Center for Training Transportation Professionals

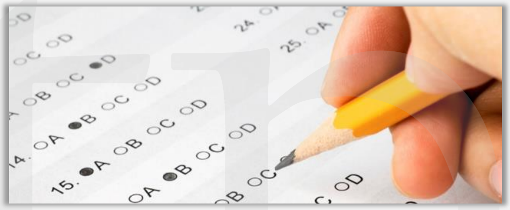
Concrete Strength

Testing Technician

Course Topics

- **ASTM C 617 (T 231)**
  - **Capping Cylindrical Concrete Specimens**
- **ASTM C 1231**
  - **Use of Unbonded Caps in Determination of Compressive Strength of Hardened Concrete Cylinders**
- **ASTM C 39 (T 22)**
  - **Compressive Strength of Cylindrical Concrete Specimens**
- **ASTM C 78 (T 97)**
  - **Flexural Strength of Concrete**

Concrete Strength Testing Technician Program



- **5 Year Certification**
  - **Written Exam**
  - **Performance Exam**
- **Failure of Either Exam**
  - **Requires retake of failed exam within 1 year**
    - **Entire written exam**
    - **Entire performance exam**
    - **If date is missed, student must retake both exams**
  - **Student is responsible for rescheduling of retake**

Written Exam

- **Questions**
  - **Standards**
  - **Special Applications**
- **~ 40 Questions**
  - **Multiple Choice**
  - **True / False**
  - **At least 8 questions on each of the test methods**
- **Limitations**
  - **1 Hour Exam**
  - **Closed Book**
- **Passing Requirements**
  - **60 % Each Standard**
  - **70 % Overall**

Performance Exam

- **Passing Requirements**
  - **Successfully perform all standards in the laboratory**
    - **Two trials are allowed per standard**
    - **One additional retrial allowed per standard**
      - Student must request retrial
      - Proctor may not stop you
      - Student retrial starts over at beginning of test
  - **Failure to pass any standard within the allowable trials requires retaking of the entire performance exam**

ARDOT Standard Specifications

ARDOT ARKANSAS DEPARTMENT OF TRANSPORTATION

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Pavements

~501.03 (Mix Design)

- ~ **Minimum 28 day compressive strength: 4000 psi**
- ~ **Test according to AASHTO T22 Compressive Strength**

Pavements

~501.04 (a) (Quality Control)

- ~ **Performed by Contractor in qualified laboratory by a certified technician**
- ~ **Contractor shall determine the specific locations for samples and frequency of sampling for quality control**
- ~ **AASHTO T 22 Compressive Strength**
  - ~ **AASHTO T 24 Cores and R 100 Cylinders**
- ~ **Compression Machine**
  - ~ **Verify and Document**

Pavements

~501.04 (b) (Acceptance Testing)

- Acceptance by lot (4000 yd^3)
  - Each lot divided into four sublots (1000 yd^3)
  - Engineer may establish a partial lot at anytime
- Thickness determination (AASHTO T148)
  - Shall be made from cores sampled for compressive strength tests
- Compressive strength
  - Determined by testing pavement cores 28 days and no more than 90 days after concrete placement
  - Remove base course adhering to core

Pavements

~501.04 (b) (Acceptance Testing)

- Sampling
  - Contractor
    - 1 sample taken at random from each sublot
    - ARDOT will determine the location for each sample using ARDOT Test Method 465
  - ARDOT
    - A minimum of one sample taken at random from each lot, including partial lots
    - ARDOT will determine the location for each sample using ARDOT Test Method 465

Structures

~802.04

- ~ **Bridges, culverts, miscellaneous structures**

Class	Typical Uses	Max. Agg. Size	Entrained Air Content	Strength @ 28 days
A	Wingwalls & Miscellaneous	1 ½"	None	2100
B	Mass Use	3"	None	3000
S	Piers, Floor Slabs, Box Culverts	1 ½"	None	3500 *5000
M	Miscellaneous Const.	1 ½"	None	2100
SEAL	Concrete deposited under Water	1 ½"	None	2100
S (AE)	Bridge Decks, Piers, Pavements, Box Culverts	1 ½"	6% ± 2%	4000 *5000
	* Required strength @ 28 days for pre-stressed members			

Structures

~802.06 (a) (Quality Control)

- ~ **Contractor responsible for testing**
- ~ **Compressive strength**
  - ~ **AASHTO T22**
  - ~ **Minimum of two cylinders cast and tested**
- ~ **Compression Machine**
  - ~ **Verify and Document**

Structures

~802.06 (b) (Acceptance Testing)

- Acceptance by lot (400 yd^3)
  - Each lot divided into four sublots (100 yd^3)
  - Engineer may establish a partial lot at anytime
- For Class S(AE) concrete the maximum sublot size will be 100 cubic yards or one deck pour, whichever is less
- A minimum of one set of tests per bridge structure is required

Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

AASHTO T 24

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Cores for Compressive Strength

- **Minimum diameter of 3.70"**
  - **Nominal diameter shall be at least 3.70 or at least 2x the NMAS, whichever is larger**
  - **Less than 3.70 is permitted to obtain L/D greater than 1, if justified**
- **Length – 1.9 to 2.1 times diameter**
  - **Less than 1.75 requires correction**
- **Thickness determination – T148**

Cores for Compressive Strength

- **End preparation**
  - **No projections greater than 0.2" above end**
  - **End surface shall not depart from perpendicularity by a slope of more than 1:8d (d is average core diameter)**
  - **Diameter of ends shall not depart from mean diameter by more than 0.1"**

Cores for Compressive Strength

- **Moisture conditioning**
  - **Wipe off surface moisture after drilling**
  - **When surfaces appear dry, but within one hour store in plastic bags**
  - **Maintain at ambient temperature**
  - **Wait at least 5 days after last being wetted before testing**
    - **To reduce moisture gradients**

Cores for Compressive Strength

- **Measure length for L/D ratio**
- **Measure two diameters**
  - **Do not test if largest and smallest diameter exceed 5 percent of average**
- **Test within 7 days, unless specified otherwise**
- **Test according to T 22**
- **Report**

Measuring Length of Drilled Concrete Cores

AASHTO T 148

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Apparatus

- **3-point calipering device (Core length measuring device)**

Apparatus

- ~Measuring Rod
  - ~Shall be rounded to a radius of 0.125”
  - ~The spacing of the graduations shall be 0.10”

• Each increment is 0.10”

Apparatus

- ~Establish Calibrated length
  - ~Verification Gauges
    - ~Right circular cylinders with flat ends
    - ~Diameter approximately equal to diameter of cores to be measured

Procedure

- **Load core in measuring device**
  - **Place smooth end of core down (the end that represents the upper surface of the pavement slab)**
  - **Center core in measuring device**

Procedure

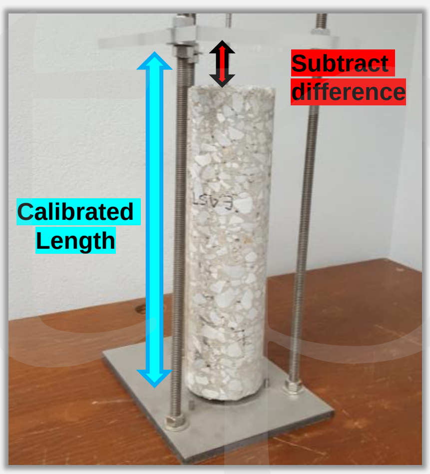
- **Make 9 measurements**
  - **One at the center and one each at 8 additional positions spaced at equal intervals along the circumference of the circle of measurement**
  - **Read each of these 9 measurements to the nearest 0.05”**

