Basic Concrete Tests

Hardened Concrete

Basic Concrete Tests

Cylinder Compression

Splitting Tension

Beam Flexure

Elastic Modulus

Slump

Unit Weight

Air Content

Cylinder Compression

What do we mean when we say
"I need 10 yd^3 of 4500-psi concrete"?

It's the uniaxial unconfined compressive strength of concrete cylinders that are made and cured according to either ASTM C31 (field samples) or C192 (lab samples) then tested according to ASTM C39.

Designation: C 31/C 31M – 06

Standard Practice for Making and Curing Concrete Test Specimens in the Field[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 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 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 applica-*

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

Designation: C 192/C 192M – 07

Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory[1]

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.[2])

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

Designation: C 39/C 39M – 05$^{\epsilon 1}$

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

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.

ϵ^1 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/ft^3 [800 kg/m^3].

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

C 31/C 31M Practice for Making and Curing Concrete Test Specimens in the Field

C 42/C 42M Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C 617 Practice for Capping Cylindrical Concrete Specimens

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C 873 Test Method for Compressive Strength of Concrete Cylinders Cast in Place in Cylindrical Molds

C 1077 Practice for Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Laboratory Evaluation

C 1231/C 1231M Practice for Use of Unbonded Caps in Determination of Compressive Strength of Hardened Concrete Cylinders

ASTM C39

unconfined uniaxial loading

cylindrical specimen

6" diameter × 12" high

cured 28 days @ 95% relative humidity

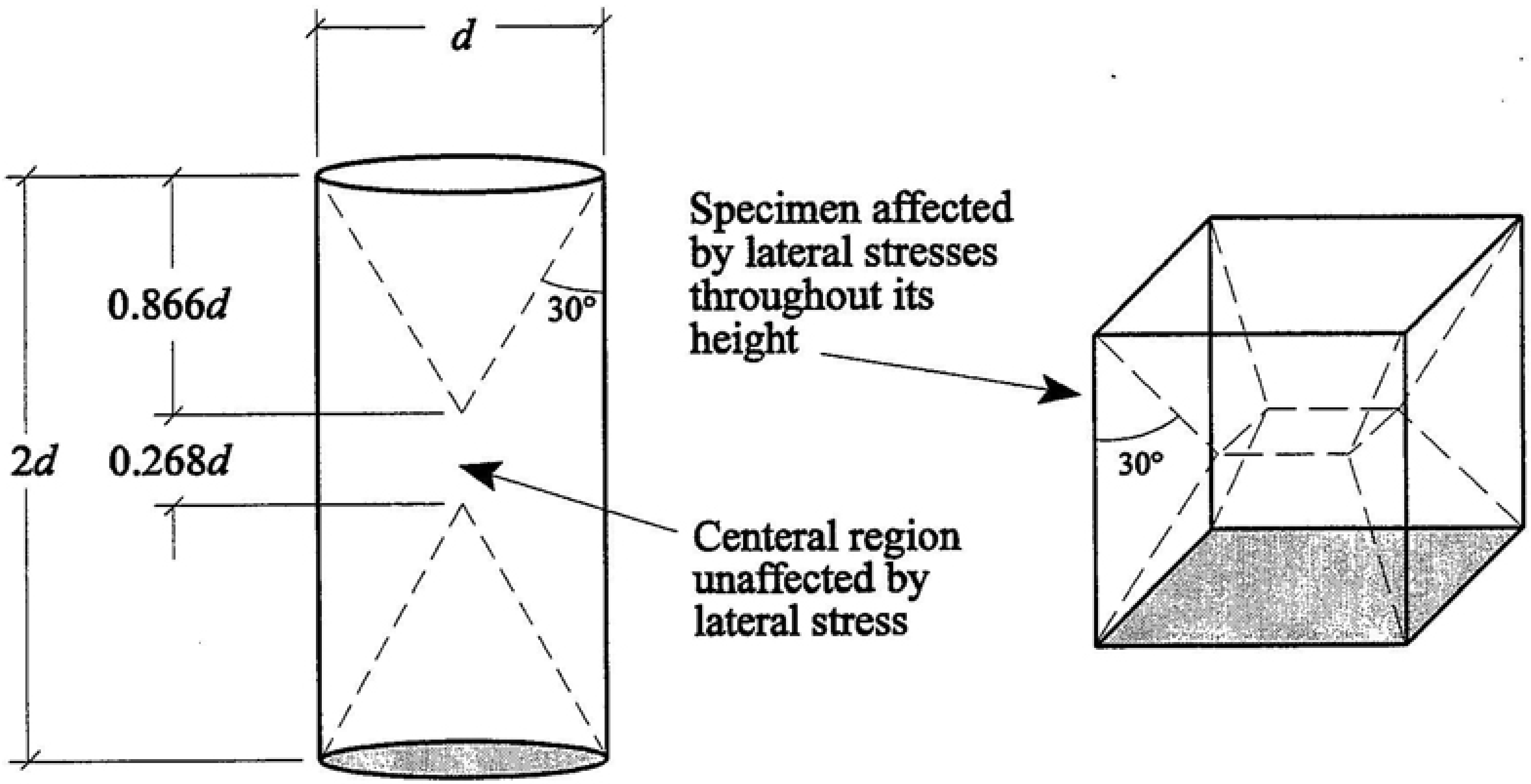
loaded at 35 ± 7 psi/s

loaded using appropriate end caps

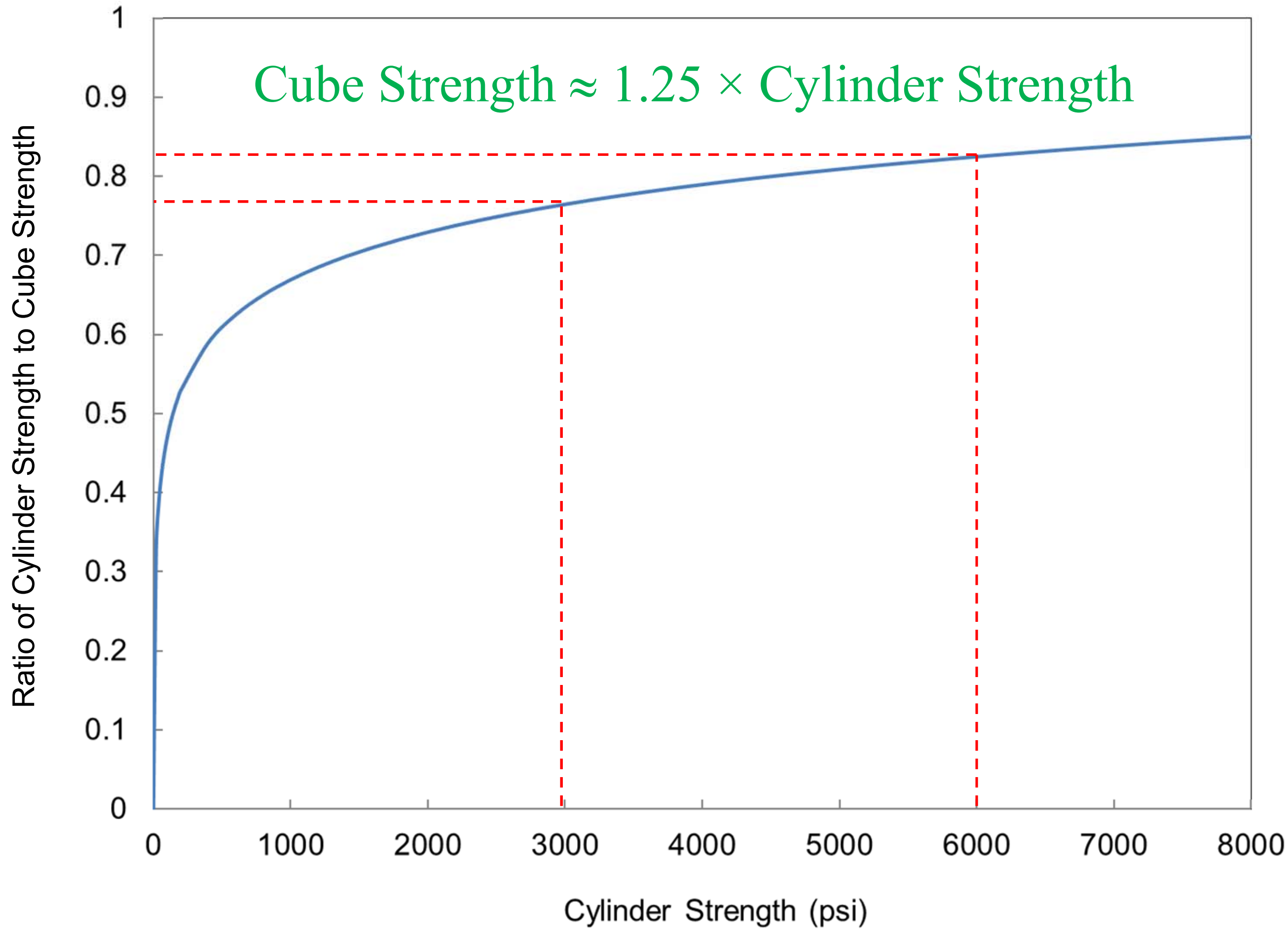
Why Cylindrical Specimens?

Ideally, you want the stress in the concrete to be uniaxial. Unfortunately, friction between the ends of the specimen and the testing machine imposes lateral stresses that confine the concrete and make it fail at a higher load than it should. In cubical specimens, the lateral stresses are present throughout the specimen. In cylindrical specimens, the concrete at the cylinder mid-height is far enough from the ends to be free of lateral stresses. As a result, cubical specimens fail at a load roughly 25% higher than cylindrical specimens.

