

# Course: Concrete Technology

## Lecture 13: Testing of hardened concrete

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# Session Objectives

- Understand ASTM-based concrete quality control procedures.
- Evaluate concrete using destructive and nondestructive tests.
- Interpret results affecting performance, durability, and reliability.



# Content

- Quality Control of Fresh Concrete
- Quality Control of Hardened Concrete

# Fresh and Hardened Concrete Relationship

- Fresh properties influence hardened concrete performance.
- Concrete exhibits complex, non-linear material behavior.
- Workability affects strength, durability, and deformability.
- Testing evaluates quality throughout concrete development.



# **Quality Control of Fresh Concrete**

# Standards for fresh concrete tests

ASTM  
**C172**

SAMPLING OF  
FRESH CONCRETE



ASTM  
**C143**

SLUMP TEST



ASTM  
**C1064**

TEMPERATURE  
MEASUREMENT



ASTM  
**C231**

AIR CONTENT  
DETERMINATION



ASTM  
**C138**

UNIT WEIGHT  
(DENSITY)



ASTM  
**C192**

MAKING AND CURING  
CONCRETE SPECIMENS



# Concrete Sampling: Purpose and Equipment

- Obtain representative fresh concrete sample.
- Required for quality control testing.
- Uses shovel, scoop, and wheelbarrow.
- PPE ensures safe field operations.



Source: ASTM International

# Sampling Procedure Requirements

- Moisten equipment without leaving free water.
- Sample from middle third of discharge.
- Collect sufficient concrete volume.
- Remix sample before testing procedures.



Source: Open AI (2026)

# Sampling Time and Volume Requirements

- Collect at least two sample portions.
- Begin testing within five minutes.
- Minimum sample volume: one cubic foot.
- Complete tests within fifteen minutes.



Source: ASTM International

# Slump Test Equipment

- Evaluates fresh concrete workability.
- Uses Abrams cone and base plate.
- Consolidation performed with tamping rod.
- PPE required during testing.



Source: ASTM International

# Slump Test Procedure



Source: ASTM International

# Fresh Concrete Temperature Test

- Temperature affects concrete performance.
- Influences setting and strength development.
- Conducted according to ASTM C1064.
- Uses thermometer and concrete sample.