Procedure

~**What are these measurements?**

Report

- **Report the length of the core**
  - **Subtract the measurement from the Calibrated Length for all 9 measurements (this gives you the core length of each measurement)**
  - **Average each of these 9 measurements and report to the nearest 0.1”**



Example Report

Measurement	Calibrated Length (in.)	Measured Length (in.)	Core Length (in.)
1	16	1.25	14.75
2	16	1.35	14.65
3	16	1.30	14.70
4	16	1.40	14.60
5	16	1.20	14.80
6	16	1.10	14.90
7	16	1.15	14.85
8	16	1.20	14.80
9	16	1.25	14.75
		Reported length (in.)	14.8

Measuring Length of Drilled Concrete Cores

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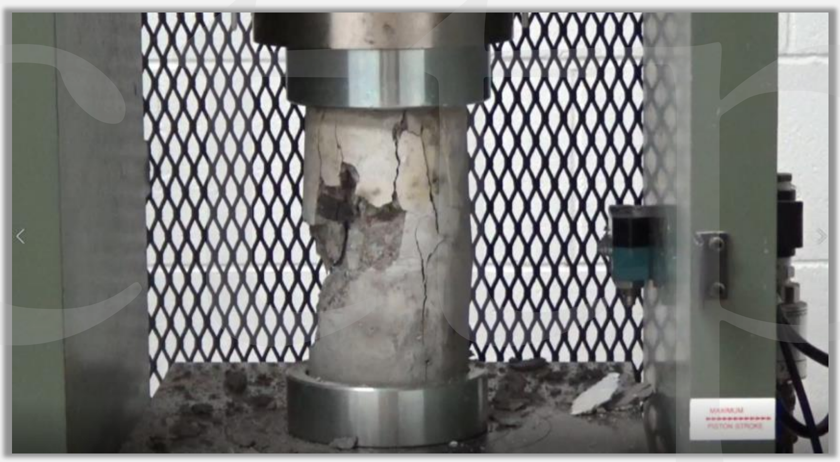
CONCRETE STRENGTH TESTING TECHNICIAN



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CAPPING CYLINDRICAL CONCRETE SPECIMENS

ASTM C 617
AASHTO T 231

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Scope

- **Covers apparatus, materials, and procedures for capping**
  - **Freshly molded concrete cylinders with neat cement**
  - **Hardened cylinders and drilled concrete cores with high-strength gypsum plaster or sulfur mortar**
- **SI units and inch-pound units are included**
  - **May not be exact equivalents so not interchangeable**

Capping Equipment

~Capping Plates

- ~ Neat Cement Caps and High Strength Gypsum-Paste
  - ~Glass Plate at least ¼” thick
  - ~Machined Metal Plate at least 0.45” thick
  - ~Polished Plate of Granite or Diabase at least 3” thick
- ~ Sulfur Mortar Caps
  - ~Similar to above – recessed area for molten sulfur shall not be deeper than ½”

Capping

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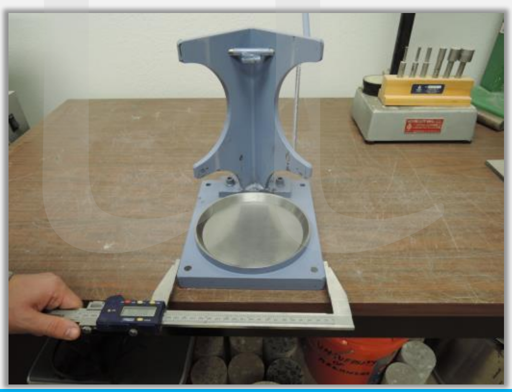
Capping Equipment

~Capping Plates

- ~ Plates shall be at least 1” greater in diameter than specimen



Capping

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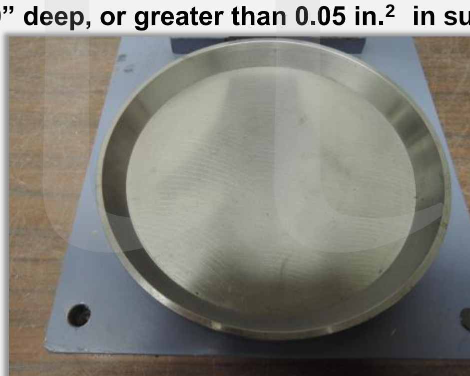
Capping Equipment

- **Capping Plates**
  - **Working surface shall not depart from plane by more than 0.002” in 6”**

Capping Equipment

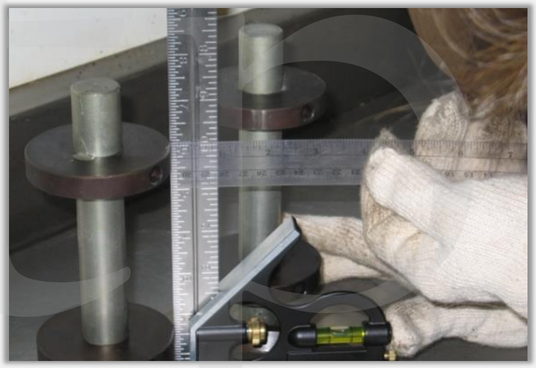
- **Capping Plates**
  - **Surface shall be free from gouges, grooves, and indentations**
    - **Greater than 0.010” deep, or greater than 0.05 in.^{2} in surface area**



Capping Equipment

~Alignment Devices

- ~Axis of the alignment device and the surface of a capping plate
  - ~Perpendicular to 0.5°
    - ~Note 2: 1 mm in 100 mm [1/8" in 12"]
  - ~Located so that no cap off-centered by more than 1/16"



Capping

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Capping Equipment

~Melting Pots for Sulfur Mortar

- ~Equipped with automatic temperature controls
- ~Metal or lined with material that is not reactive with molten sulfur
- ~Use in a hood to exhaust fumes
- ~Open flame dangerous: flash point of sulfur is 405°F

Capping

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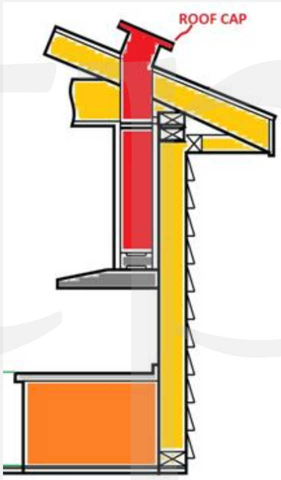
Capping Equipment

~**WARNING:**
- **Melting pot must be located under a hood with an exhaust fan**
- **Well ventilated**
- **High concentrations are lethal**
- **Lesser dosages may cause illness**



Capping Materials

~**Strength and Thickness shall conform to:**

Cylinder Compressive Strength (psi)	Minimum Strength of Capping Material	Maximum Cap Thickness	Maximum Average Cap Thickness
500 to 7000 psi	5000 psi or cylinder strength, whichever is greater	5/16 in. (8 mm)	1/4 in. (6 mm)
> 7000 psi	At least as strong as cylinder strength or qualified	3/16 in. (5 mm)	1/8 in. (3 mm)

Capping Materials

- Sulfur mortar or gypsum used to test concretes with strengths greater than 7000 psi, that has a strength less than the cylinder strength can be qualified as follows:
  - Make 30 cylinders
  - One set of 15 of these cylinders will be capped and tested with the capping material being qualified
  - The other 15 are capped with neat cement paste and tested or ground plane to 0.002 in.
  - After the cylinders are tested, the results from each set of 15 are averaged and compared.
  - The average strength of the cylinders capped with the capping material being tested must be at least 98% of the average strength of the companion cylinders
  - See specification for further qualification requirements