Shape Effects



Shape Effects



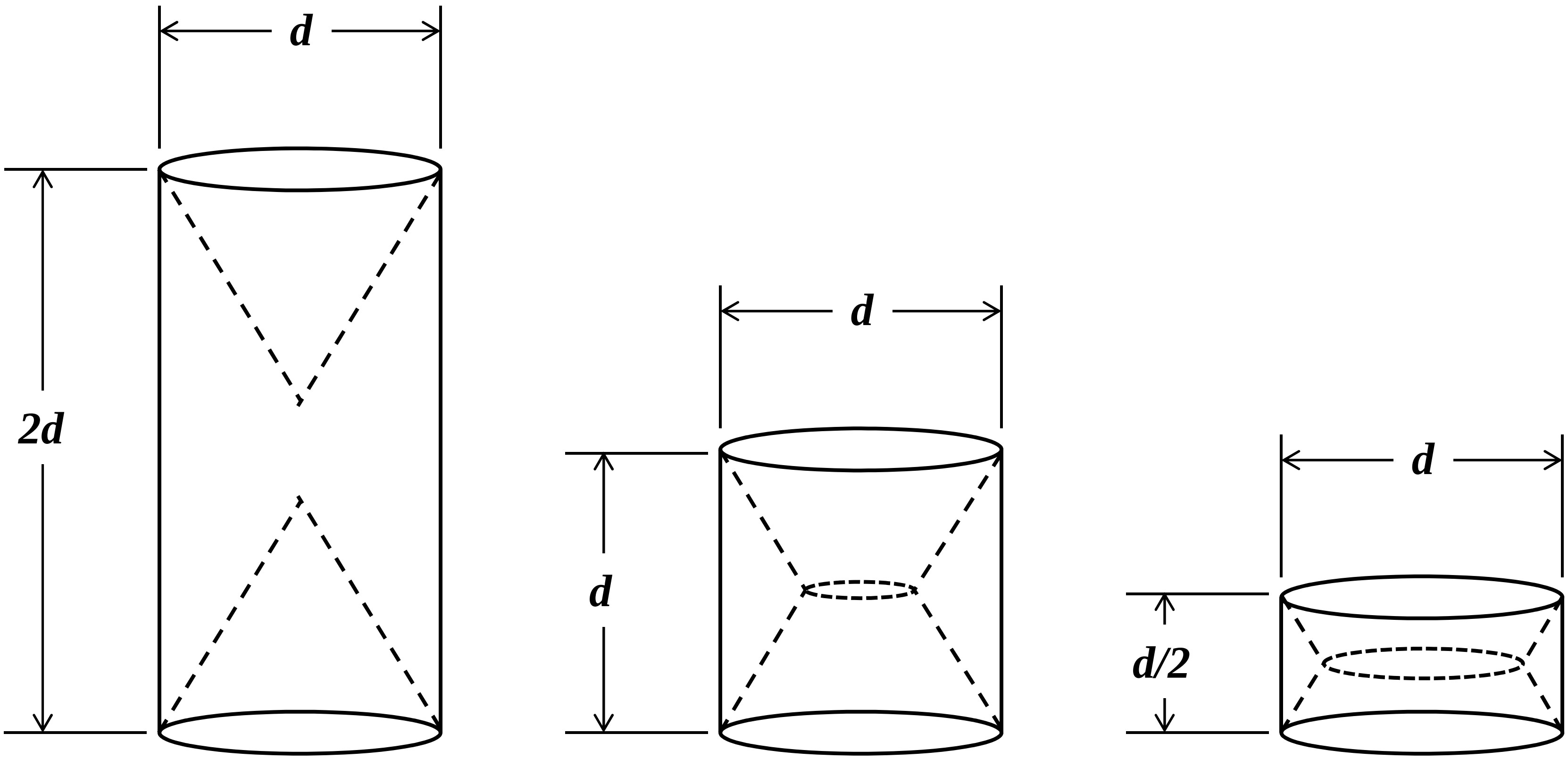
Why a 2:1 Aspect Ratio?

The 2:1 aspect ratio ensures that the concrete at the mid-height of the specimen is free of lateral stresses.

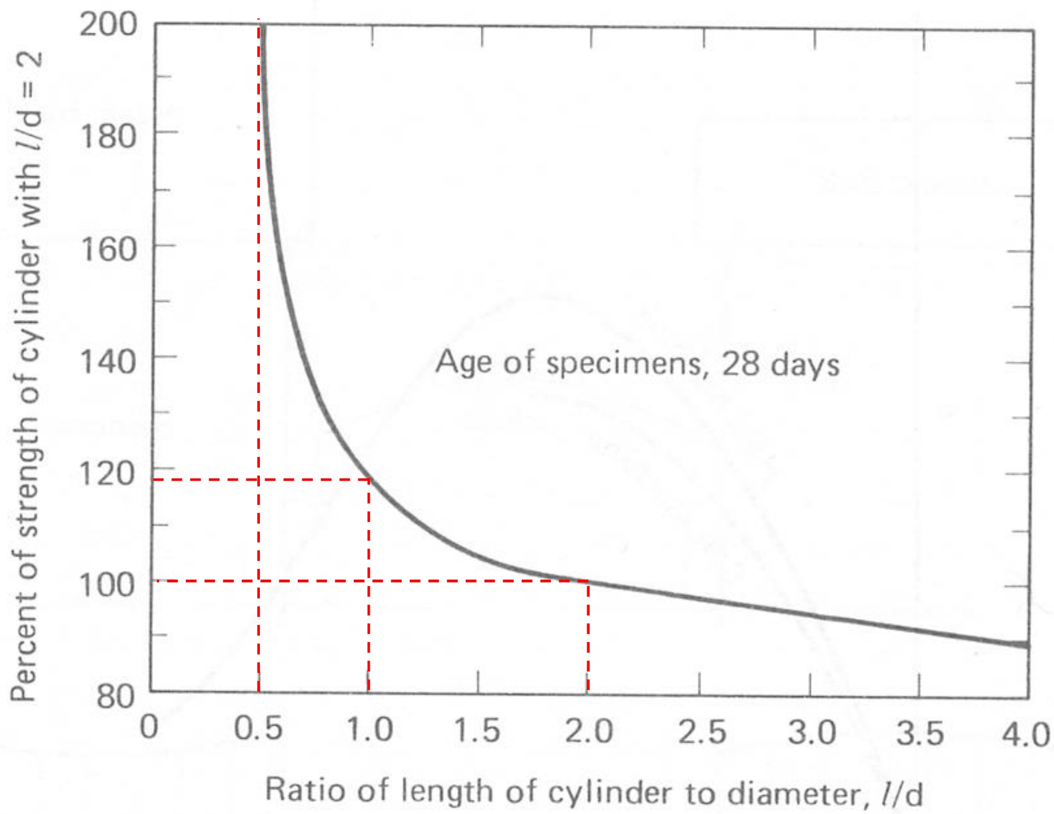
If you use a cylinder with a 1:1 aspect ratio, it would not significantly differ from a cube; there would be at least some confining stress throughout the specimen.

If you use a 1:2 aspect ratio, the lateral stresses are so high that the concrete almost can't fail except by crushing the aggregate particles themselves.

Shape Effects



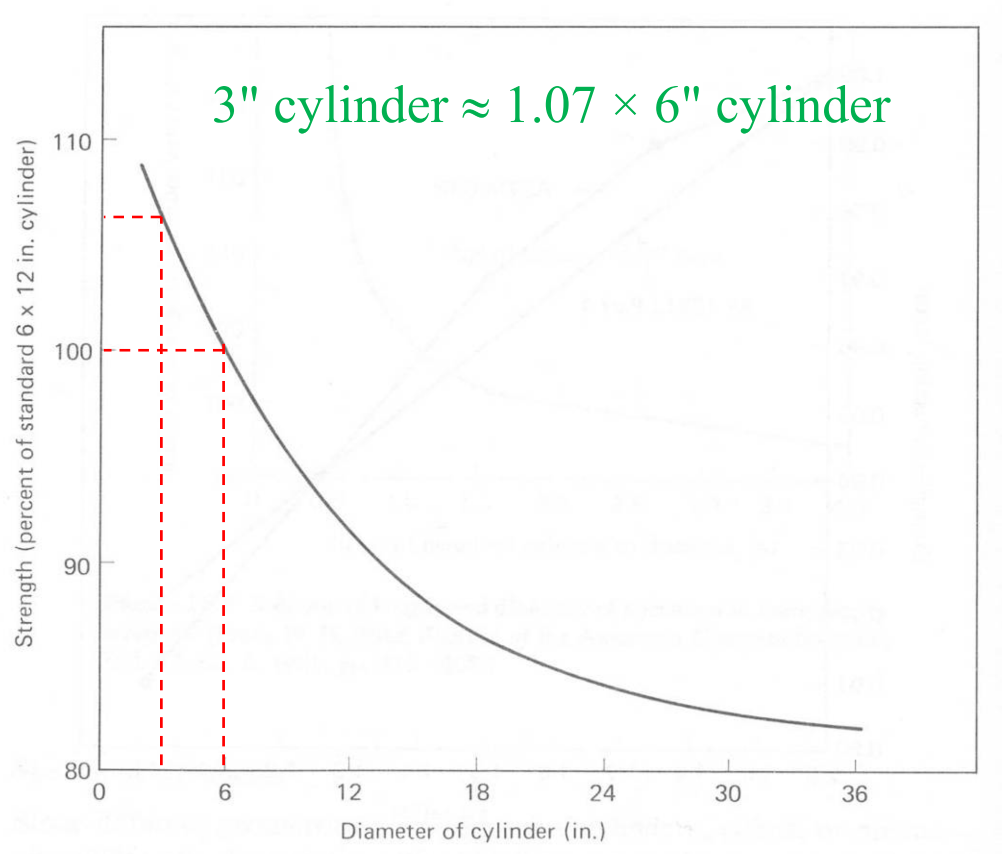
Shape Effects



Size Effects

The measured strength of concrete cylinders decreases as the specimen size increases. All concrete contains flaws arising from things like autogenous shrinkage cracks, incomplete cement-aggregate bonds, etc. The strength of a concrete specimen is governed by the weakest flaw within it. The larger the specimen the more likely it is to contain a critical flaw that will precipitate failure at a low load.