Source: ASTM International

# Fresh Concrete Temperature Measurement



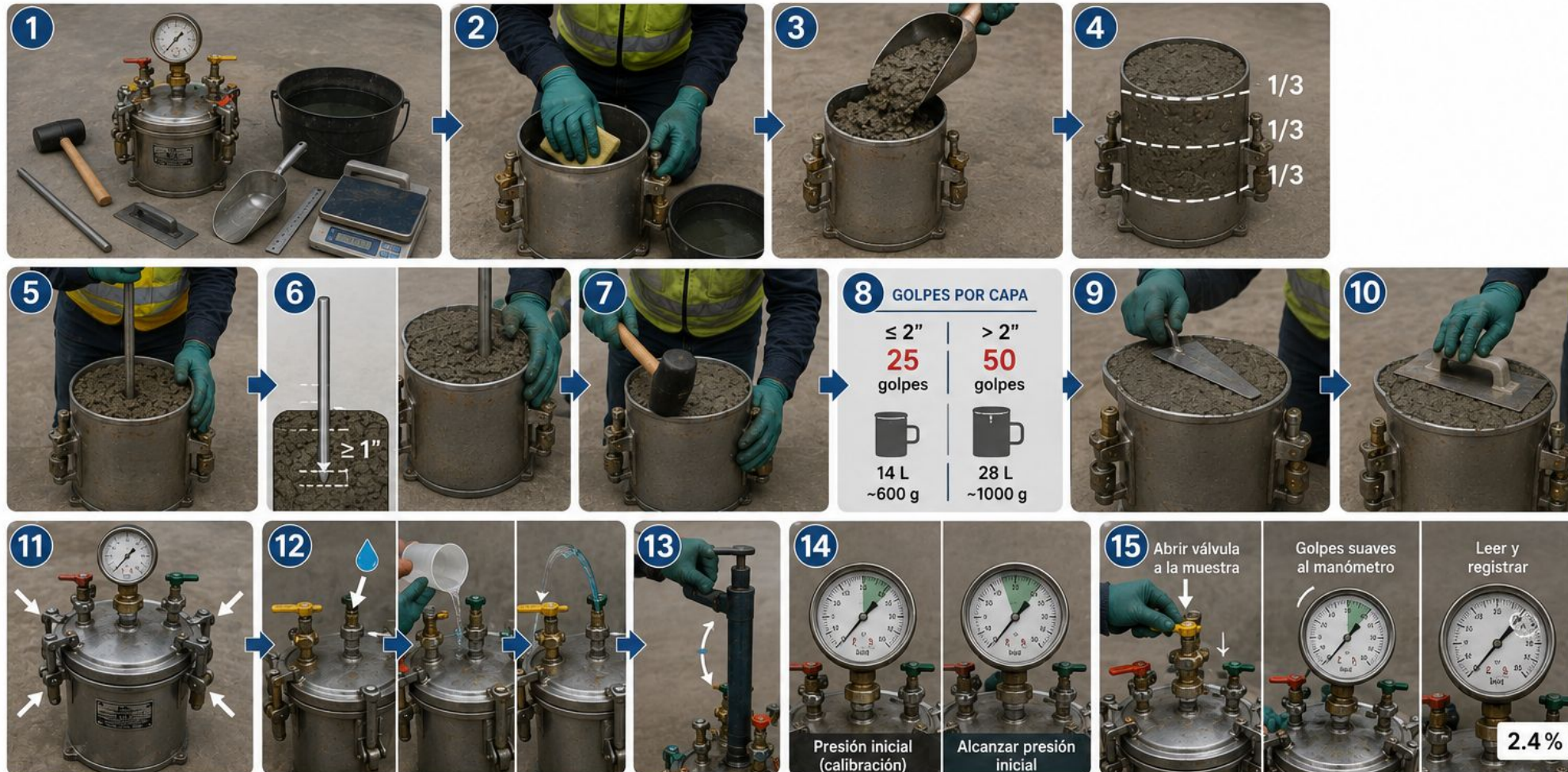
# Air Content Test Equipment

- Measures entrained and entrapped air content.
- Conducted according to ASTM C231 requirements.
- Uses Washington air meter and accessories.
- PPE required during testing procedures.



Source: ASTM International

# Air Content Test Preparation



Source: ASTM International

# Unit Weight Test Equipment



Moisten the container.



Fill the container with the first layer (1/3).



25 blows (≤ 2")  
50 blows (> 2")

Rod the layer.

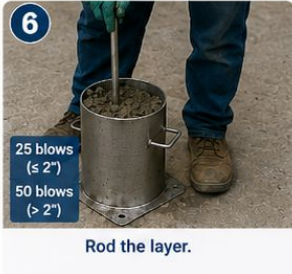


10-15 taps

Tap the sides.



Fill the container with the second layer (2/3).



25 blows (≤ 2")  
50 blows (> 2")

Rod the layer.



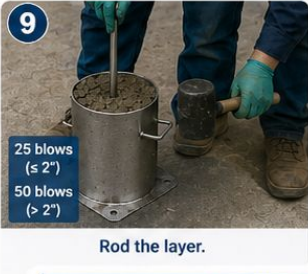
10-15 taps

Tap the sides.



3/3

Fill the container with the final layer (3/3).



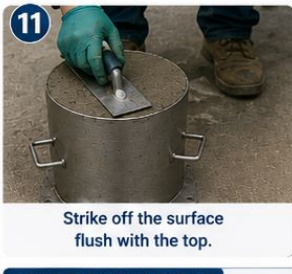
25 blows (≤ 2")  
50 blows (> 2")

Rod the layer.



10-15 taps

Tap the sides.



Strike off the surface flush with the top.



Clean the outside of the container.



Weigh the container with the concrete.

**EQUIPMENT AND MATERIALS**



Washington bucket



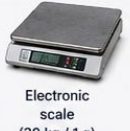
Tamping rod



Rubber mallet



Metal scoop



Electronic scale (30 kg / 1 g)



Wheelbarrow / buggy (with fresh concrete)



PPE

**UNIT WEIGHT CALCULATION**

Mass of container + concrete	Mass of container	Net mass of concrete	Volume of container
24.680 kg	6.320 kg	18.360 kg	0.01413 m <sup>3</sup>

$$\text{Unit weight} = \frac{\text{Net mass of concrete}}{\text{Volume of container}} = \frac{18.360}{0.01413} = 2,300 \text{ kg/m}^3$$

$$\text{Yield} = \frac{\text{Actual unit weight}}{\text{Design unit weight}}$$

**Acceptable range: 0.98 – 1.02**

# Specimen Molding and Curing

- Prepare specimens for hardened concrete testing.
- Conducted according to ASTM C192.
- Uses cylindrical or prism molds.
- Apply release agent before casting.