Capping 43

Capping Materials

- Compressive strength of capping materials shall be determined using 2" cubes (ASTM C109/AASHTO T106)
  - Cure same as material capping cylinders
- Strength determined on receipt of new lot and at intervals not to exceed three months

Capping 44

Capping Materials

~Neat Hydraulic Cement Paste

- ~ **Make qualification tests on 2" cubes**
  - ~ **To determine effect of water-cement ratio and age**
- ~ **Mix to desired consistency generally 2 to 4 hours before paste is to be used**

Capping

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Capping Materials

~High-Strength Gypsum Cement Paste

- ~ **Make qualification tests on 2" cubes**
  - ~ **To determine effect of water-cement ratio and age**
- ~ **Mix to desired consistency and use promptly**

Capping

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Capping Materials

~ **Sulfur Mortar**
  - ~ **Harden 2 hours – strengths less than 5000 psi**
  - ~ **Harden 16 hours – strengths 5000 psi or greater**

Capping Materials

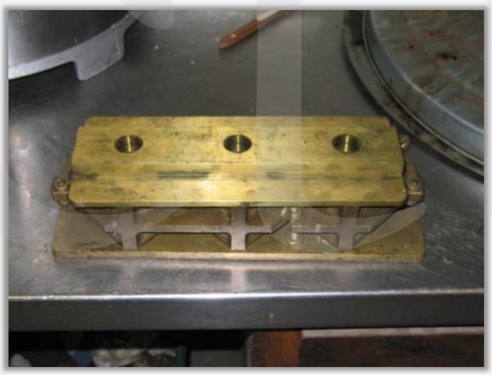
~ **Sulfur Mortar**
  - ~ **Qualification test**
    - ~ **Bring apparatus to temperature of 68 to 86°F**
    - ~ **Lightly coat surfaces with mineral oil**

Capping Materials

- **Sulfur Mortar**
  - **Qualification test**
    - **Bring mortar temperature to 265 to 290°F**

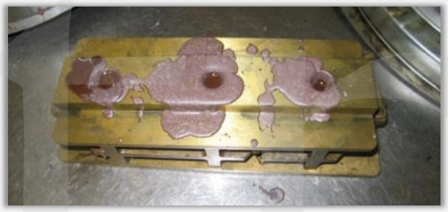
Capping Materials

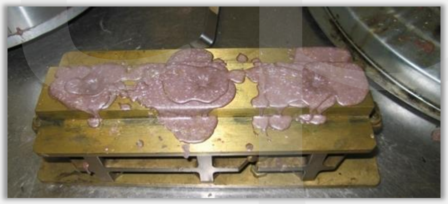
- **Sulfur Mortar**
  - **Stir sulfur**



Capping Materials

~**Sulfur Mortar**
- ~ **Fill to top**
- ~ **Allow for shrinkage**
  - ~**Approx. 15 minutes**
- ~ **Refill with sulfur**





Capping

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Capping Materials

~**Sulfur Mortar**
- ~ **Allow to solidify**
- ~ **Remove from molds without breaking knob**

Capping

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Capping Materials

- **Sulfur Mortar**
  - **Remove oil, sharp edges, and fins**
  - **Check planeness**
  - **Test cubes in compression – (ASTM C109)**
  - **Calculate compressive strength**

Capping 53

Capping Procedures

- **Freshly Molded Cylinders**
  - **Use only neat portland cement pastes**
  - **Mix the material as described**
  - **Do not exceed the water-cement ratio determined in qualification testing**

Capping 54

Capping Procedures

~Freshly Molded Cylinders

- Place conical mound of paste on specimen 2-4 hours after molding cylinder

Capping Procedures

~Freshly Molded Cylinders

- Press freshly oiled capping plate until plate contacts rim of mold
- Make as thin as possible
- Cover
- Remove after hardening
  (after 12 hours)

Capping Procedures

- Hardened Concrete Specimens
  - General
    - Remove any coatings or deposits from cylinder end

Capping Procedures

- Hardened Concrete Specimens
  - General
    - Use a carpenter square across the top and down the side of the cylinder to check that the difference between the highest point and lowest point across the ends of the cylinder is not more than 1/8”
    - Cut/grind to correct

Capping Procedures

~Capping with High-Strength Gypsum Paste

- ~ **Mix the material as described**
- ~ **Do not exceed the water-cement ratio determined in qualification tests**

Capping

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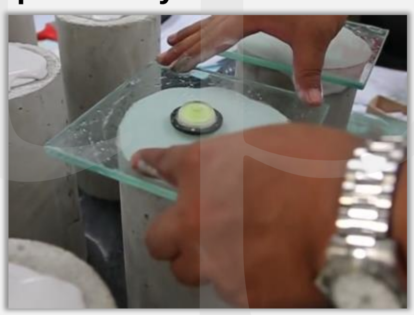
Capping Procedures

~Capping with High-Strength Gypsum Paste

- ~ **Form the caps by placing a mound of paste on top of the cylinder**
- ~ **Press an oiled capping plate on top of the paste by applying downward pressure until the plate contacts the top of the cylinder**



Capping

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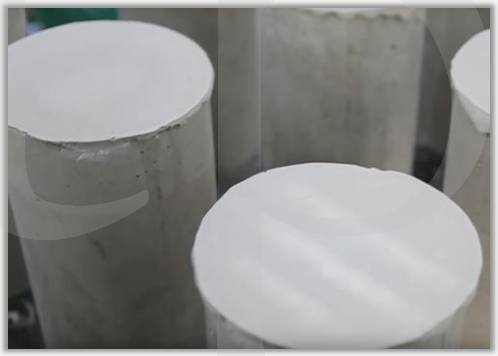
Capping Procedures

~Capping with High-Strength Gypsum Paste

- Generally, capping plates may be removed within 45 minutes



Capping Procedures

~Capping with Sulfur Mortar

- Heat sulfur between 265 to 290°F
- Check temperature hourly
- Five use limit
- No reuse for concrete compressive strength greater than 5000 psi

Capping Procedures

~Capping with Sulfur Mortar

- ~ Warm capping device to cause the sulfur to harden slower. The resulting caps will be thinner.

Capping Procedures

~Capping with Sulfur Mortar

- ~ Oil capping plate lightly
- ~ Stir sulfur before each use

Capping Procedures

~Capping with Sulfur Mortar

- ~ Ends of specimen must be dry so that steam pockets or voids greater than ¼” do not form

Capping Procedures

~Capping with Sulfur Mortar

- ~ Pour mortar onto surface of capping plate

Capping Procedures

~Capping with Sulfur Mortar

- ~ **Lift cylinder and use guides to slide the cylinder onto the capping plate**

Capping Procedures

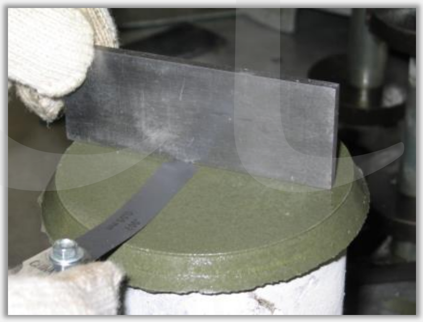
~Capping with Sulfur Mortar

- ~ **Cylinder end should rest on capping plate in positive contact with alignment guides**
- ~ **Make contact until sulfur hardens**

Capping Procedures

~Daily Check during capping

- ~Check planeness of caps before compression testing on at least 3 specimens making 3 measurements across different diameters