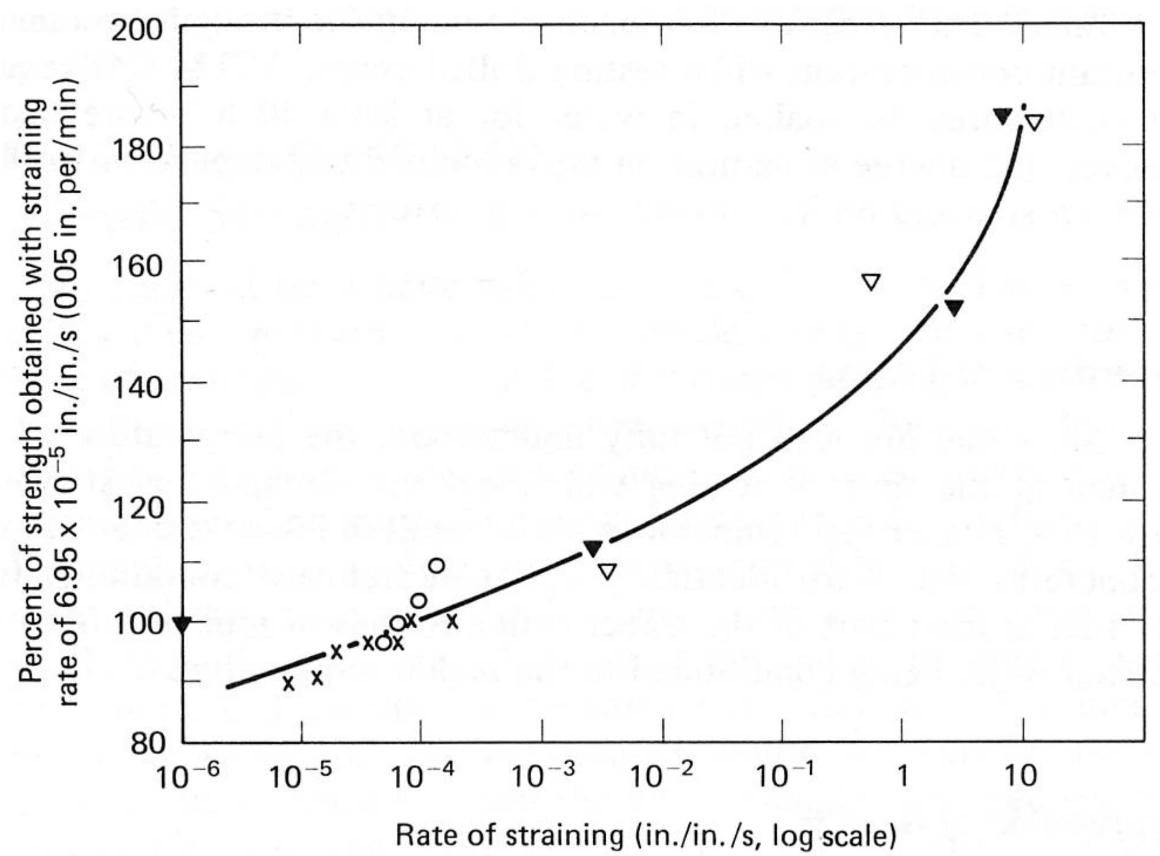
Size Effects



Loading Rate Effects

The faster you load a concrete specimen, the stronger it appears to be. The reasons are not completely clear but one postulate is that slow loading allows small cracks to propagate to failure while fast loading stays one step ahead of the crack growth, allowing a larger load to be applied before the concrete visibly fails. Another postulate is that slower rates allow creep to occur, which increases the internal strains at a given load. Concrete failure is controlled by the strains that develop in the specimen, not the stresses!

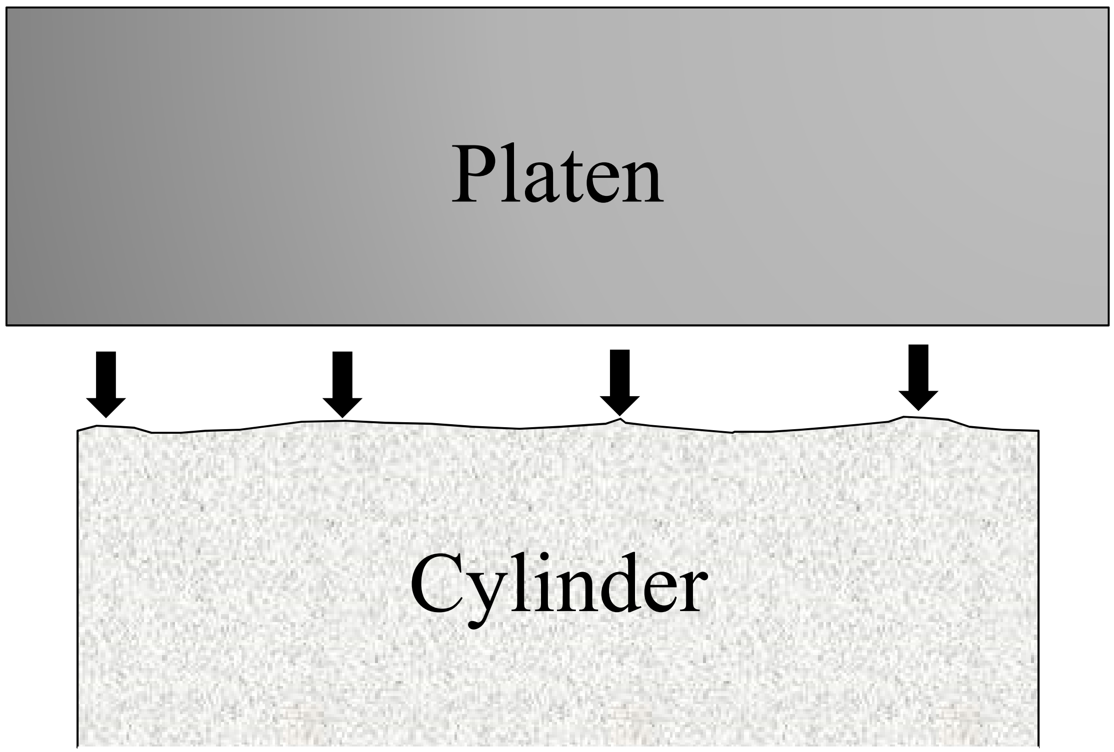
Loading Rate Effects



Cylinder Caps

Concrete cylinders have end surfaces that are rough and may not necessarily be flat or perpendicular to the direction of loading. If they are tested like that, stress concentrations will cause the cylinder to fail at a lower load than it otherwise would.

Cylinder Caps



Cylinder Caps

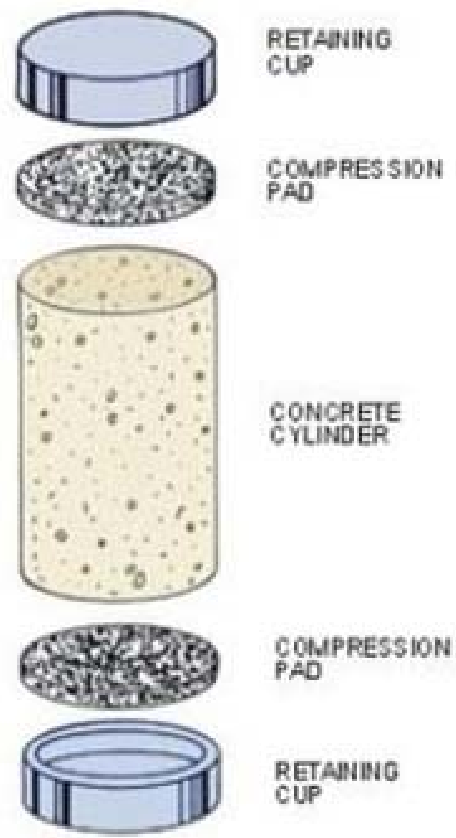
One solution is to ***grind*** the ends of the cylinders so they are smooth, flat, and horizontal. This is time consuming and therefore expensive.

Another solution is to ***cap*** the cylinders with high strength gypsum plaster or molten sulfur mortar. Both are liquid when first applied (to fill in all of the irregularities) and harden into material just as strong as the concrete and with similar stiffness properties.

Cylinder Caps

Another option is to use ***unbonded caps*** (also called pad caps). These are neoprene rubber pads that are confined within a metal retaining ring and placed over the ends of the cylinder. The pad conforms to the irregular surface of the specimen but is prevented from spreading laterally by the metal retaining ring.

Cylinder Caps



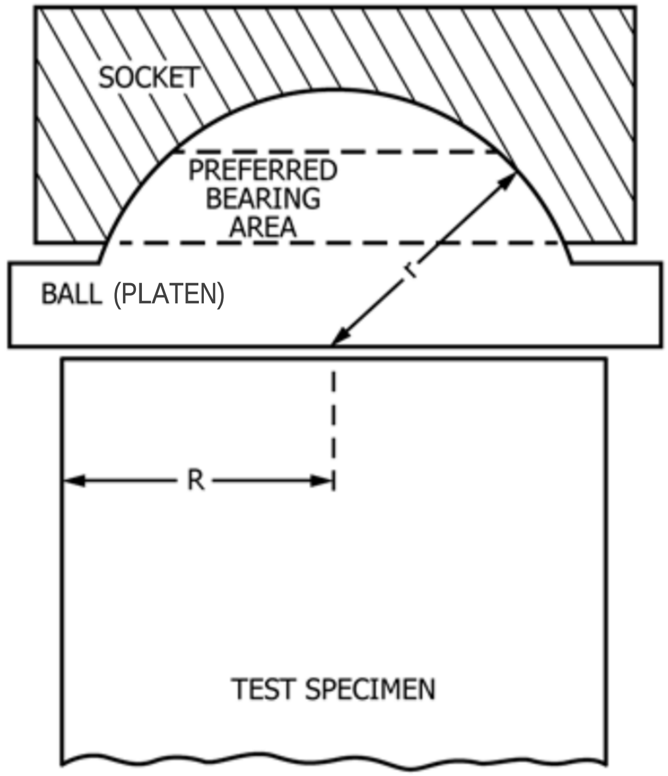
Source: https://www.certifiedmtp.com

Cylinder Caps

Bonded and unbonded cylinder caps can compensate for cylinder ends that aren't smooth and plane, but it is difficult in practice to ensure the cylinder ends are exactly perpendicular to the direction of loading. For this reason, testing machines use spherically seated platens to transfer the load from the testing machine to the cylinder. The spherical seats ensure that the line of action of the applied force is vertical even if the cylinder ends are not perfectly horizontal.