Source: ASTM International

# Finishing and Initial Storage

**1** Prepare equipment and molds.

**2** Apply a thin layer of release agent.

**3** LAYER 1/3  
Fill the mold with the first layer (1/3).

**4** 25 BLOWS  
Rod the layer.

**5** LAYER 2/3  
10-15 TAPS  
Add the second layer (2/3) and tap the sides.

**6** 25 BLOWS  
10-15 TAPS  
Rod the layer.

**7** LAYER 3/3  
Add the final layer (3/3).

**8** 25 BLOWS  
10-15 TAPS  
Rod the layer.

**9** Tap the sides.

**10** 5-10 MIN  
Strike off and finish the surface.

**11** Cover and store.  
16-27 °C (60-80 °F)

**12** FINAL STRENGTH 24 ± 2 h  
Remove the mold.

**13** Finished test specimens.

**14** CURING TANK  
WATER LEVEL 3 in (75 mm) MIN  
21-23 °C (70-73 °F)  
Cure in water.

**15** TEMPERATURE CONTROL  
23.0 (73.4 °F)  
Monitor and control water temperature.

**16** ALTERNATIVE CURING METHODS  
Moist room or other approved methods.

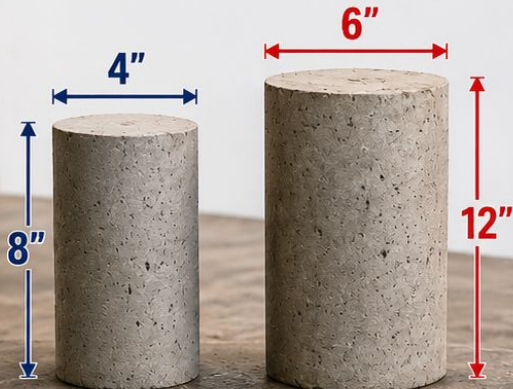
**SPECIMEN REQUIREMENTS (ASTM C192)**

- 3 specimens for each age or test
- 2 layers of concrete
- 4 in (100 mm) diameter
- 8 in (200 mm) length
- 3/8 in (10 mm) maximum nominal aggregate size


Source: ASTM International

# Requirements for 4x8-Inch Cylinders


**4"x8" SPECIMENS vs 6"x12"**




**1** For compression strength tests, prepare **THREE** specimens for each test age (instead of two).



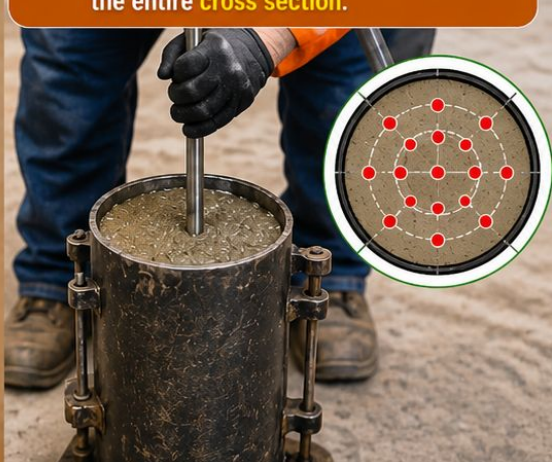
**2** Consolidation must be performed using a smooth steel rod **3/8"** in diameter, with a rounded tip and a length of approximately **12 inches**.



**3** Filling of the mold is done in **TWO** layers of equal volume.



**4** Each layer must be consolidated with **25** evenly distributed roddings over the entire **cross section**.



Source: ASTM International



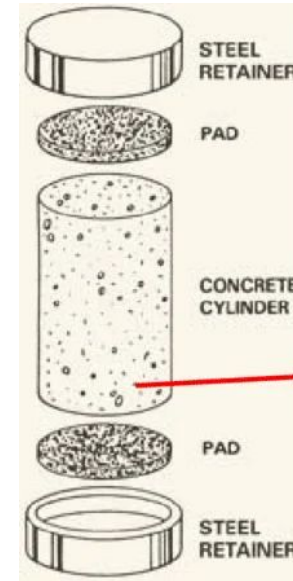
# Quality Control of Hardened Concrete

# Standards for hardened concrete tests

<p><b>1</b> COMPRESSIVE STRENGTH TEST — ASTM C39</p> 	<p><b>2</b> STATIC MODULUS OF ELASTICITY AND POISSON'S RATIO — ASTM C469</p> 	<p><b>3</b> FLEXURAL STRENGTH</p> <table border="1"><tr><td data-bbox="1080 368 1319 802"><p>ASTM C293 (CENTER-POINT LOADING)</p></td><td data-bbox="1327 368 1567 802"><p>ASTM C78 (THIRD-POINT LOADING)</p></td></tr></table>		<p>ASTM C293 (CENTER-POINT LOADING)</p> 	<p>ASTM C78 (THIRD-POINT LOADING)</p> 	<p><b>4</b> SPLITTING TENSILE STRENGTH — ASTM C496</p> 
<p>ASTM C293 (CENTER-POINT LOADING)</p> 	<p>ASTM C78 (THIRD-POINT LOADING)</p> 					
<p><b>5</b> REBOUND HAMMER OR SCHMIDT HAMMER TEST — ASTM C805</p> 	<p><b>6</b> DRILLED CORES AND SAWED BEAM TESTING — ASTM C42</p> <table border="1"><tr><td data-bbox="665 939 861 1302"><p>DRILLED CORES</p></td><td data-bbox="868 939 1021 1302"></td><td data-bbox="1054 939 1431 1302"><p>SAWED BEAMS</p></td></tr></table>		<p>DRILLED CORES</p> 		<p>SAWED BEAMS</p> 	<p><b>7</b></p>  <p>THESE STANDARDS PROVIDE UNIFORM METHODS FOR EVALUATING THE MECHANICAL PROPERTIES AND IN-SITU QUALITY OF CONCRETE.</p>
<p>DRILLED CORES</p> 		<p>SAWED BEAMS</p> 				

# Compressive Strength Test Equipment

- Compressive strength evaluates concrete load-carrying capacity.
- Hydraulic press applies controlled axial compression.
- Calipers measure specimen dimensions for calculations.
- Neoprene pads improve load distribution uniformity.