Capping Procedures

~Daily Check during capping

- ~Check planeness of caps before compression testing
  - ~Three specimens tested at random
    - ~Representing start, middle, and end of run
  - ~Use straight edge and feeler gauge
  - ~Three measurements on different diameters must not depart from plane by more than 0.002”
  - ~Check for hollow areas

Capping Procedures

- **Daily Check during compression testing**
  - **Thickness of caps on at least three specimens**
    - **Recover at least six pieces of capping material**
    - **Measure thickness to the nearest 0.01"**
    - **Compare averages and maximum thickness to values in specification**

Cylinder Compressive Strength (psi)	Minimum Strength of Capping Material	Maximum Cap Thickness	Maximum Average Cap Thickness
500 to 7000 psi	5000 psi or cylinder strength, whichever is greater	5/16 in. (8 mm)	1/4 in. (6 mm)
> 7000 psi	At least as strong as cylinder strength or qualified	3/16 in. (5 mm)	1/8 in. (3 mm)

Capping 71

Capping Procedures

- **Do not test capped cylinders before the caps have had enough time to develop strength**
- **This is at least 2 hours for sulfur-capped cylinders with a design strength less than 5000 psi**
- **This is generally 16 hours for sulfur-capped cylinders with a design strength 5000 psi or greater unless qualification checks show that less time is sufficient**

Capping 72

Protection of Specimens

- Maintain moist cured specimens in moist condition
- Place sulfur-capped specimens back into a moist storage room, into water storage tanks, or wrap in a double layer of wet burlap
- Cylinders capped with gypsum cannot go back into water tanks; they must be either wrapped in a double layer of wet burlap or placed in a moist room for less than 4 hours
- Protect gypsum caps from dripping water

UNBONDED CAPS FOR CONCRETE CYLINDERS

ASTM C 1231

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Scope

- Practice covers requirements for capping system
- Unbonded neoprene pads are permitted for a specified number of uses up to a certain concrete strength level and then require qualification testing
- Qualification testing is required for all other elastomeric materials
- Unbonded caps not to be used for compressive strength below 1500 psi or above 12000 psi

Referenced Documents

- **ASTM C42 now referenced**
  - Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
  - Cores are referenced throughout the specification

Significance and Use

- Provides for use of an unbonded capping system in place of capping by ASTM C617
- Pads deform to the contour of the ends of the specimen in metal retainers to provide uniform distribution of the load

Materials and Apparatus

- **Elastomeric pads**
  - Thickness – 1/2 ± 1/16”

Materials and Apparatus

- **Elastomeric pads**
  - **Diameter – not more than 1/16” smaller than the inside diameter of the retaining ring**

Materials and Apparatus

Cylinder Compressive Strength (psi)	Shore A Durometer Hardness	Qualification Tests Required	Maximum Reuses
< 1500	Not Allowed		
1500 to 6000	50	None	100
2500 to 7000	60	None	100
4000 to 7000	70	None	100
7000 to 12000	70	Required	50
> 12000	Not Allowed		

Materials and Apparatus

- **Elastomeric pads**
  - **Other elastomeric materials that meet the performance requirements are permitted.**
  - **All elastomeric pads must supply the following information**
    - **Manufacturer or supplier name**
    - **Shore A hardness**
    - **Applicable range of concrete compressive strength**

Materials and Apparatus

- **Elastomeric pads**
  - **User shall maintain record indicating**
    - **Date pads are placed into service**
    - **Pad Durometer**
    - **Number of uses**

Materials and Apparatus

~Retainers

- ~Provide support for and alignment of pads and test specimens
- ~Height shall be 1.0 ± 0.1”

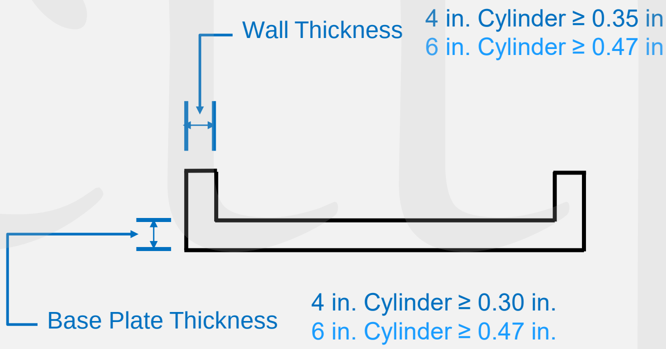
Materials and Apparatus

~Retainers

- ~Inside diameter shall not be less than 102% or greater than 107% of the diameter of cylinder

Materials and Apparatus

Retainers



Unbonded Caps

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Materials and Apparatus

- **Retainers**
  - **Surface shall be plane to within 0.002"**
  - **Bearing surfaces of retainers**
    - **No gouges, grooves, or indents – larger than 0.01" deep or 0.05 in^2 in surface area**

Unbonded Caps

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Test Specimens

- ~Made according to ASTM C31 or C192 or cores obtained according to C42 (6.1)
- ~Depressions under a straight edge shall not exceed 0.20”
  - ~Measured with round wire gage and straight edge
  - ~Corrections must be made before testing
    - ~Sawing or grinding

Unbonded Caps

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Test Specimens

- ~Unbonded caps permitted on one or both ends
- ~Verify that pads meet specified requirements
  - ~½” thick
  - ~Diameter not more than 1/16” smaller than inside diameter of ring
  - ~Pad Hardness and Maximum Uses
- ~Insert pad into retainer before placing on cylinder

Unbonded Caps

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Test Specimens

- Complete testing according to ASTM C39 – Compressive Strength of Cylindrical Concrete Specimens

Qualification and Verification of Reuse of Pads

- Polychloroprene (neoprene) Table 1
- Other elastomeric materials
  - Must be qualified
  - By supplier or user
- Establishing additional reuses
  - Only tests that are within 2000 psi of highest strength level can be included in reuse count
  - Records must be maintained

Qualification and Verification of Reuse of Pads

- **Specimen Preparation for Qualification and Pad Reuse Testing**
  - **Pairs of cylinders cured alike**
  - **Make 10 pairs at both highest and lowest strength levels anticipated**
  - **Test one by grinding or capping and one by unbonded capping**
  - **Average strength obtained using unbonded caps must not be less than 98% of the average strength of capped/ground cylinders**

Unbonded Caps

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COMPRESSIVE STRENGTH OF CYLINDRICAL CONCRETE SPECIMENS

ASTM C 39
AASHTO T 22

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Compressive Strength

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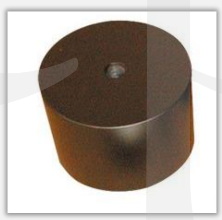
Scope

- **Compressive Strength**
  - **Molded Specimens**
  - **Drilled Cores**
  - **Limited to concrete with density in excess of 50 lb/ft3**

Terminology

- **Lower Bearing Block**
  - **Steel piece to distribute the load from the testing machine to the specimen**
- **Upper Bearing Block**
  - **Steel assembly suspended above the specimen that is capable of tilting to bear uniformly on the top of the specimen**
- **Spacer**
  - **Steel piece used to elevate the lower bearing block to accommodate test specimens at various heights**



Summary of Test Method

- **A compressive load is applied to test specimens within a specified range**
- **Compressive strength is calculated by dividing the maximum load by the cross-sectional area of the specimen**

Compressive Strength

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Significance and Use

- **Care must be used in interpretation of the results:**
  - **Size**
  - **Shape**
  - **Batching**
  - **Mixing Procedures**
  - **Sampling**
  - **Molding**
  - **Fabrication**
  - **Age, Temperature, and Moisture Conditions during curing**