Compression Tester

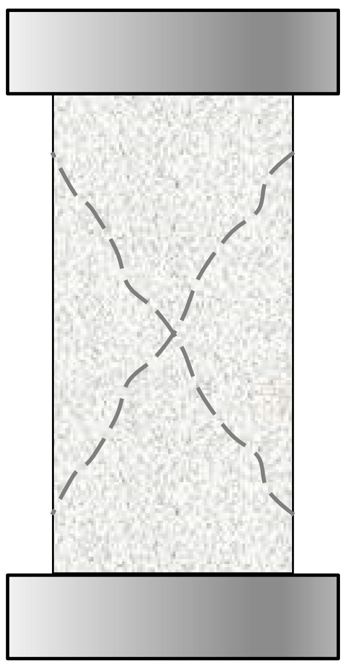
Compression Tester



Corrects for cylinder ends that aren't horizontal

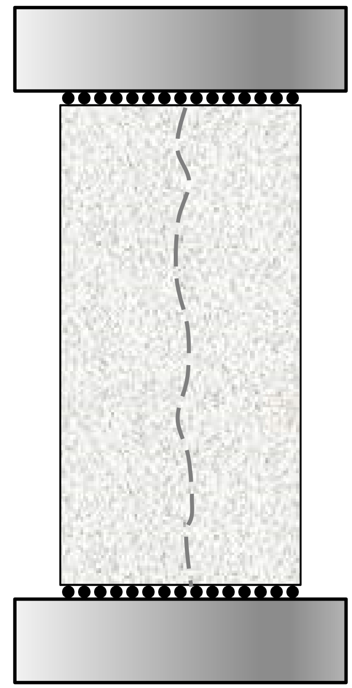
Failure Types

Fixed End



Fixed End

Frictionless End



Frictionless End

Failure Types (ASTM C39)

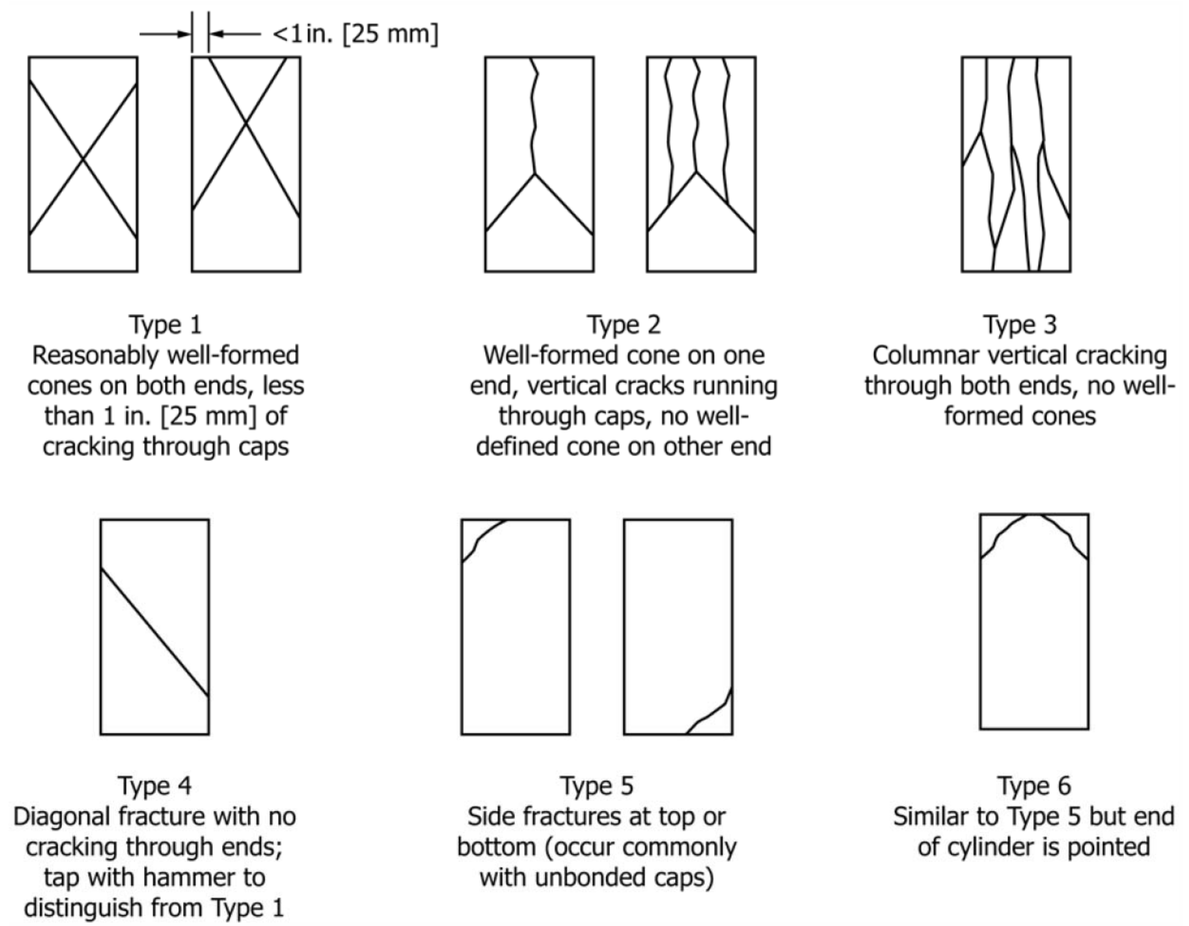
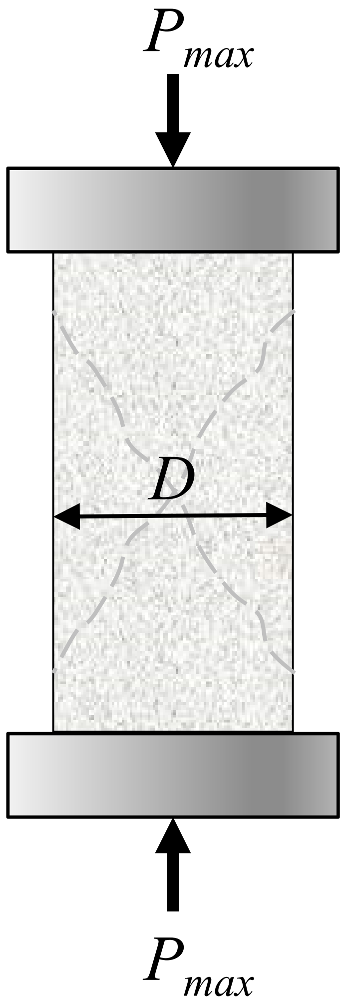


FIG. 2 Schematic of Typical Fracture Patterns

Compressive Strength



$$f_c = \frac{4P_{max}}{\pi D^2}$$

Basic Tests

Cylinder Compression

Splitting Tension

Beam Flexure

Elastic Modulus

Slump

Unit Weight

Air Content

Designation: C 496/C 496M – 04

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

This standard is issued under the fixed designation C 496/C 496M; 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 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.

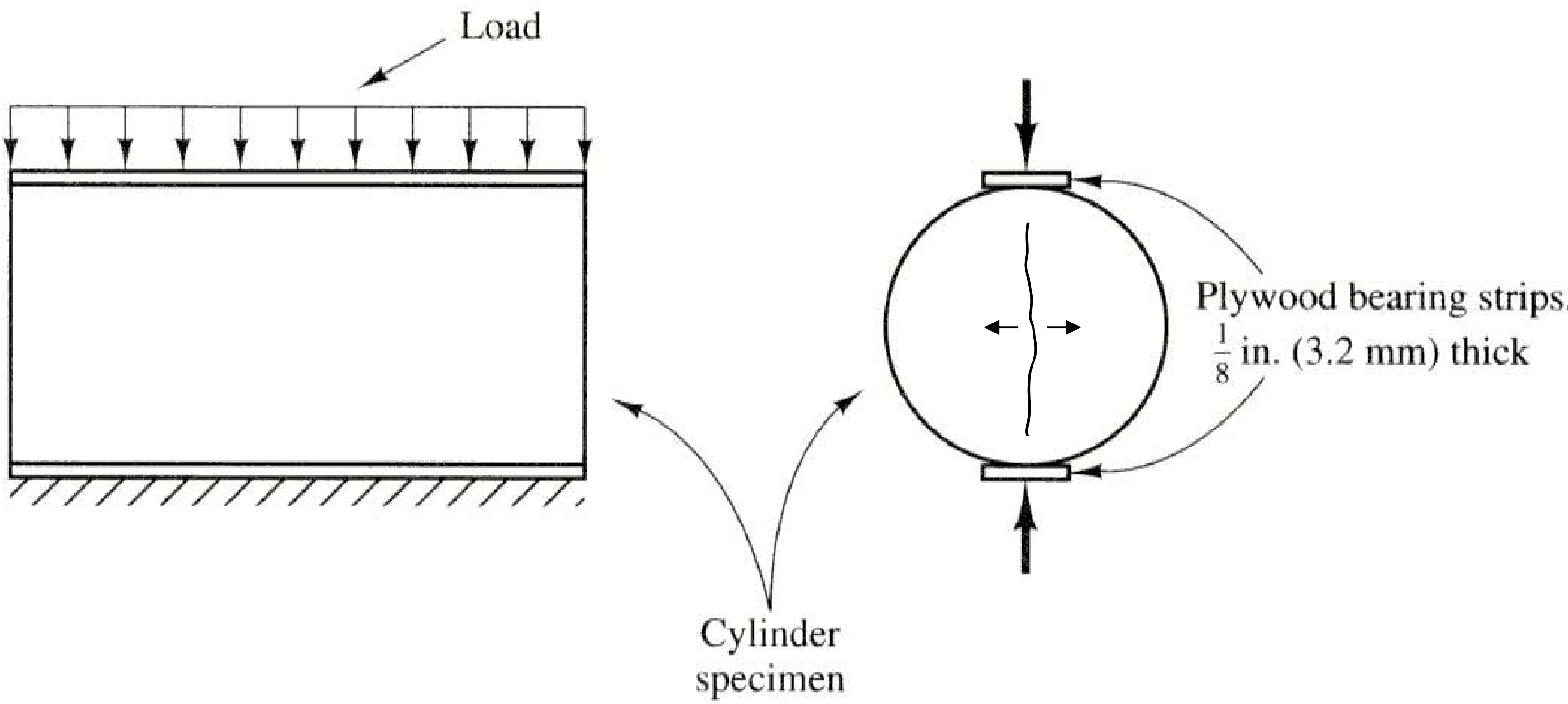
3.3 The maximum load sustained by the specimen is divided by appropriate geometrical factors to obtain the splitting tensile strength.

