, or keeping specimens under lime water in containers near the flexural testing machine until time of testing.

6.2 When using 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 system in relation to the applied force. Bring the load-applying blocks in contact with the surface of the specimen at the third points and apply a load of between 3 and 6 % of the estimated ultimate load. 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 load-applying 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 inasmuch as grinding may change the physical characteristics of the specimens. Capping shall be in accordance with the applicable sections of Practice C617/C617M.

6.3 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.].

## 7. Measurement of Specimens After Test

7.1 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.

## 8. Calculation

8.1 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.

8.2 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.

8.3 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.

## 9. Report

9.1 Report the following information:

- 9.1.1 Identification number,
- 9.1.2 Average width to the nearest 1 mm [0.05 in.],
- 9.1.3 Average depth to the nearest 1 mm [0.05 in.],
- 9.1.4 Span length in mm [in.],
- 9.1.5 Maximum applied load in N [lbf],
- 9.1.6 Modulus of rupture calculated to the nearest 0.05 MPa [5 psi],
- 9.1.7 Curing history and apparent moisture condition of the specimens at the time of test,
- 9.1.8 If specimens were capped, ground, or if leather shims were used,
- 9.1.9 Whether sawed or molded and defects in specimens, and
- 9.1.10 Age of specimens.

## 10. Precision and Bias

10.1 *Precision*<sup>6</sup>—The single-operator coefficient of variation has been found to be 5.7 %. Therefore, results of two properly conducted tests by the same operator on beams made from the same batch sample are not expected to differ from each other by more than 16 %. The multilaboratory coefficient of variation has been found to be 7.0 %. Therefore, results of two different laboratories on beams made from the same batch sample are not expected to differ from each other by more than 19 % (Note 7 and Note 8).

NOTE 7—This precision statement was determined using 150 by 150 by 510 mm [6 by 6 by 20 in.] and 115 by 115 by 395 mm [4.5 by 4.5 by 15.5

in.] specimens and based on two concrete mixtures with flexural strength of 3.65 and 6.15 MPa [530 psi and 890 psi]<sup>4</sup>. In a separate study,<sup>3</sup> 21 mixtures with flexural strength ranging from 4.25 to 7.15 MPa [615 to 1040 psi] were tested and the single operator coefficient of variation for 100 by 100 by 355 mm [4 by 4 by 14 in.] specimens obtained was 5.2 %. A complete precision statement for 4 by 4 by 14 in. [100 by 100 by 355 mm] specimens is not available but will be prepared. The variability of test results changes with specimen dimensions<sup>3,4</sup> and should not be extrapolated to specimen sizes different than those reported here.

NOTE 8—This precision statement was determined using a single brand and model testing machine (Rainhart Series 416, Recording Beam tester).<sup>4</sup> Different testing machine brands and models may yield results with different variability than those stated here.

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

<sup>6</sup> See “Improved Concrete Quality Control Procedures Using Third Point Loading” by P. M. Carrasquillo and R. L. Carrasquillo, Research Report 119-1F, Project 3-9-87-1119, Center For Transportation Research, The University of Texas at Austin, November 1987, for possible guidance as to the relationship of strength and variability.

## 11. Keywords

11.1 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 – 15b, that may impact the use of this test method. (Approved July 1, 2016.)

(1) Revised 6.1.

(2) Added Note 3 and Note 4, and renumbered subsequent notes.

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