Compressive Strength

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Apparatus

- **Testing Machine**
  - **Sufficient Capacity**
  - **Capability to provide rates of loading in section 7.5**
  - **Verification in accordance with Practice E4**
    - **Within 13 months of last calibration**
    - **Original installation or relocation**
    - **After repairs or adjustments**
    - **Reason to doubt accuracy**

Apparatus

- **Design of machine must include:**
  - **Continuous application of load, without shock**

Apparatus

- **Accuracy:**
  - **Percent error shall not exceed ± 1.0% of the indicated load**
  - **Verified by five test loads in four equal increments**

Compressive Strength

104

Apparatus

- **Two steel bearing blocks with hardened faces**
  - **Minimum dimension – 3% larger than specimen nominal diameter**
    - **Upper Block – Ball and Socket (Spherical Head)**
    - **Lower Block – Solid Steel**

Compressive Strength

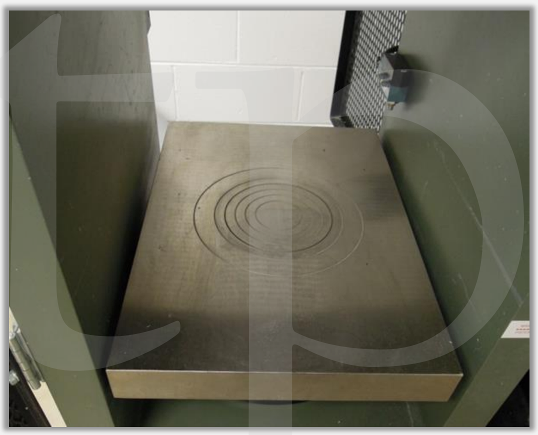
105

Apparatus

- Bearing blocks
  - Must not depart from plane by more than 0.001” in 6”
  - Larger upper blocks shall have concentric circles to facilitate centering when larger than specimen diameter more than 0.5”

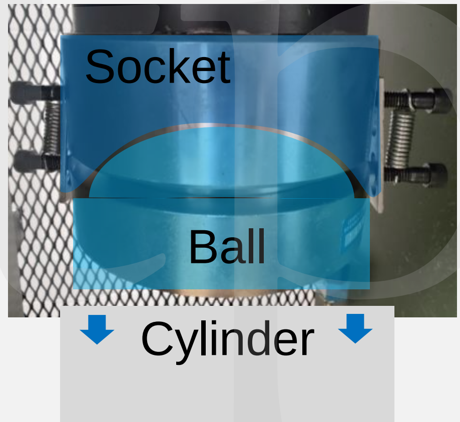
Apparatus

- Bearing blocks
  - Top and bottom must be parallel
  - Concentric circles on bottom block are optional
    - 1” thick when new
    - 0.9” after any resurfacing



Apparatus

- Clean and lubricate the curved surfaces of the upper spherical block
  - At least every six months
  - As specified by the manufacturer
  - Petroleum type oil
    - Motor oil
    - As specified by manufacturer



Apparatus

- Clean and lubricate the curved surfaces

Apparatus

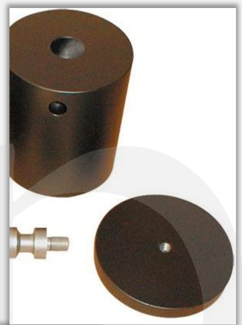
- Final centering of specimen made using upper spherical block
- The dimensions of the bearing face of the upper bearing block:

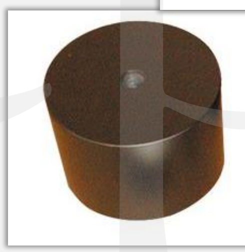
Specimen Nominal Diameter	Maximum Diameter of Bearing Face
4 in.	6.5 in.
6 in.	10 in.

Apparatus

- **Load Indication**
  - Dial
    - Readable to the nearest 0.1% of full scale load
  - Digital
    - Numerical increment shall not exceed 0.1% of full scale load

Apparatus





~Spacers

- ~If used, loose spacers should be placed under the lower bearing block
  - ~Made of solid steel
  - ~One vertical opening in the center of the spacer is permissible
  - ~Shall fully support the lower bearing block and any spacers above
  - ~Shall not be in direct contact with the specimen or the retainers of unbonded caps

Specimens

~Ends must not depart from perpendicularity to the axis by more than 0.5º

- ~(2mm for 8" tall cylinder, 3mm for 12" tall cylinder)

Specimens

~ **If using Unbonded Caps (ASTM C1231), check cylinder ends for depressions ≥ 0.20 in.**

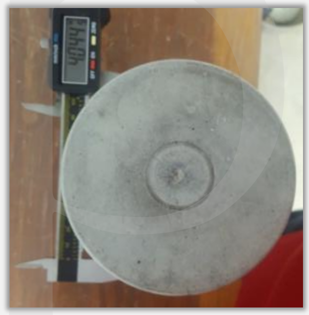
Specimens

~ **Ends that are not plane within 0.002” shall be sawed, ground or capped**

Specimens

- **Average diameter (report to nearest 0.01”)**
  - **Two measurements at right angles taken at midheight of specimen**



Specimens

- **Specimen shall not be tested if any individual diameter differs from any other diameter by more than 2%**
  - **Ratio Range = 0.98 – 1.02**
  - **Divide two measurements to find ratio**


Specimens

- Do the individual diameters differ from each other by more than 2%? Determine the average diameter.

Diameter 1 = 4.02”
Diameter 2 = 4.04”

Ratio

$$\frac{4.02}{4.04} = .9950$$

Range = 0.98 – 1.02 P

Average Diameter

$$\frac{(4.02+4.04)}{2} = \frac{8.06}{2} = 4.03”$$

Practice Problem

- Do the individual diameters differ from each other by more than 2%? Determine the average diameter.

Diameter 1 = 3.96”
Diameter 2 = 4.06”

Specimens

- **Average diameter**
  - **Number measured:**
    - **If made from molds that produce average diameters within a range of 0.02”**
      - **One for each ten specimens or three per day (whichever is greater)**
    - **If not, measure every specimen**

Compressive Strength

121

Specimens

- **Determine length to diameter ratio when less than 1.8 or greater than 2.2**

Compressive Strength

122

Procedure

- Test in a moist condition
- Tolerances on test age for breaking:

Age of Cylinder	Allowable Testing Time Tolerance
24 hours	± 1/2 hour
3 days	± 2 hours
7 days	± 6 hours
28 days	± 20 hours
90 days	± 2 days

- Unless otherwise specified, test age will start at the beginning of casting specimens

Procedure

- Wipe clean the bearing faces of the upper and lower blocks

Procedure

- **When using unbonded caps:**
  - **Wipe clean the bearing surfaces of the retaining rings**
  - **Center the unbonded caps on the cylinder**

Procedure

- **Align specimen with center of thrust of the upper spherically seated block**

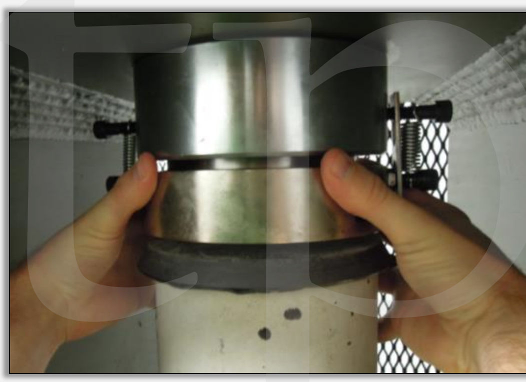
Procedure

- Verify that the load indicator is zero

Compressive Strength 127

Procedure

- Tilt the spherically seated block gently by hand so that uniform seating will be obtained