Compression test configuration (concrete cylinder).  
Source: ASTM International

# Compressive Strength Test Procedure

**1 SPECIMEN CURING**  
Cylinders are cured in saturated limewater at approximately 23 °C for at least 28 days.



CURING TANK

**2 CLEAN THE SPECIMEN**  
Remove the specimen from the curing tank and wipe the surfaces to remove excess moisture and debris.



TOWEL MARKER

**3 MEASURE DIAMETER**  
Measure the diameter of the cylinder at two perpendicular directions and record the average value.



CALIPER

**4 CAPPING (IF REQUIRED)**  
If the end surfaces are not plane and true, cap the specimen using capping pads or sulfur capping.



NEOPRENE PADS STEEL CAPPING PLATES

**5 PLACE IN THE PRESS**  
Center the specimen on the lower platen of the compression testing machine.



STEEL PLATE SEATING RING

**6 CLOSE THE SAFETY DOOR**  
Close the safety door of the testing machine.



COMPRESSION TESTING MACHINE

**7 APPLY THE LOAD**  
Apply the load continuously at the rate specified in ASTM C39.




**8 SPECIMEN FAILURE**  
Continue loading until the specimen fails. Record the maximum load sustained by the specimen.




**9 RECORD DATA**  
Record the maximum load and the specimen dimensions.



$P = 356.4 \text{ kN}$   
 $d = 150.2 \text{ mm}$   
 $A = \frac{\pi d^2}{4}$   
 $A = \frac{3.1416 (150.2^2)}{4} 5$   
 $A = 17706 \text{ mm}^2$   
 $f'_c = \frac{P}{A}$   
 $f'_c = \frac{356400 \text{ N}}{17706 \text{ mm}^2}$   
 $f'_c = 20.1 \text{ MPa}$



**10 CALCULATE COMPRESSIVE STRENGTH**  
The compressive strength is obtained by dividing the maximum load by the cross-sectional area of the cylinder.

$f'_c =$   
**20.1 MPa**

RESULT  
(AVERAGE)



Source: ASTM International

# Testing Age Tolerances

- Concrete strength changes continuously with age.
- Testing ages require specific permissible tolerances.
- Record molding and testing times accurately.
- Proper timing ensures reliable result interpretation.

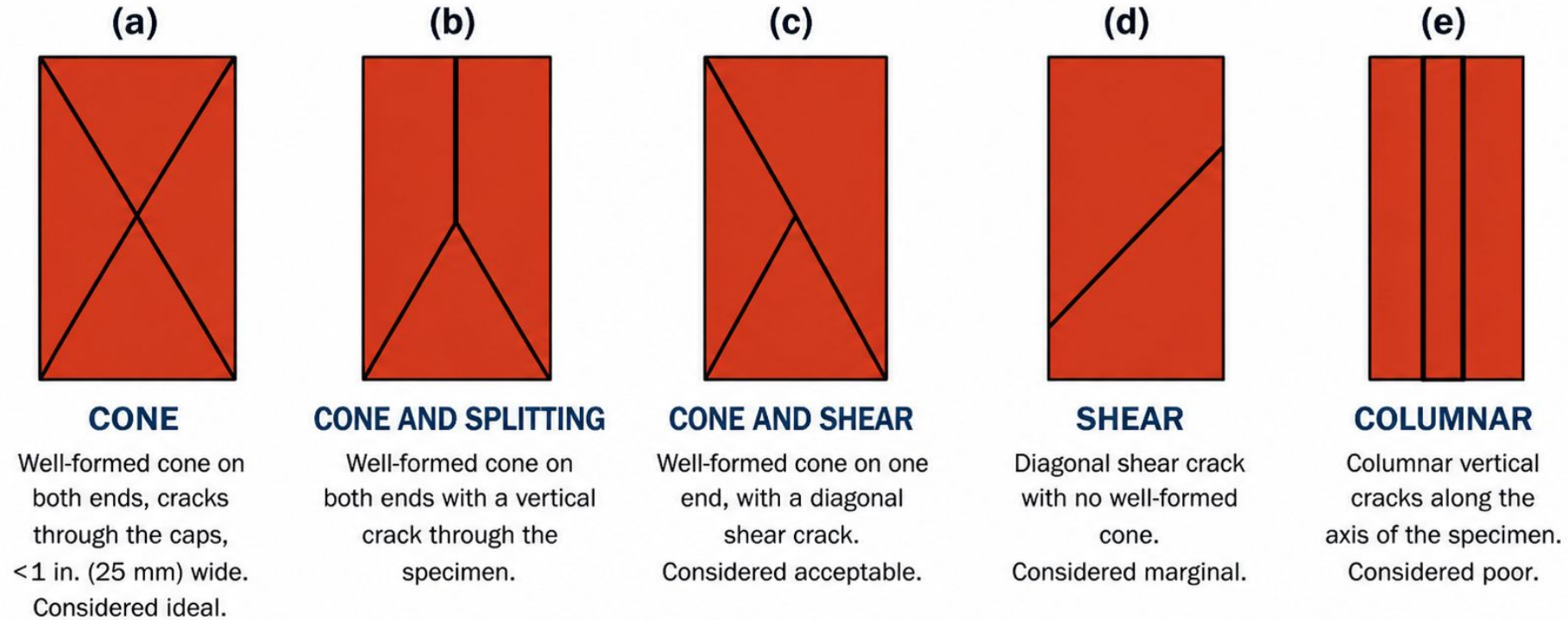
AGE OF TEST	PERMISSIBLE TOLERANCE
1 day	± 0.5 hr
3 days	± 2 hr
7 days	± 6 hr
28 days	± 20 hr
90 days	± 2 days

