Basic Concrete Tests
Basic Tests

Cylinder Compression
Split Tension
Beam Flexure
Elastic Modulus
Slump
Air Content
Standard Practice for
Making and Curing Concrete Test Specimens in the
Laboratory

This standard is issued under the fixed designation C 192/C 192M: 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 Department of Defense.

1. Scope

1.1 This practice covers procedures for making and curing test specimens of concrete in the laboratory under accurate control of materials and test conditions using concrete that can be consolidated by rodding or vibration as described herein.

1.2 The values stated in either inch-pound units or SI units shall be regarded separately as standard. The SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of each other. Combining values from the two systems may result in nonconformance.

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. (Warning—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to exposed skin and tissue upon prolonged exposure.)

C 143/C 143M Test Method for Slump of Hydraulic-Cement Concrete
C 172 Practice for Sampling Freshly Mixed Concrete
C 173/C 173M Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method
C 231 Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
C 330 Specification for Lightweight Aggregates for Structural Concrete
C 403/C 403M Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance
C 470/C 470M Specification for Molds for Forming Concrete Test Cylinders Vertically
C 494/C 494M Specification for Chemical Admixtures for Concrete
C 511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes
C 566 Test Method for Total Evaporable Moisture Content
Standard Practice for Making and Curing Concrete Test Specimens in the Field\textsuperscript{1}

This standard is issued under the fixed designation C 31/C 31M; 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 reaffirmation. A superscript epsilon (\(\epsilon\)) indicates an editorial change since the last revision or reaffirmation.

\textit{This standard has been approved for use by agencies of the Department of Defense.}

1. Scope\textsuperscript{*}

1.1 This practice covers procedures for making and curing cylinder and beam specimens from representative samples of fresh concrete for a construction project.

1.2 The concrete used to make the molded specimens shall be sampled after all on-site adjustments have been made to the mixture proportions, including the addition of mix water and admixtures. This practice is not satisfactory for making specimens from concrete not having measurable slump or requiring other sizes or shapes of specimens.

1.3 The values stated in either inch-pound units or SI units shall be regarded separately as standard. The SI units are shown in brackets. The values stated may not be exact equivalents; therefore each system must be used independently of the other. Combining values from the two units may result in nonconformance.

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.

C 138/C 138M Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete
C 143/C 143M Test Method for Slump of Hydraulic-Cement Concrete
C 172 Practice for Sampling Freshly Mixed Concrete
C 173/C 173M Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method
C 231 Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
C 330 Specification for Lightweight Aggregates for Structural Concrete
C 403/C 403M Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance
C 470/C 470M Specification for Molds for Forming Concrete Test Cylinders Vertically
C 511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes
C 617 Practice for Capping Cylindrical Concrete Specimens
Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens

This standard is issued under the fixed designation C 39/C 39M; 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 Department of Defense.

Note—Note 1 was corrected editorially in September 2006.

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 unit weight in excess of 50 lb/ft³ [800 kg/m³].

1.2 The values stated in either inch-pound or SI units are to be regarded separately as standard. The SI 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 nonconformance 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. (Warning—Means should be provided to contain concrete fragments during sudden rupture of specimens. Tendency for sudden rupture...
Concrete Strength

unconfined compression
cylindrical specimen
6" diameter
12" height
35 ± 7 psi/s loading
cured 28-days
95% relative humidity
Shape Effects

Specimen affected by lateral stresses throughout its height

Central region unaffected by lateral stress
Shape Effects

![Graph showing the relationship between Cylinder Strength (psi) and Ratio of Cube Strength to Cylinder Strength]
Slenderness Effects

Age of specimens, 28 days

Percent of strength of cylinder with $l/d = 2$

Ratio of length of cylinder to diameter, $l/d$
Size Effects
Loading Rate Effects

[Diagram showing a graph with the x-axis labeled 'Rate of straining (in./in./s, log scale)' and the y-axis labeled 'Percent of strength obtained with straining rate of 6.95 x 10^{-5} in./in./s (0.05 in./per/min).']
Standard Test Method for
Splitting Tensile Strength of Cylindrical Concrete Specimens

1. Scope*

1.1 This test method covers the determination of the splitting tensile strength of cylindrical concrete specimens, such as molded cylinders and drilled cores.