Compressive Strength 128

Procedure

- When using unbonded caps:
  - Verify alignment:
    - Before reaching 10% of specimen strength
    - Check that specimen does not depart from alignment by more than 0.5°
  - Centered in rings

Procedure

Procedure

- ~Apply load continuously and without shock
- ~Stress rate on the specimen of 35 ± 7 psi/s (maintained at least during latter half of the anticipated load)
- ~Make no adjustment in the rate of movement as the ultimate load is being approached
- ~Apply load until specimen displays a well-defined fracture pattern

Compressive Strength

131

Procedure

- ~Record the Maximum Load

- ~Note the type of fracture pattern
- ~Calculate Compressive Strength

Compressive Strength

132

Calculation

~Compressive Strength

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

P_{max} = Maximum Load (lb)
f_{cm} = compressive strength (psi)
D = average diameter (nearest 0.01")

Results rounded to the nearest 10 psi

Compressive Strength

133

Calculation

~Compressive Strength

Calculate the compressive strength of the cylinder

Average Diameter = 4.03"
Maximum Load = 76880 lb

$$f_{cm} = \frac{(4)(P_{max})}{(\pi)(D^2)} = \frac{(4)(76880)}{(\pi)(4.03)(4.03)} = \frac{(307520)}{(51.02229)} = 6027 \text{ psi}$$

Reported Compressive Strength = 6030 psi

Compressive Strength

134

Practice Problem

~**Compressive Strength**

Calculate the <u>Reported</u> Compressive Strength of the cylinder

Average Diameter = 6.01”
Maximum Load = 122360 lb

Calculation

~**When length to diameter is 1.75 or less:**

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

~**Multiply unrounded compressive strength by correction factor then round to the nearest 10 psi**

Calculation

~Correction Factor

A cylinder has a length of 6 inches and a diameter of 4 inches. The compressive strength was 5286 psi.
What is the *Reported* Compressive Strength?

$$L/D = \frac{6}{4} = 1.5$$

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

Compressive Strength = (5286) (0.96) = 5074.56

Reported Compressive Strength = 5070 psi

Specimens

~Density (if required)

- **Determine by either of the following 2 methods**
  - **Specimen Dimension Method**
  - **Submerged Weighing Method**
    - **For either method use a scale that is accurate to within 0.3% of the mass being measured**

Specimens

~Density - Specimen Dimension Method

- ~ Remove any surface moisture with a towel
- ~ Weigh (before capping)
- ~ Measure length to 0.05” at 3 locations around circumference and average
- ~ Refer to section 9.3.1 for calculation

Specimens

~Density – Submerged Weighing Method

- ~ Remove any surface moisture with a towel
- ~ Determine weight in air
- ~ Submerge the specimen in water at a temperature of 73.5 ± 3.5°F and determine weight
- ~ Refer to section 9.3.2 for calculation

Calculation

~**Density (when required)**

Specimen Dimension Method

$$P_s = \frac{6912(W)}{(L)(D^2)(\pi)}$$

Where:

Ps = specimen density (lb/ft^3)
W = mass of specimen in air (lb.)
L = average measured length (in.)
D = average measured diameter (in.)

Submerged Weighing Method

$$P_s = \frac{(W)(Yw)}{W - Ws}$$

Where:

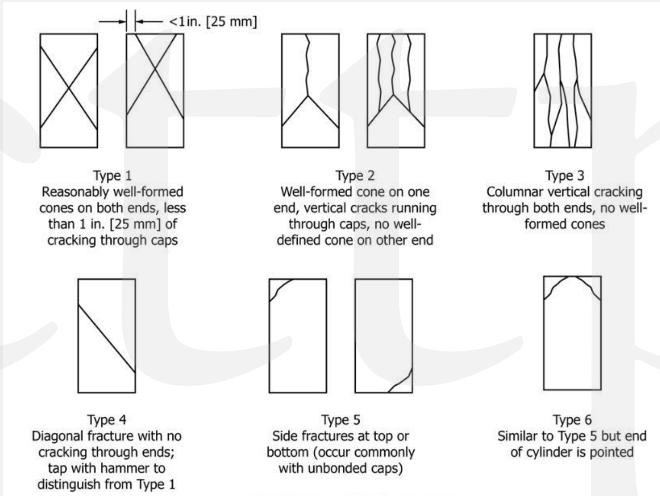
Ps = specimen density (lb/ft^3)
W = mass of specimen in air (lb.)
W_s = apparent mass of submerged specimen (lb.)
Y_w = density of water at 73.5°F = 62.27 lb/ft^3

Report

~**Report the following information:**

- ~**ID number**
- ~**Diameter**
- ~**Cross-sectional area**
- ~**Maximum load**
- ~**Compressive Strength**
- ~**Type of Fracture**
- ~**Defects**
- ~**Age**
- ~**Density**

Calculation



Compressive Strength

144

FLEXURAL STRENGTH OF CONCRETE (USING SIMPLE BEAM WITH THIRD POINT LOADING)

ASTM C 78
AASHTO T 97

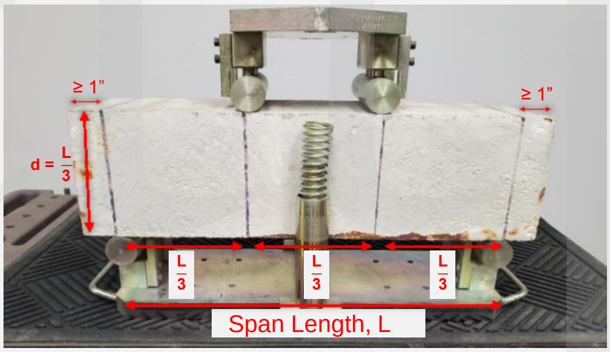
cttp
Center for Training Transportation Professionals

Flexural Strength

148

Scope

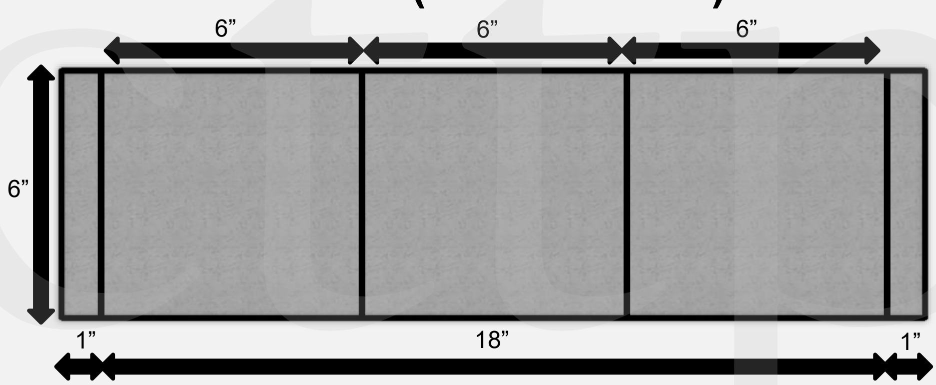
~Covers determination of flexural strength by use of simple beam with third-point loading



Flexural Strength 149

Terminology

~Standard Size Beam (6" x 6" x 20")