Source: Author's own elaboration

# Failure Types in Compression Testing

## TYPES OF FRACTURE IN CONCRETE CYLINDERS

Typical fracture patterns after compressive strength testing (ASTM C39)

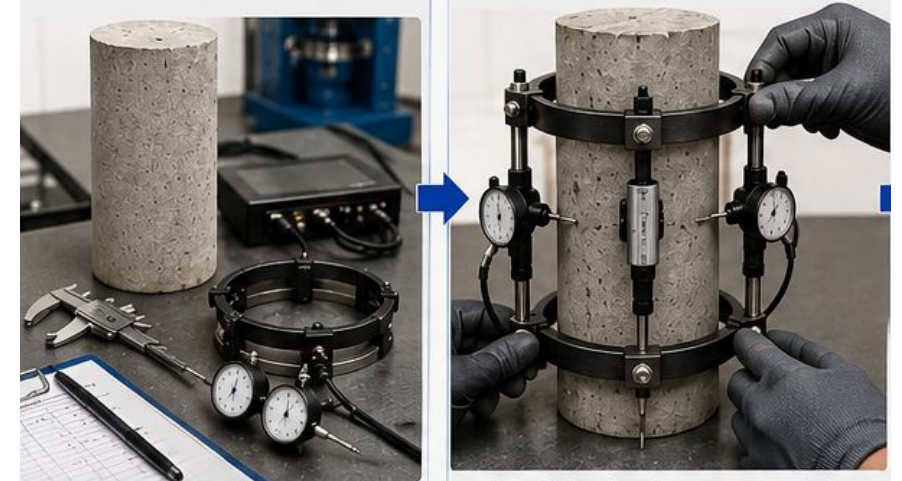


# Variables Affecting Strength Results

- Curing conditions strongly influence strength development, variability, and long-term concrete performance.
- Improper sampling, consolidation, transportation, or moisture control increases result variability significantly.
- Loading rate, specimen alignment, and equipment calibration directly affect measured strengths.
- Standardized procedures minimize variability and ensure reliable, representative compression test results.

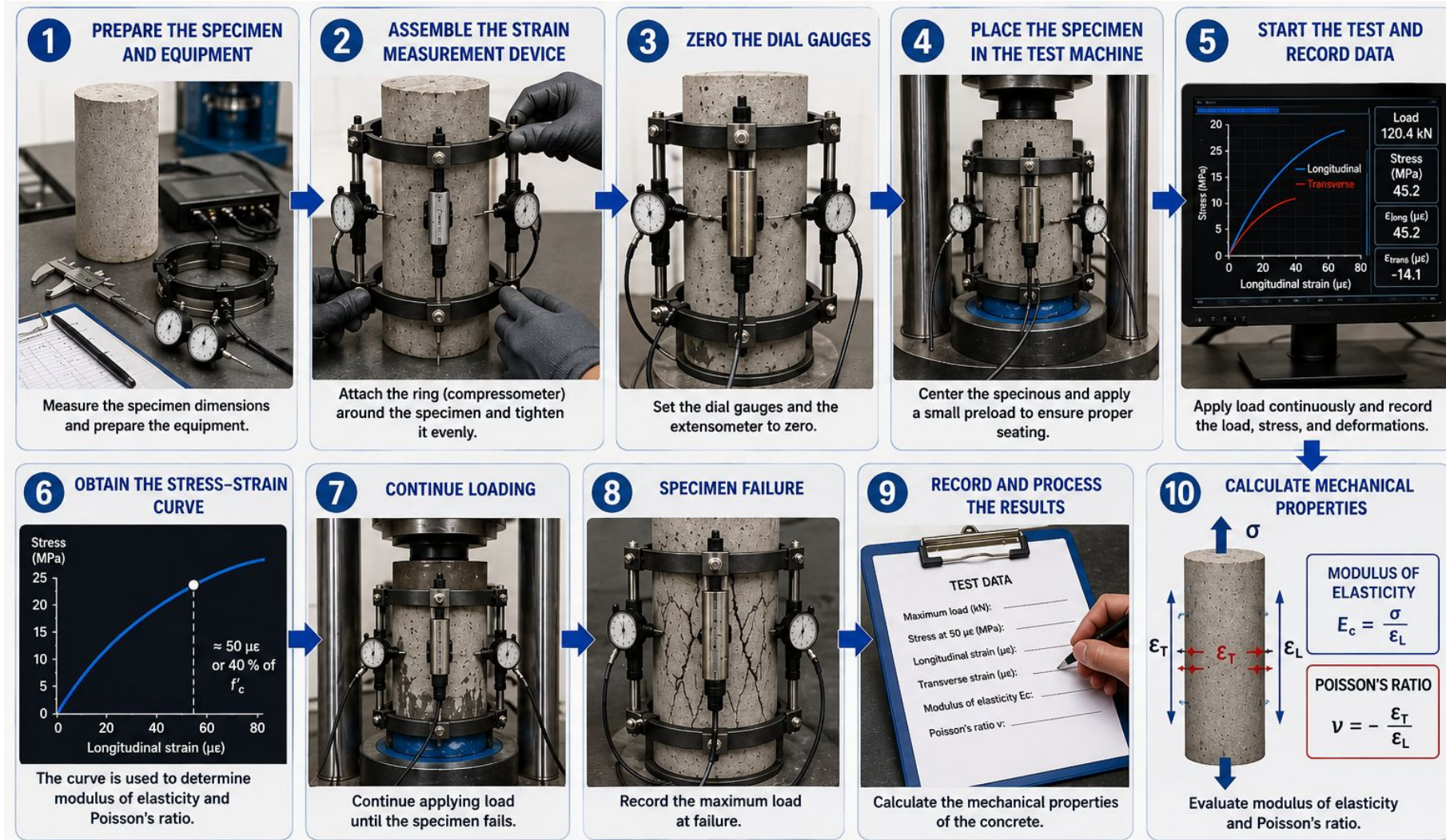
# Modulus of Elasticity and Poisson's Ratio Equipment