4. Significance and Use

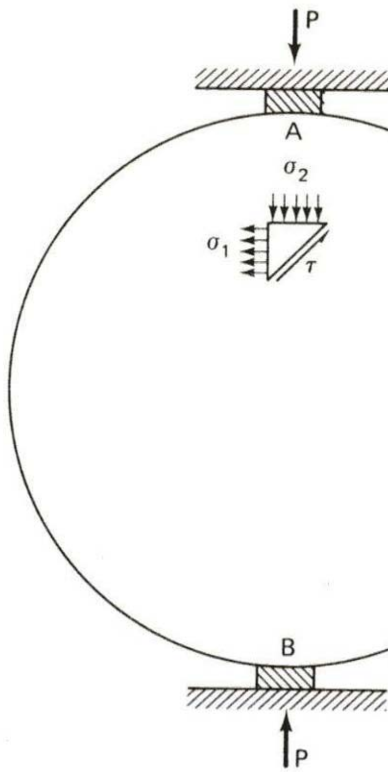
Splitting Tension Test

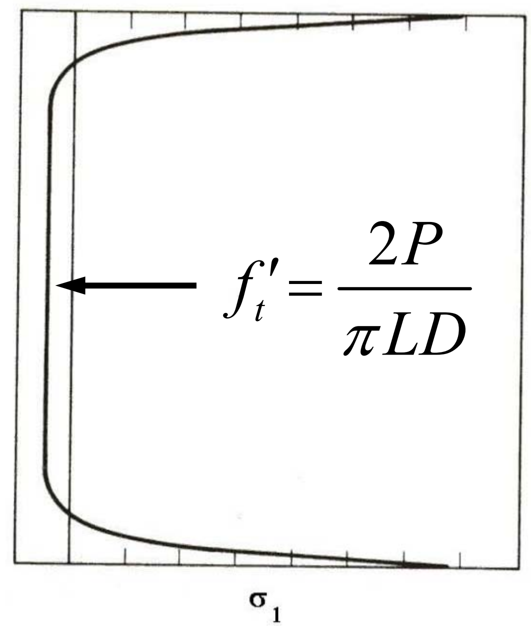
Source: https://www.quora.com

Splitting Tension Test



Splitting Tension Test





$$f_t' = \frac{2P}{\pi L D}$$

Basic Tests

Cylinder Compression

Splitting Tension

Beam Flexure

Elastic Modulus

Slump

Unit Weight

Air Content

Designation: C 78 – 02

Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)[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[2]

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

beam has been molded or sawed to size.

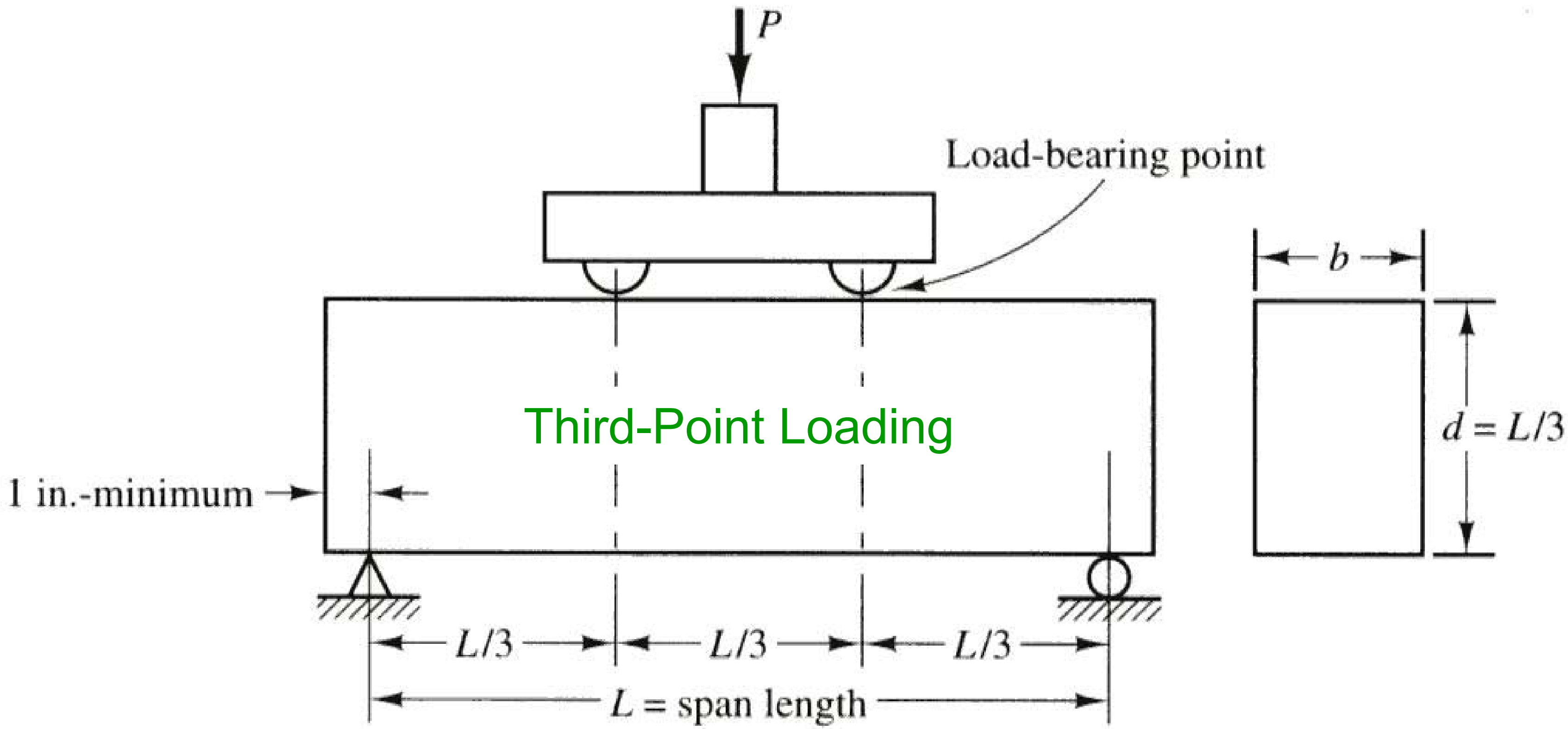
3.2 The results of this test method may be used to determine compliance with specifications or as a basis for proportioning, mixing and placement operations. It is used in testing concrete for the construction of slabs and pavements (Note 1).

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.

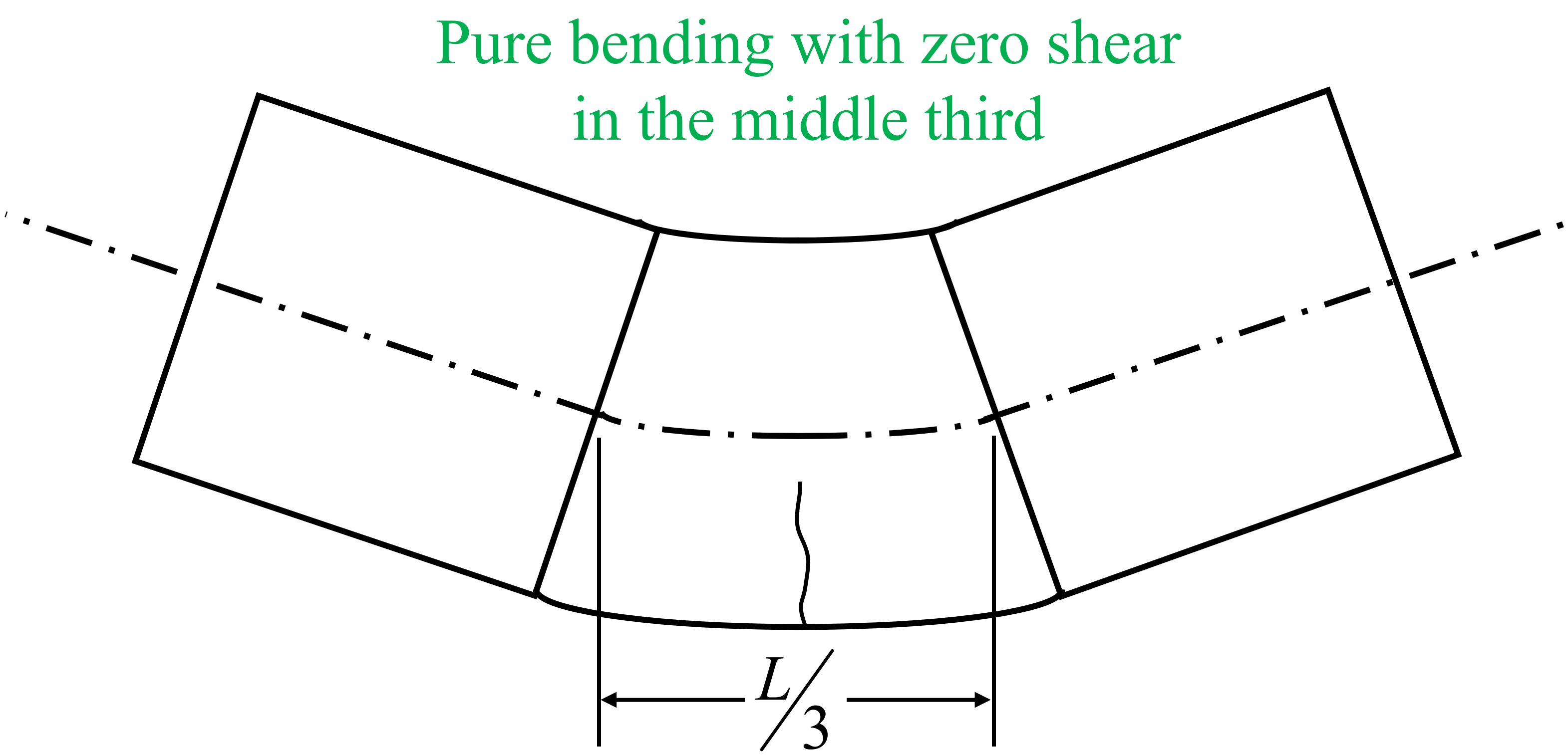
4.2 *Loading Apparatus*—The third point loading method shall be used in making flexure tests of concrete employing