1.2 The values stated in either inch-pound or SI units are to be regarded separately as standard. The SI 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 nonconformance 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.

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

3. Summary of Test Method

3.1 This test method consists of applying a diametral compressive force along the length of a cylindrical concrete specimen at a rate that is within a prescribed range until failure occurs. This loading induces tensile stresses on the plane containing the applied load and relatively high compressive stresses in the area immediately around the applied load. Tensile failure occurs rather than compressive failure because the areas of load application are in a state of triaxial compression, thereby allowing them to withstand much higher compressive stresses than would be indicated by a uniaxial compressive strength test result.

3.2 Thin, plywood bearing strips are used to distribute the load applied along the length of the cylinder.

3.3 The maximum load sustained by the specimen is divided by appropriate geometrical factors to obtain the splitting tensile strength.

4. Significance and Use
Splitting Tension Test

Cylinder specimen

Plywood bearing strips, \( \frac{1}{8} \) in. (3.2 mm) thick
Splitting Tension Test

\[ f_t' = \frac{2P}{\pi LD} \]
Splitting Tension Test
Standard Test Method for
Flexural Strength of Concrete (Using Simple Beam with
Third-Point Loading)\textsuperscript{1}

This standard is issued under the fixed designation C 78; 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 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 inch-pound units are to be regarded as the standard. The SI equivalent of inch-pound units has been rounded where necessary for practical application.

1.3 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:
C 31 Practice for Making and Curing Concrete Test Specimens in the Field\textsuperscript{2}
C 42 Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete\textsuperscript{2}
beam has been molded or sawed to size.

3.2 The results of this test method may be used to determine compliance with specifications or as a basis for proportioning, mixing and placement operations. It is used in testing concrete for the construction of slabs and pavements (Note 1).

4. Apparatus

4.1 The testing machine shall conform to the requirements of the sections on Basis of Verification, Corrections, and Time Interval Between Verifications of Practices E 4. 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.

4.2 Loading Apparatus—The third point loading method shall be used in making flexure tests of concrete employing
Beam Flexure Test

1 in.-minimum

Load-bearing point

$P$

$L/3$

$d = L/3$

$L = \text{span length}$
Beam Flexure Test
Beam Flexure Test

\[ \text{MOR} = \frac{PL}{bd^2} \]
Beam Flexure Test

\[ MOR = \frac{PL}{bd^2} \]
Designation: C 469 – 02<sup>ε</sup>¹

Standard Test Method for Static Modulus of Elasticity and Poisson’s Ratio of Concrete in Compression<sup>¹</sup>

This standard is issued under the fixed designation C 469; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

<sup>ε</sup>¹ Note—Adjunct references were corrected editorially in April 2006.

1. Scope

   1.1 This test method covers determination of (1) chord modulus of elasticity (Young’s) and (2) Poisson’s ratio of molded concrete cylinders and diamond-drilled concrete cores when under longitudinal compressive stress. Chord modulus of elasticity and Poisson’s ratio are defined in Terminology E 6.

   1.2 The values stated in inch-pound units are to be regarded as the standard.

   1.3 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

   2.1 ASTM Standards: ²
    C 31/C 31M Practice for Making and Curing Concrete Test Specimens in the Field

E 83 Practice for Verification and Classification of Extensometer System
E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

2.2 ASTM Adjuncts:
Compressometers (two drawings) and Extensometers (two drawings)<sup>³</sup>

3. Significance and Use

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

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

Stress (psi) vs. Strain ($\times 10^{-4}$)

- Elastic Range
- $E$
- Failure
Elastic Modulus

\[
E = \frac{0.4f'_c - \sigma_1}{\varepsilon_2 - 0.00005}
\]

\((0.00005, \sigma_1)\)

\((\varepsilon_2, 0.4f'_c)\)
Elastic Modulus

\[ f'_c = 5800 \]

\[ E = \frac{2320 - 250}{0.0007 - 0.00005} = 3.2 \times 10^6 \text{ psi} \]
Compressometer
Compressometer

\[ L = \frac{1}{2} H \]
Compressometer

Pivot rod

$L - \Delta$

$L - 2\Delta$

d/2   d/2
Standard Test Method for Slump of Hydraulic-Cement Concrete

This standard is issued under the fixed designation C 143/C 143M; 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 Department of Defense.