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

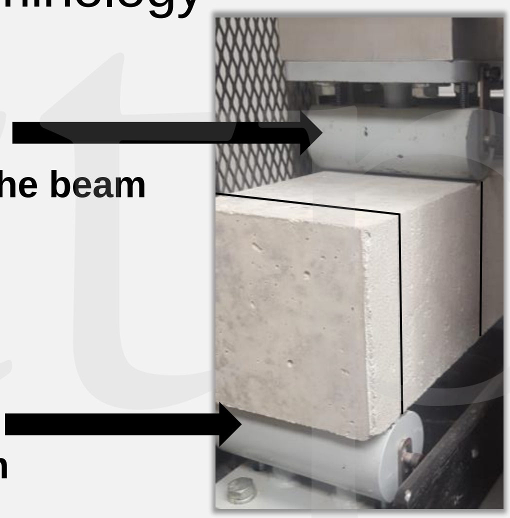
Flexural Strength 150

Terminology

- **Flexural Strength**
  - **Bending resistance of a specimen**
- **Modulus of Rupture**
  - **Calculated stress in the tensile face of a beam specimen at the maximum bending moment**

Terminology

- **Loading block**
  - **Used to apply a force to the beam**
- **Support block**
  - **Used to support the beam**



Significance and Use

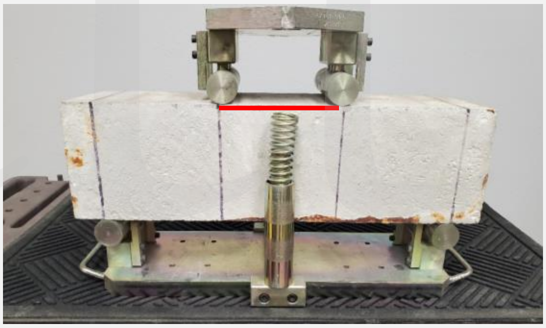
- Strength may vary based on:
  - Size
  - Preparation
  - Moisture condition
  - Curing
  - Molded or sawed
- Results
  - Used to determine compliance with specifications
  - Basis for proportioning, mixing and placing
  - Used in testing concrete for slabs and pavements

Apparatus

- Shall conform to Practice E 4
- Must be capable of applying load at uniform rate without shock or interruption

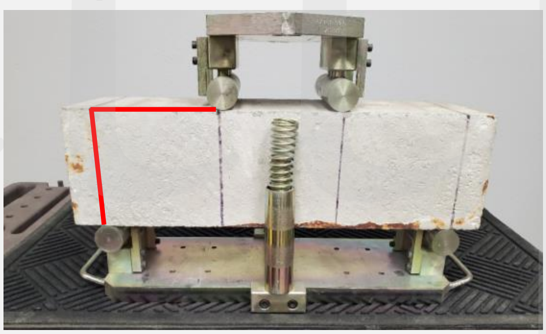
Apparatus

~**Capable of maintaining span length and distance between the lines of loading within ± 0.05”**



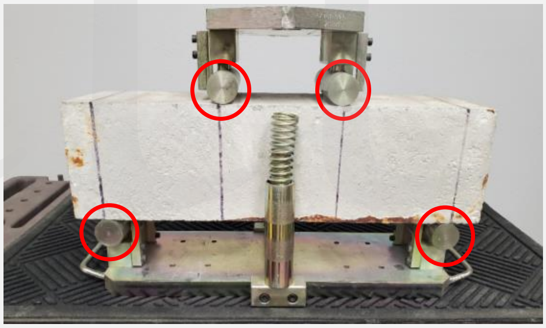
Apparatus

~**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**



Apparatus

- Loading blocks and support blocks
  - Should not be more than 2 ½” high
  - Extend full width of specimen



Test Specimens

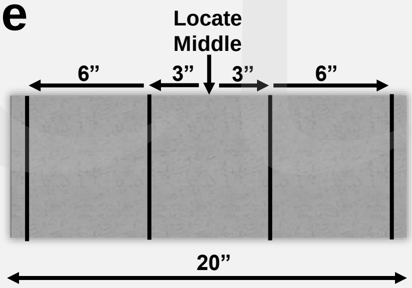
- Test span shall be within 2% of three times the tested depth
- Sides shall be at right angles to the top with smooth surfaces

Procedure

- ~Keep specimen moist between removal of storage and testing
- ~Turn molded specimen on side for testing
- ~Position sawed specimens with tension face up or down with respect to parent material

Procedure

- ~Center loading system in relation to applied force

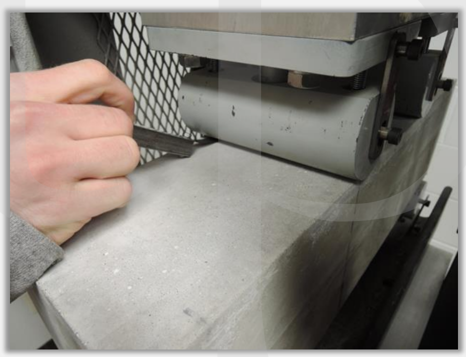


Procedure

~**Bring load applying blocks into contact and apply a load of between 3 and 6% of the estimated total load**

Procedure

~**Use feeler gauges (0.004" and 0.015") to check for gaps over a length of 1"**



Procedure

- Grind, cap, or use leather shims to eliminate gaps in excess of 0.004”
- Shims
  - uniform to ¼” thickness
  - 1 to 2” wide
  - Full width of specimen
- Cap or grind only gaps in excess of 0.015”

Procedure

- Load specimen continuously without shock until break occurs
- Apply at a rate that constantly increases the maximum stress on the tension face between 125 – 175 psi/min until rupture

Procedure

~**Loading rate:**

$$r = \frac{Sbd^2}{L}$$

- ~ **r = loading rate (lb/min)**
- ~ **S = rate of increase in max stress on tension face (psi/min)**
- ~ **b = average width (assume 6.00”)**
- ~ **d = average depth (assume 6.00”)**
- ~ **L = span length (assume 18.00”)**

Procedure

~**Loading rate:**

$$r = \frac{Sbd^2}{L}$$

r = loading rate (lb/min)
S = 125 (psi/min)
b = 6.00”
d = 6.00”
L = 18.00”

$$r = \frac{(S)(b)(d)(d)}{L} = \frac{(125)(6.00)(6.00)(6.00)}{18} = \frac{27000}{18}$$

r = **1500 lb/min**

Practice Problem

Given the following information, calculate the Loading rate.

Loading rate:

$$r = \frac{Sbd^2}{L}$$

r = loading rate (lb/min)
S = 175 (psi/min)
b = 6.00”
d = 6.00”
L = 18.00”

Flexural Strength

167

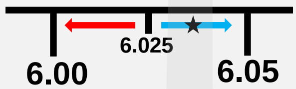
Measurement of Specimen After Test

- **Determine dimensions across fractured face**
  - **Three measurements across each direction (center and ends)**
  - **Measure to nearest 0.05”**
  - **If capped, include capped thickness in measurement**

Flexural Strength

169

Caliper Rounding Review - Beams

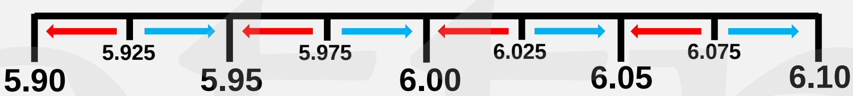


= 6.05

Flexural Strength

170

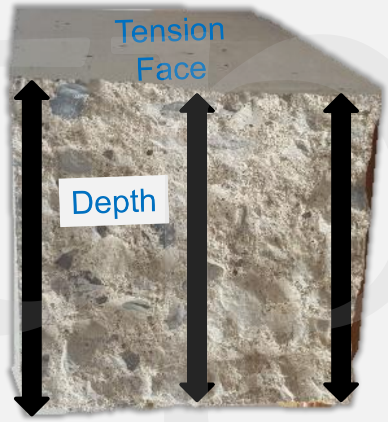
Caliper Rounding Review - Beams



Flexural Strength

171

Measurement of Specimen After Test

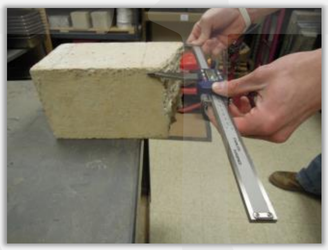


Flexural Strength

173

Measurement of Specimen After Test

~3 measurements – average width (b)