Beam Flexure Test



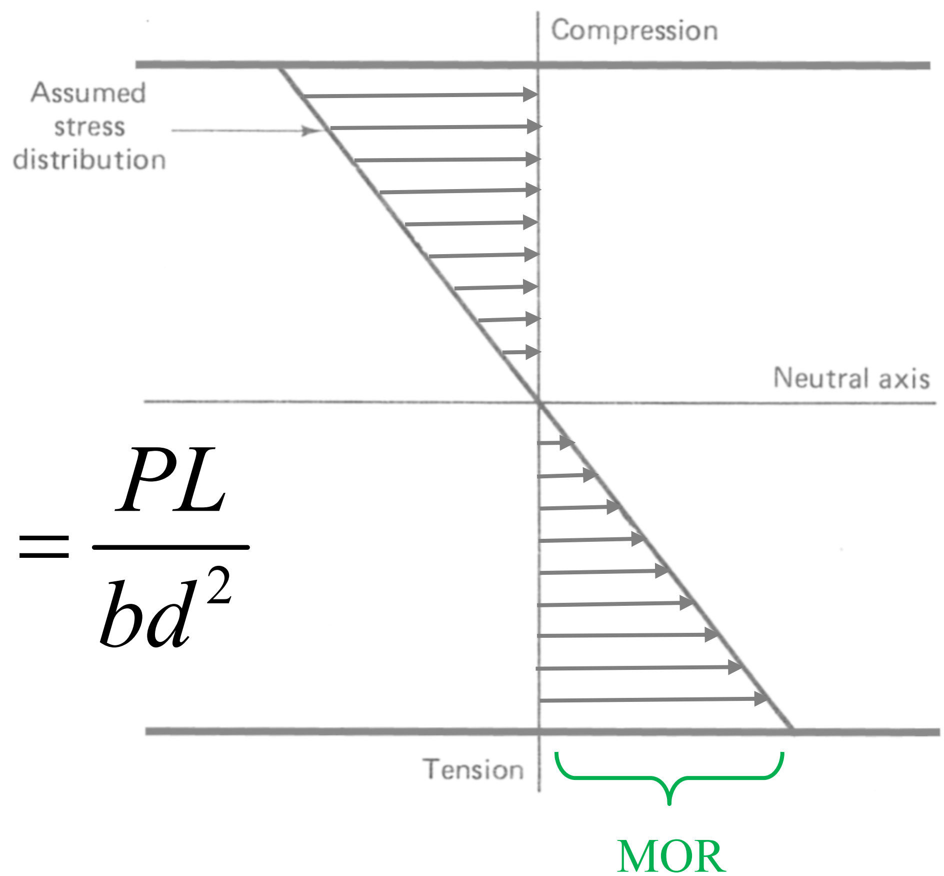
Beam Flexure Test

Beam Flexure Test



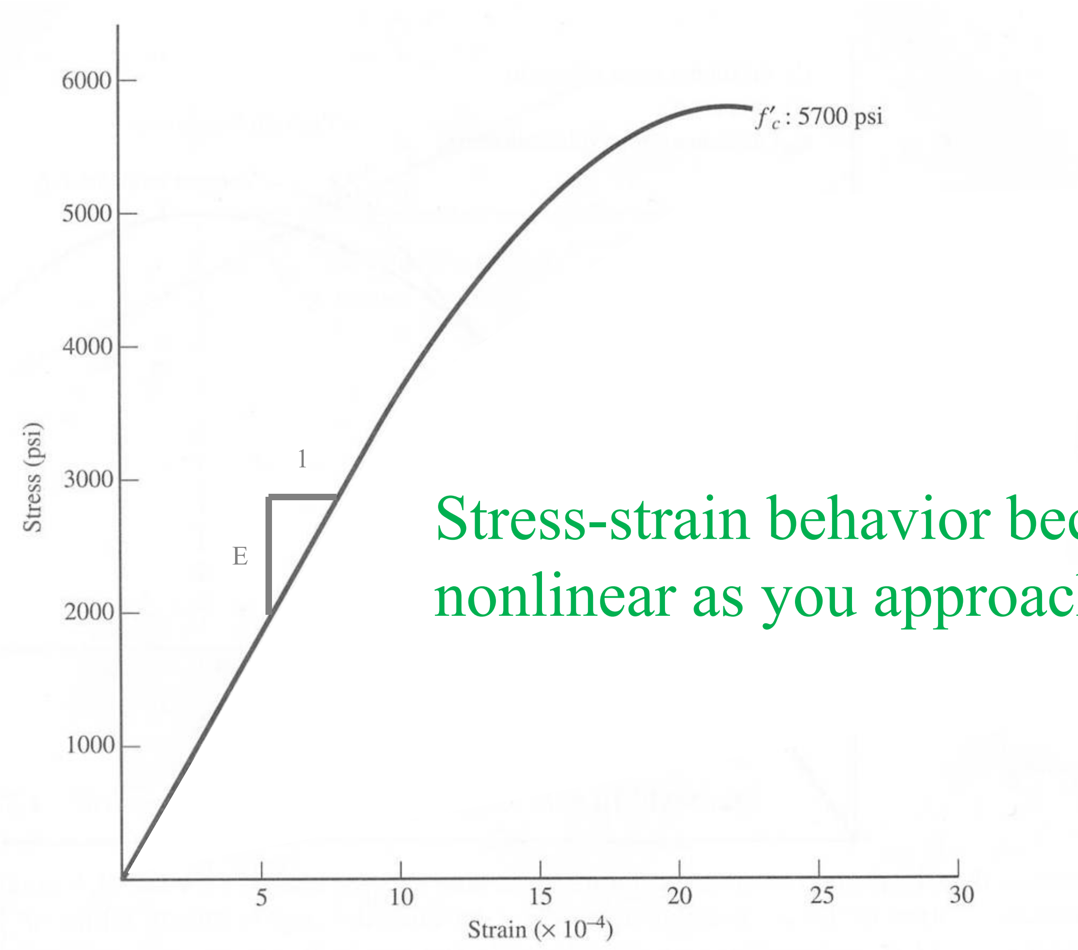
Modulus of Rupture

Based on beam bending formula



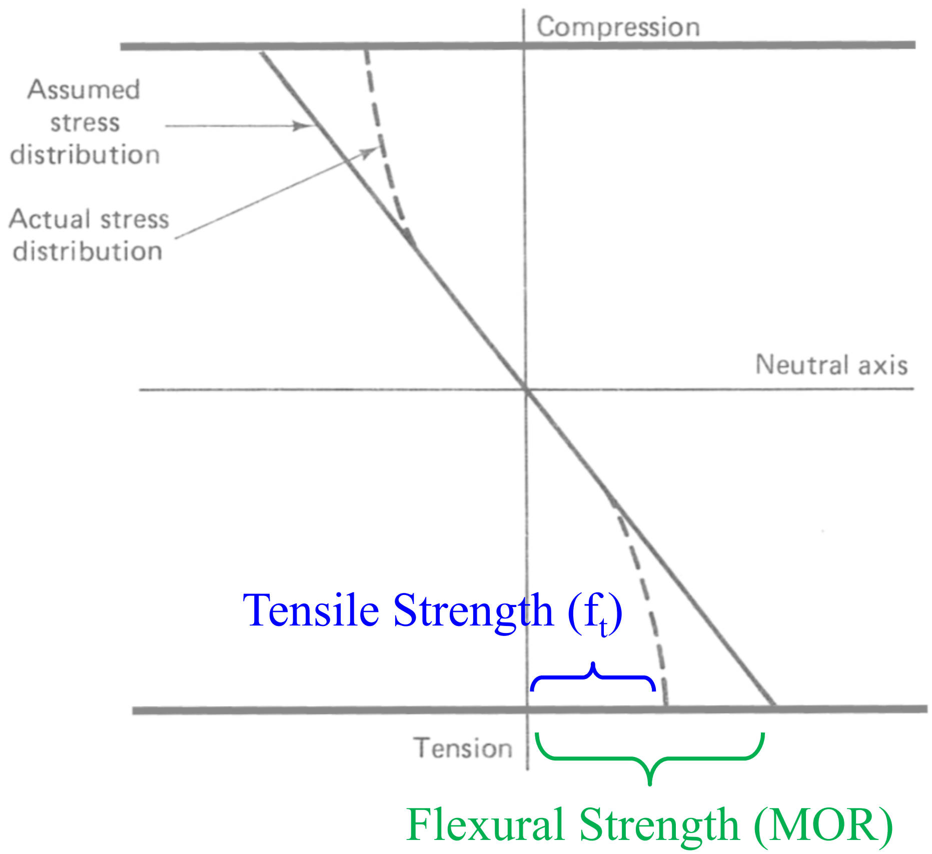
$$MOR = \frac{PL}{bd^2}$$

Concrete Behavior



Stress-strain behavior becomes nonlinear as you approach failure

Flexural vs. Tensile Strength



Basic Tests

Cylinder Compression

Splitting Tension

Beam Flexure

Elastic Modulus

Slump

Unit Weight

Air Content

Designation: C 469 – 02$^{\epsilon 1}$