1. Scope®

1.1 This test method covers determination of slump of hydraulic-cement concrete, both in the laboratory and in the field.

1.2 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

1.3 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of 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—Fresh hydraulic-cementitious mixtures are caustic and may cause the vertical distance between the original and displaced position of the center of the top surface of the concrete is measured and reported as the slump of the concrete.

4. Significance and Use

4.1 This test method is intended to provide the user with a procedure to determine slump of plastic hydraulic-cement concretes.

Note 1—This test method was originally developed to provide a technique to monitor the consistency of unhardened concrete. Under laboratory conditions, with strict control of all concrete materials, the slump is generally found to increase proportionally with the water content of a given concrete mixture, and thus to be inversely related to concrete strength. Under field conditions, however, such a strength relationship is not clearly and consistently shown. Care should therefore be taken in relating slump results obtained under field conditions to strength.

4.2 This test method is considered applicable to plastic concrete having coarse aggregate up to 1½ in. [37.5 mm] in size. If the coarse aggregate is larger than 1½ in. [37.5 mm] in size, the test method is applicable when it is performed on the...
Slump Test

Fill the cone in the prescribed manner

Strike off the excess

Raise the cone, invert it, and measure slump to the center of the sample
Slump Types

“True” slump
Good cohesion
Good consistency

Shear Slump
Lacks cohesion
May segregate

Collapse Slump
Too lean or too wet
May be harsh
Methods for Determining Air Content

gravimetric method (ASTM C-138)
volumetric method (ASTM C-173)
pressure method (ASTM C-231)
Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method

This standard is issued under the fixed designation C 231; 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 Department of Defense.

1. Scope*

1.1 This test method covers determination of the air content of freshly mixed concrete from observation of the change in volume of concrete with a change in pressure.

1.2 This test method is intended for use with concretes and mortars made with relatively dense aggregates for which the aggregate correction factor can be satisfactorily determined by the technique described in Section 6. It is not applicable to concretes made with lightweight aggregates, air-cooled blast-furnace slag, or aggregates of high porosity. In these cases, Test Method C 173/C 173M should be used. This test method is also not applicable to nonplastic concrete such as is commonly used in the manufacture of pipe and concrete masonry units.

1.3 The text of this test method references notes and footnotes that provide explanatory information. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of this standard.

1.4 The values stated in inch-pound units are to be regarded

C 138/C 138M Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete
C 172 Practice for Sampling Freshly Mixed Concrete
C 173/C 173M Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method
C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory
C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

3. Significance and Use

3.1 This test method covers the determination of the air content of freshly mixed concrete. The test determines the air content of freshly mixed concrete exclusive of any air that may exist inside voids within aggregate particles. For this reason, it is applicable to concrete made with relatively dense aggregate particles and requires determination of the aggregate correction.
Gravimetric Method

air content = \left(1 - \frac{\gamma_{\text{actual}}}{\gamma_{\text{no-air}}}\right) \times 100\%
Air-Free Unit Weight

\[ \gamma_{\text{no-air}} = \frac{W_{\text{water}} + W_{\text{cement}} + W_{\text{gravel}} + W_{\text{sand}}}{V_{\text{water}} + V_{\text{cement}} + V_{\text{gravel}} + V_{\text{sand}}} \]

\[ V_{\text{ingredient}} = \frac{W_{\text{ingredient}}}{G_{\text{bulk}} \gamma_w} \]
Example

\[ W_{\text{water}} = 320 \text{ lb} \]
\[ W_{\text{cement}} = 580 \text{ lb} \]
\[ W_{\text{gravel}} = 1940 \text{ lb} \]
\[ W_{\text{sand}} = 1110 \text{ lb} \]

\[ G_{\text{water}} = 1.00 \]
\[ G_{\text{cement}} = 3.15 \]
\[ G_{\text{gravel}} = 2.68 \]
\[ G_{\text{sand}} = 2.65 \]

\[
\gamma_{\text{no-air}} = \frac{(320 + 580 + 1940 + 1110)}{(5.13 + 2.95 + 11.60 + 6.71)} \frac{\text{lb}}{\text{ft}^3} = 149.7 \frac{\text{lb}}{\text{ft}^3}
\]
Assume

$$\gamma_{\text{actual}} = 146.2 \text{ lb/ft}^3$$

\[
\text{air content} = \left(1 - \frac{146.2}{149.7}\right) \times 100\% = 2.3\%
\]
Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method

This standard is issued under the fixed designation C 173/C 173M; 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 Department of Defense.