- Conducted according to ASTM C469 requirements.
- Uses cylinders similar to compression testing specimens.
- Compressometer measures longitudinal and transverse deformations simultaneously.
- Data acquisition system records loads and strains.



Source: ASTM International

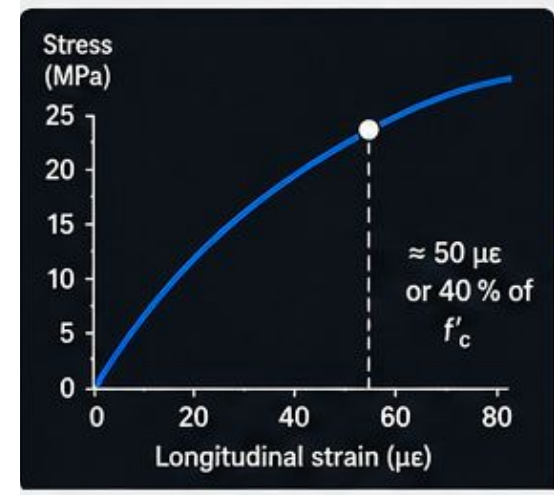
# Modulus of Elasticity Test Procedure



Source: ASTM International

# Interpretation of Elastic Properties

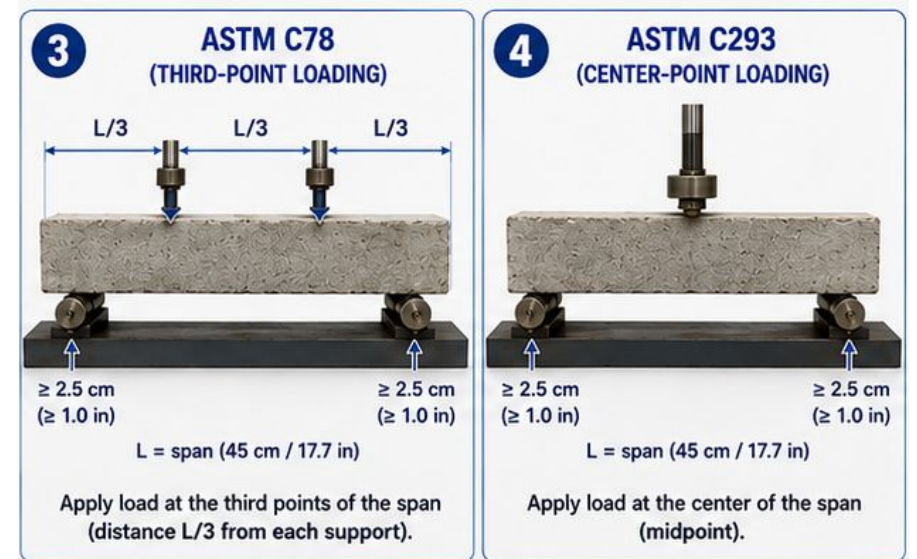
- Modulus represents concrete stiffness under applied loading.
- ASTM uses secant modulus for nonlinear behavior.
- Poisson's ratio relates lateral and longitudinal strains.
- Stress-strain curve reveals deformation characteristics clearly.



Source: Open AI (2026)

# Flexural Strength Test Equipment


- Evaluates tensile resistance induced by bending stresses.
- ASTM C293 uses single-point loading configuration.
- ASTM C78 uses third-point loading configuration.
- Prism beams tested using flexural loading apparatus.



Source: ASTM International

# Flexural Strength Test Procedure

**1 CURING**



23 ± 2 °C  
(73 ± 4 °F)

Cure the specimens in clean water at 23 ± 2 °C (73 ± 4 °F) until the test age.