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

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

ϵ^1 NOTE—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:*

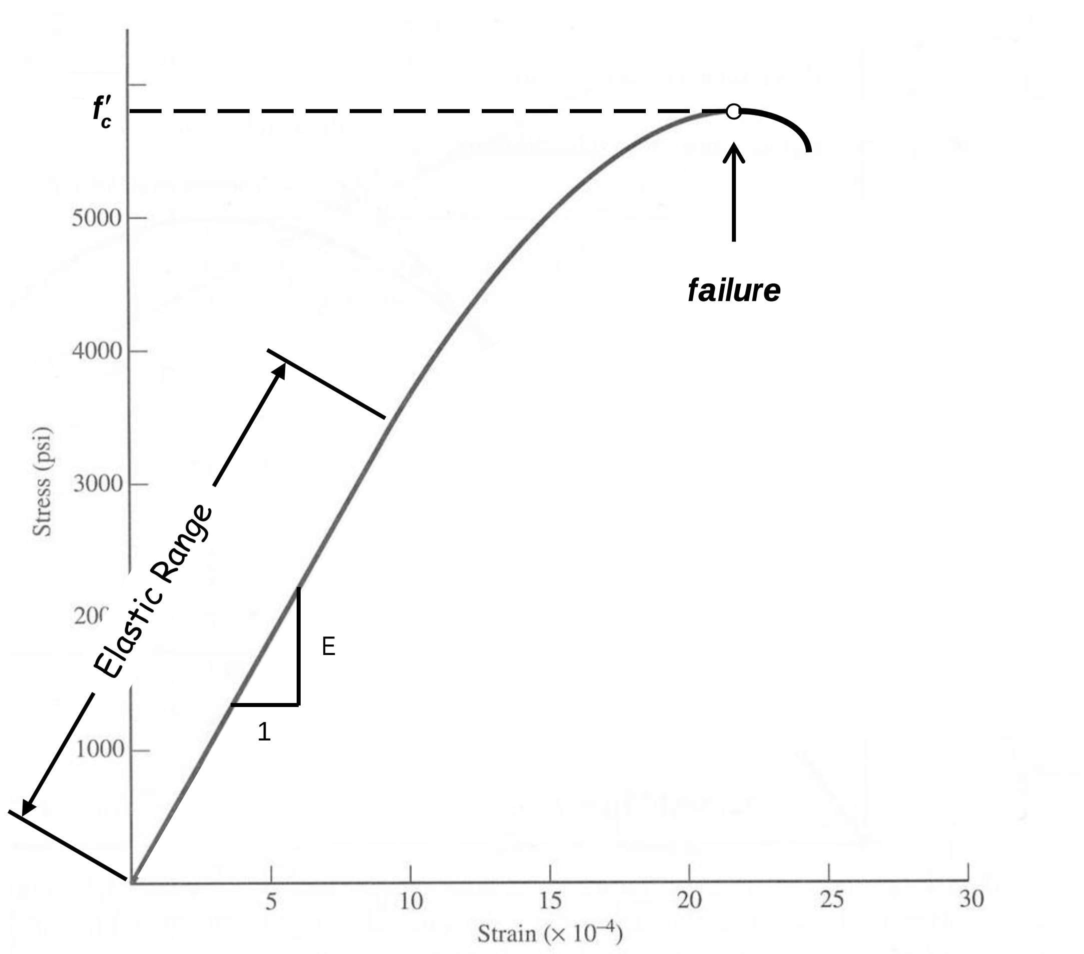
Compressometers (two drawings) and Extensometers (two drawings)[3]

3. Significance and Use

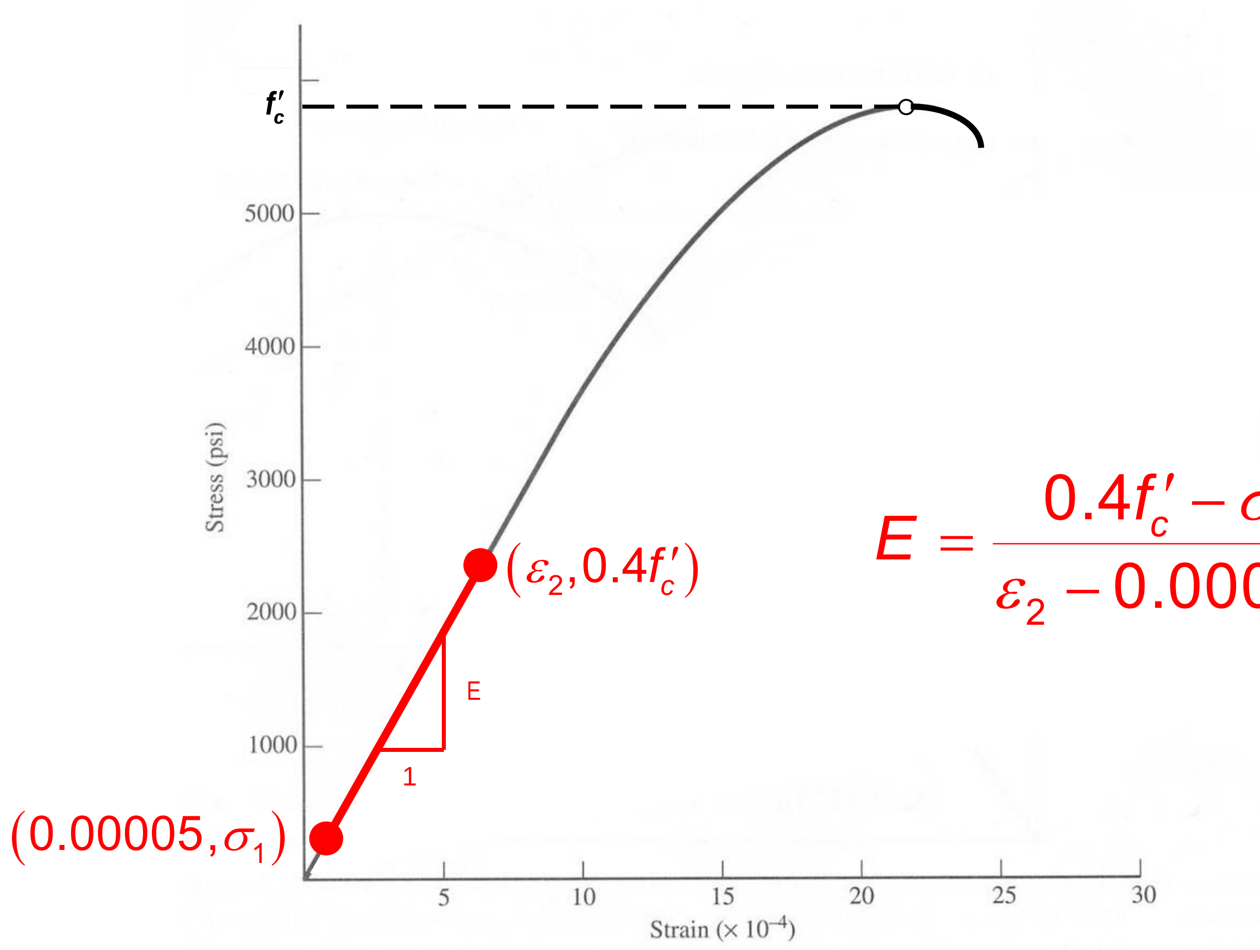
3.1 This test method provides a stress to strain ratio value and a ratio of lateral to longitudinal strain for hardened concrete at whatever age and curing conditions may be designated.