1. Scope

1.1 This test method covers determination of the air content of freshly mixed concrete containing any type of aggregate, whether it be dense, cellular, or lightweight.

1.2 The values stated in either inch-pound or SI units shall be regarded separately as standard. The SI units are shown in brackets. The values stated are not exact equivalents; therefore each system must be used independently of the other. Combining values from the two units may result in nonconformance.

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. (Warning—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.)

2. Referenced Documents

in the mortar fraction of the concrete, but is not affected by air that may be present inside porous aggregate particles.

3.1.1 Therefore, this is the appropriate test to determine the air content of concretes containing lightweight aggregates, air-cooled slag, and highly porous or vesicular natural aggregates.

3.2 This test method requires the addition of sufficient isopropyl alcohol, when the meter is initially being filled with water, so that after the first or subsequent rollings little or no foam collects in the neck of the top section of the meter. If more foam is present than that equivalent to 2% air above the water level, the test is declared invalid and must be repeated using a larger quantity of alcohol. Addition of alcohol to disperse foam any time after the initial filling of the meter to the zero mark is not permitted.

3.3 The air content of hardened concrete may be either higher or lower than that determined by this test method. This depends upon the methods and amounts of consolidation effort applied to the concrete from which the hardened concrete...
Volumetric Method

The measuring bowl is filled with concrete, the device is assembled, and water is added to reach the zero mark in the neck. As the device is agitated, the air in the concrete is replaced by water from the neck and the water level drops in proportion to the air content.
Standard Test Method for
Air Content of Freshly Mixed Concrete by the Pressure Method

This standard is issued under the fixed designation C 231; 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 Department of Defense.

1. Scope*

1.1 This test method covers determination of the air content of freshly mixed concrete from observation of the change in
volume of concrete with a change in pressure.

1.2 This test method is intended for use with concretes and
mortars made with relatively dense aggregates for which the
aggregate correction factor can be satisfactorily determined by
the technique described in Section 6. It is not applicable to
concretes made with lightweight aggregates, air-cooled blast-
furnace slag, or aggregates of high porosity. In these cases, Test
Method C 173/C 173M should be used. This test method is
also not applicable to nonplastic concrete such as is commonly
used in the manufacture of pipe and concrete masonry units.

1.3 The text of this test method references notes and
footnotes that provide explanatory information. These notes
and footnotes (excluding those in tables and figures) shall not
be considered as requirements of this standard.

1.4 The values stated in inch-pound units are to be regarded
as standard. The values given in parentheses are for
information only.

C 138/C 138M Test Method for Density (Unit Weight),
Yield, and Air Content (Gravimetric) of Concrete
C 172 Practice for Sampling Freshly Mixed Concrete
C 173/C 173M Test Method for Air Content of Freshly
Mixed Concrete by the Volumetric Method
C 192/C 192M Practice for Making and Curing Concrete
Test Specimens in the Laboratory
C 670 Practice for Preparing Precision and Bias Statements
for Test Methods for Construction Materials
E 177 Practice for Use of the Terms Precision and Bias in
ASTM Test Methods

3. Significance and Use

3.1 This test method covers the determination of the air
content of freshly mixed concrete. The test determines the air
content of freshly mixed concrete exclusive of any air that may
exist inside voids within aggregate particles. For this reason, it
is applicable to concrete made with relatively dense aggregate
particles and requires determination of the aggregate correction

Pressure Method

The bowl is filled with concrete, the device is assembled, and water is added to reach the zero mark in the neck. As the unit is pressurized, the air bubbles compress, the concrete surface falls and the water level drops in proportion to the change in air volume.