**2 BEAM DIMENSIONS**



45–50 cm  
(17.7–19.7 in)

15 cm  
(5.9 in)

15 cm  
(5.9 in)

Typical beam: 15 cm × 15 cm × 45–50 cm  
(5.9 in × 5.9 in × 17.7–19.7 in).  
Measure all dimensions.

**3 ASTM C78  
(THIRD-POINT LOADING)**



L/3 L/3 L/3

≥ 2.5 cm  
(≥ 1.0 in)      ≥ 2.5 cm  
(≥ 1.0 in)

L = span (45 cm / 17.7 in)

Apply load at the third points of the span  
(distance L/3 from each support).

**4 ASTM C293  
(CENTER-POINT LOADING)**



≥ 2.5 cm  
(≥ 1.0 in)      ≥ 2.5 cm  
(≥ 1.0 in)

L = span (45 cm / 17.7 in)

Apply load at the center of the span  
(midpoint).

**5 TESTING  
(LOAD APPLICATION)**



36.75 kN

Apply load continuously at the rate specified in the standard until failure occurs.

**6 FAILURE**



Record the maximum load (P) and observe the type of failure.

**7 MARKING THE FAILURE**



Mark the crack pattern and note any unusual failure behavior.

**8 MEASURING THE SPAN (L)**

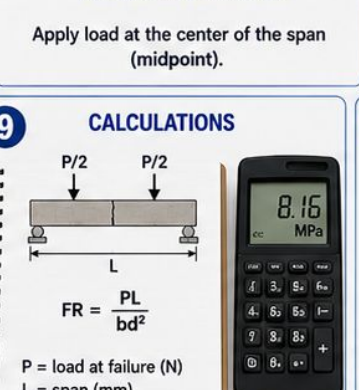


L/3 L/3 L/3

L = span (45 cm / 17.7 in)

Measure the span (distance between support lines).

**9 CALCULATIONS**



P/2 P/2

L

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

P = load at failure (N)  
L = span (mm)  
b = width (mm)  
d = depth (mm)

Calculate the flexural strength (FR) using the appropriate equation.

**10 VALID / INVALID TEST**

**VALID TEST**

✓

Single fracture within the middle third.



**INVALID TEST**

✗

Fracture outside the middle third.



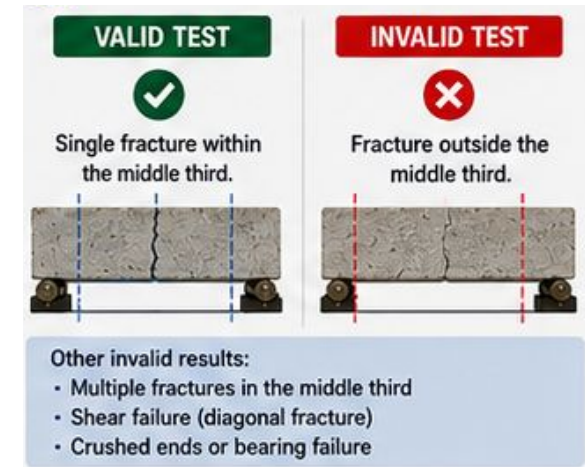
Other invalid results:

- Multiple fractures in the middle third
- Shear failure (diagonal fracture)
- Crushed ends or bearing failure

Only results that meet the valid criteria shall be considered.

# Interpretation of Flexural Strength Results

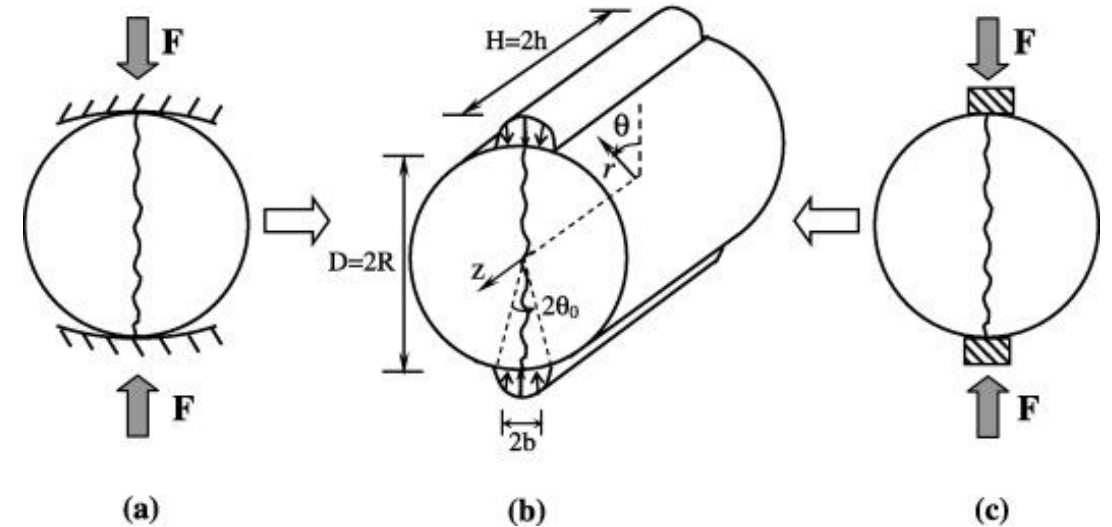
- Modulus rupture indicates bending tensile resistance.
- Strength depends on materials and curing conditions.
- Aggregate characteristics significantly influence flexural performance.
- Fracture pattern helps validate testing results.