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

Elastic Modulus

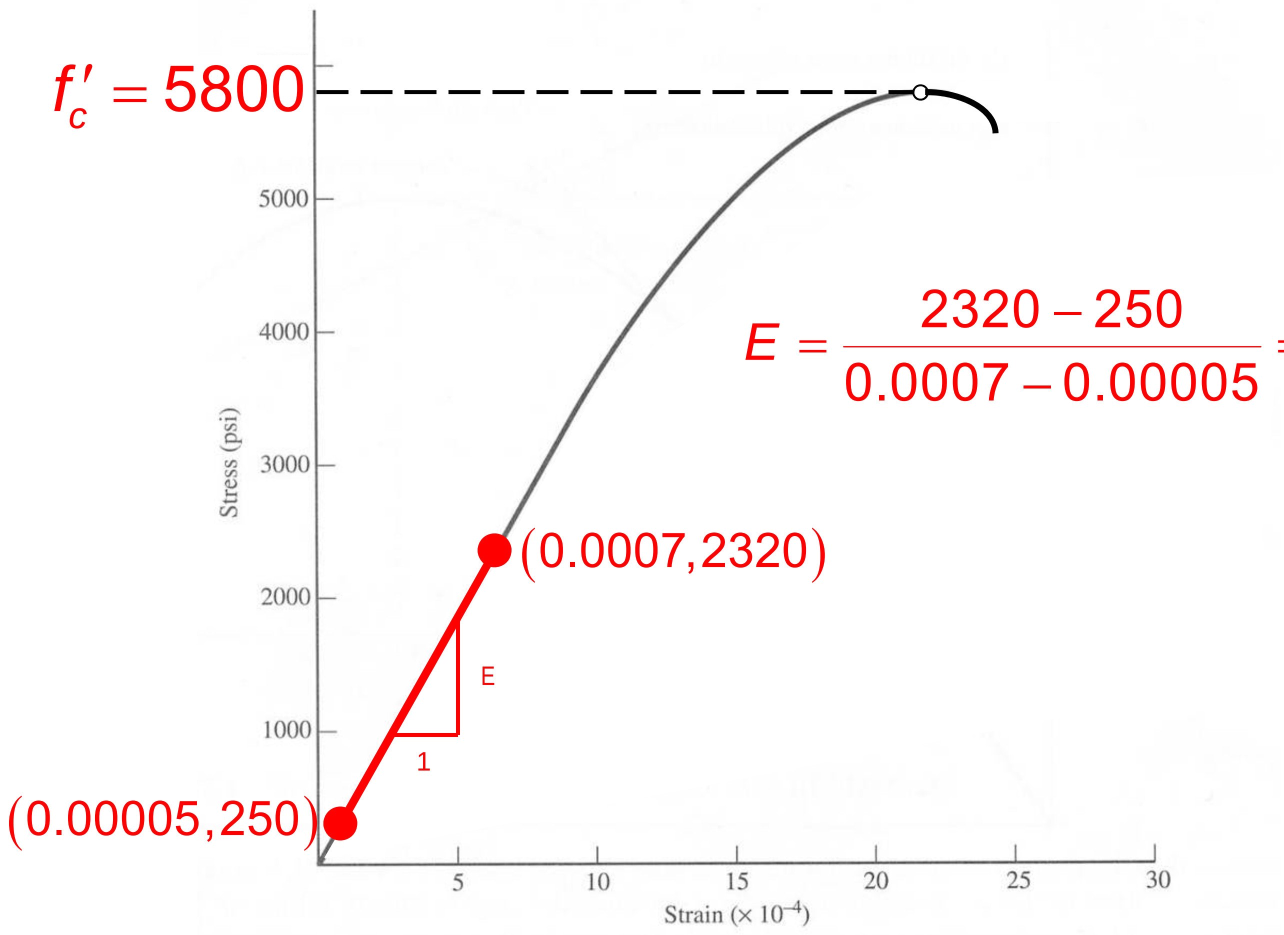


Elastic Modulus



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

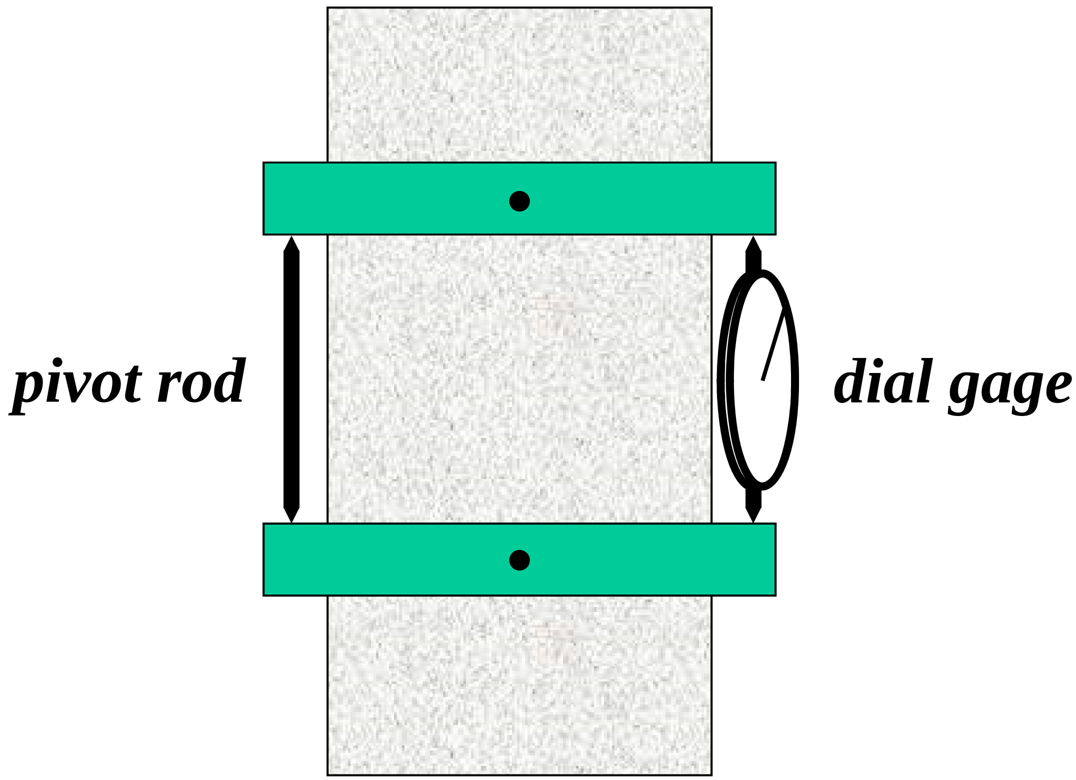
Elastic Modulus



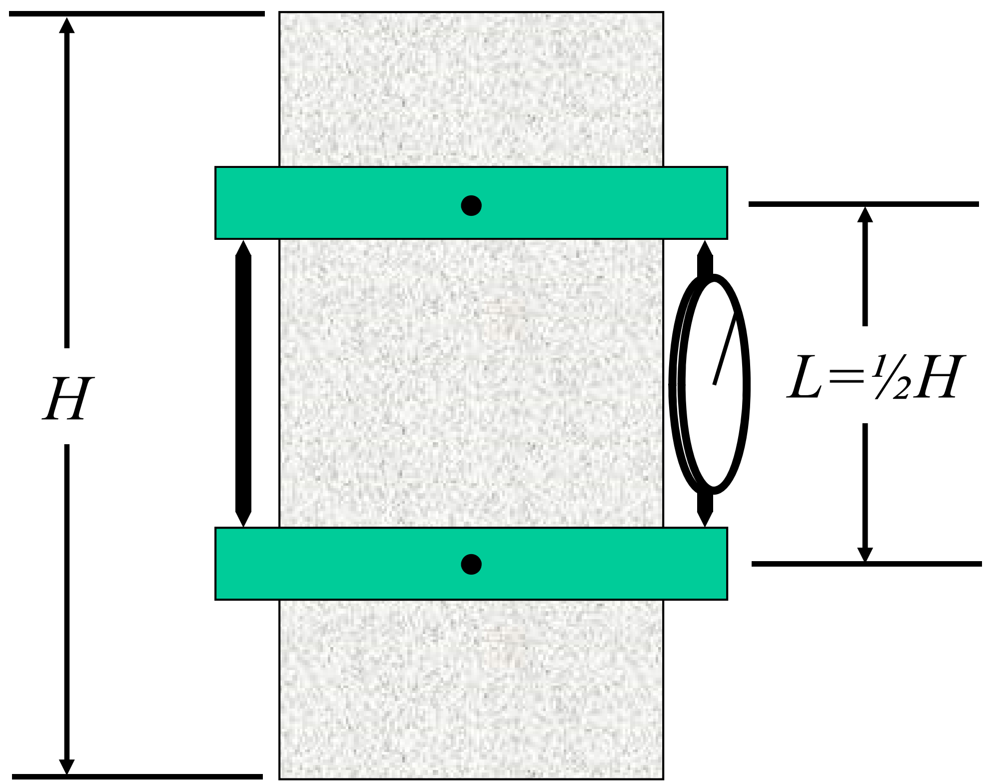
$$E = \frac{2320 - 250}{0.0007 - 0.00005} = 3.2 \times 10^6 \text{ psi}$$

Compressometer

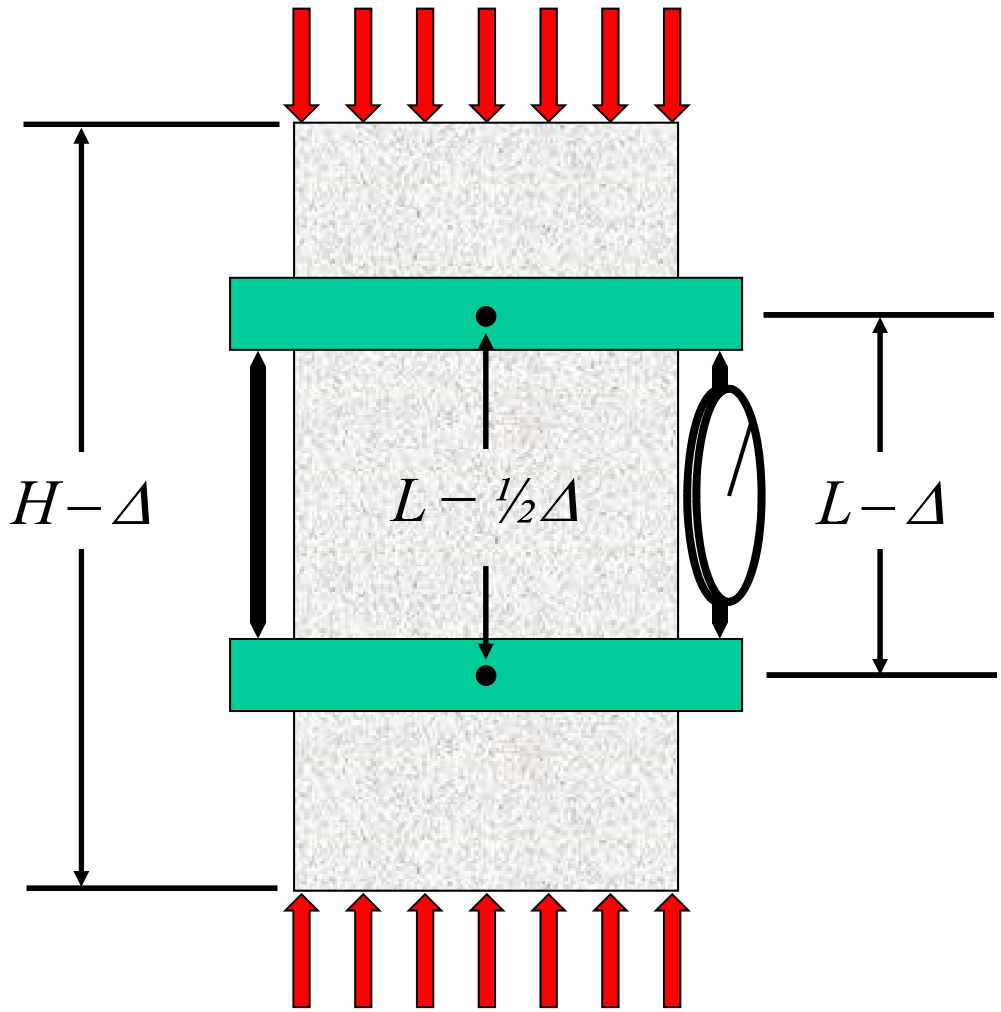
Compressometer



Compressometer



Compressometer



Compressometer