Source: Open AI (2026)

# Indirect Tensile Strength Test Equipment

- ASTM C496 uses Brazilian splitting test method.
- Cylindrical specimens similar compression test specimens.
- Bearing strips distribute load uniformly across cylinder.
- Hydraulic press applies controlled compressive loading.



A finite solid circular cylinder subjected to the indirect tensile test: (a) ISRM Brazilian test; (b) Mathematical model; and (c) ASTM test..  
Source: Mindess, Sidney, Young, J. Francis, & Darwin, David. (2013)

# Indirect Tensile Strength Procedure

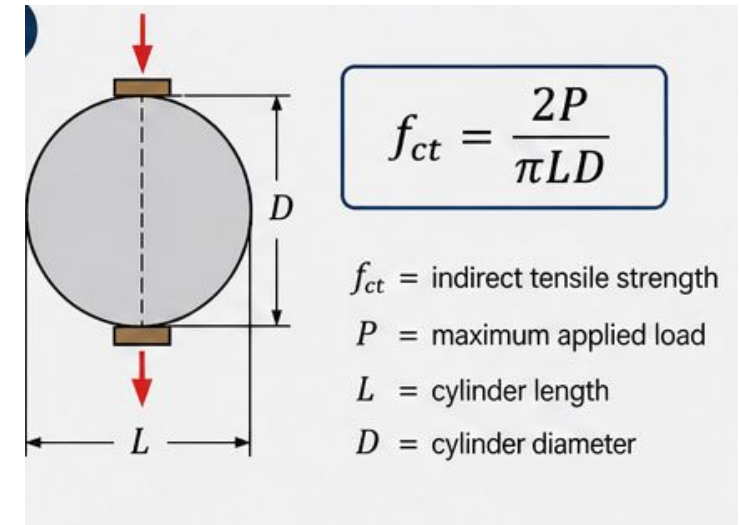
- Position cylinder horizontally between loading platens.
- Place bearing strips along opposite diametrical lines.
- Increase load continuously until specimen failure.
- Calculate tensile strength using standard equation.



Source: Author's own elaboration

# Interpretation of Tensile Strength Results

- Vertical crack indicates typical splitting test failure.
- Tensile strength exceeds direct tensile test values.
- Property depends on mixture and curing quality.
- Concrete requires reinforcement under significant tensile stresses.



Source: ASTM International

# Rebound Hammer Test Equipment

- ASTM C805 provides nondestructive evaluation procedure.
- Schmidt hammer estimates strength from surface hardness.
- Abrasive stone prepares testing surface adequately.
- Correlation curves estimate compressive strength values.



Source: ASTM International

# Rebound Hammer Test Procedure

**1** Marking a 3x3 grid on the concrete surface.

**2** Sanding the surface with a sandpaper block.

**3** Wiping the surface clean with a cloth.

**4** Diagram of a cylindrical test specimen with length  $L$  and diameter  $D$ .

**5** Holding the rebound hammer at a  $90^\circ$  angle to the surface.

**6** Taking a reading from the hammer's scale. The scale shows values from 10 to 60, with a red dot at 40.

**7** Marking the test locations with blue dots on the grid.

**8** Recording data on a clipboard. The data is as follows:

1	42
2	45
3	41
4	44
5	43
6	46
7	45
8	39
9	44
PROMEDIO 44	

**9** Graph of concrete strength  $f'_c$  (MPa) vs. Rebound Index (ÍNDICE DE REBOTE). The graph shows a curve with a red dot at approximately 44 on the x-axis and 35 on the y-axis.

**10** Final grid with numerical values and an average strength of approximately 35 MPa.

Source: ASTM International

# Core Extraction and Testing Equipment

- ASTM C42 evaluates in-place concrete strength directly.
- Core drilling machine extracts structural concrete specimens.
- Diamond bits and water cooling prevent damage.
- Compression testing determines strength of extracted cores.



Source: ASTM International

# Core Testing Procedure



Source: ASTM International

# Interpretation of Core Test Results

- Core testing directly evaluates in-place concrete strength, providing reliable information for structural condition assessments.
- Results are influenced by age, geometry, moisture, drilling damage, reinforcement, and extraction orientation.
- Core strengths are typically lower than laboratory-cured cylinders, reflecting actual field performance conditions.
- Core extraction also assesses uniformity, defects, cracking, consolidation quality, and material durability characteristics.

# Conclusions

- ❑ Quality control begins with fresh concrete evaluation and continues through hardened concrete performance and compliance verification.
- ❑ Fresh concrete tests assess workability, consistency, uniformity, and suitability before placement and consolidation operations commence.
- ❑ Proper sampling, curing, temperature control, and testing procedures ensure reliable, representative, and accurate results.
- ❑ ASTM procedures and laboratory and field testing support durable, safe, and high-performance concrete structures.

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