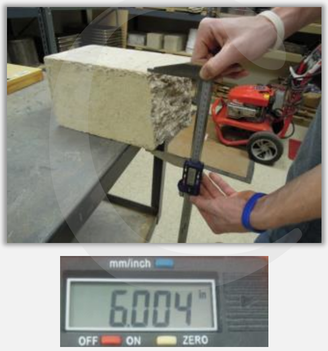
$$\textbf{(b)} = \frac{\textbf{(6.00+6.05+6.05)}}{\textbf{3}} = \frac{\textbf{18.1}}{\textbf{3}} = \textbf{6.033} = \textbf{6.05''}$$

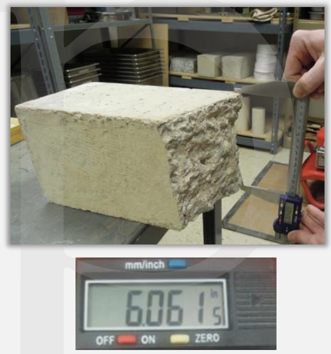
Flexural Strength

174

Measurement of Specimen After Test

~**3 measurements – average depth (d)**





$$(d) = \frac{(6.00+6.00+6.05)}{3} = \frac{18.05}{3} = 6.017 = 6.00"$$

Flexural Strength

175

Calculation

~**Fracture in middle third:**

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

- ~ **R = modulus of rupture (psi)**
- ~ **P = maximum applied load**
- ~ **L = span length (in.)**
- ~ **b = average width (nearest 0.05")**
- ~ **d = average depth (nearest 0.05")**

Calculate to the nearest 5 psi

Flexural Strength

176

Calculation

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

P = 8770
L = 18"
b = 6.05"
d = 6.00"

Calculate to the nearest 5 psi

$$R = \frac{PL}{bd^2} = \frac{(8770)(18)}{(6.05)(6.00)(6.00)} = \frac{157860}{217.8} = 724.79$$

R = 725 psi

Flexural Strength

177

Practice Problem

A beam fractures within the middle third of the span length. Given the following information, calculate the modulus of rupture.

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

Maximum applied load = 9430
Span Length = 18.0"

Width 1 = 6.033"	**Depth 1 = 5.966"**
Width 2 = 6.015"	**Depth 2 = 5.991"**
Width 3 = 5.962"	**Depth 3 = 5.942"**

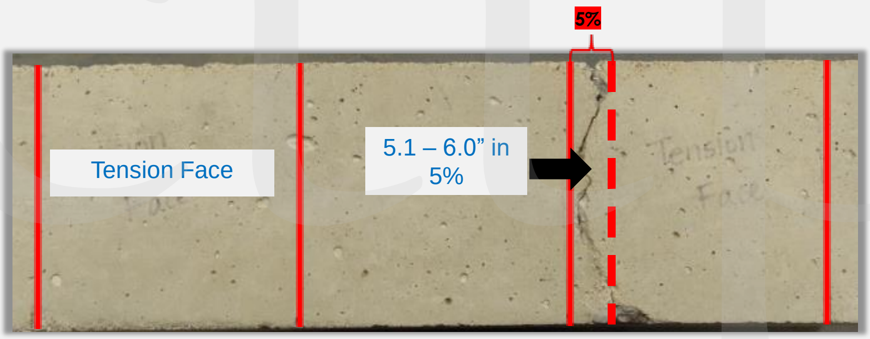
Flexural Strength

178

Measurement of Specimen After Test

~Outside the middle third but within 5% of span length

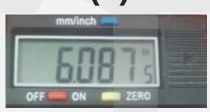
- ~ **For a standard size beam, 18 x 0.05 = 0.9"**

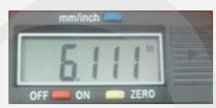


Measurement of Specimen After Test

~Outside the middle third but within 5% of span length

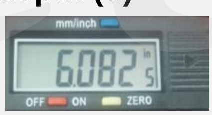
- ~ **3 measurements – average width (b)**





$$\textbf{(b)} = \frac{\textbf{(6.05+6.10+6.10)}}{\textbf{3}} = \frac{\textbf{18.25}}{\textbf{3}} = \textbf{6.083} = \textbf{6.10"}$$

- ~ **3 measurements – average depth (d)**

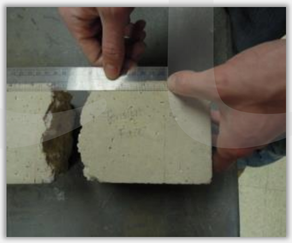


$$\textbf{(d)} = \frac{\textbf{(6.05+6.10+5.95)}}{\textbf{3}} = \frac{\textbf{18.1}}{\textbf{3}} = \textbf{6.033} = \textbf{6.05"}$$

Measurement of Specimen After Test

~Outside the middle third but within 5% of span length

- ~3 measurements – average distance between line of fracture and nearest support (a)
- ~Measure along the tension face

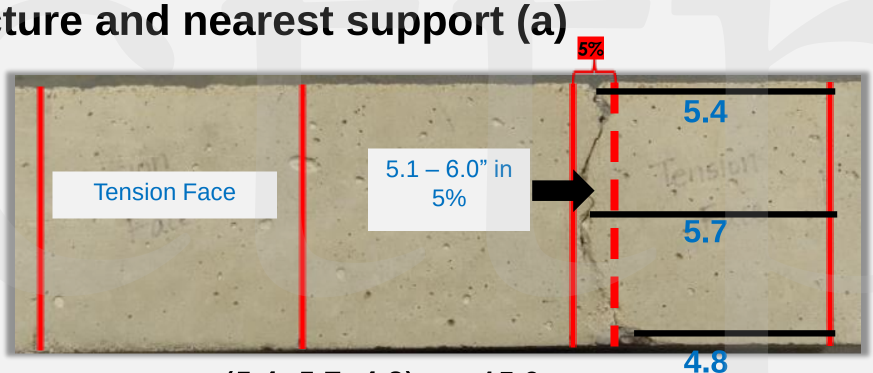




Flexural Strength

182

Calculation

~3 measurements – average distance between line of fracture and nearest support (a)



(a) = $\frac{(5.4+5.7+4.8)}{3}$ = $\frac{15.9}{3}$ = 5.3”

Flexural Strength

183

Calculation

~Fracture outside middle third but not more than 5% of span length:

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

- ~ R = modulus of rupture (psi)
- ~ P = maximum applied load
- ~ b = average width (nearest 0.05")
- ~ d = average depth (nearest 0.05")
- ~ a = average distance between line of fracture and nearest support (in.)

Calculate to the nearest 5 psi

Flexural Strength

184

Calculation

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

P = 8240
b = 6.10"
d = 6.05"
a = 5.3"

Calculate to the nearest 5 psi

$$R=\frac{3Pa}{bd^2}=\frac{(3)(8240)(5.3)}{(6.10)(6.05)(6.05)}=\frac{131016}{223.27525}=586.79$$

R = 585 psi

Flexural Strength

185

Practice Problem

A beam fractures outside the middle third but within 5% of the span length. Given the following information, calculate the modulus of rupture.

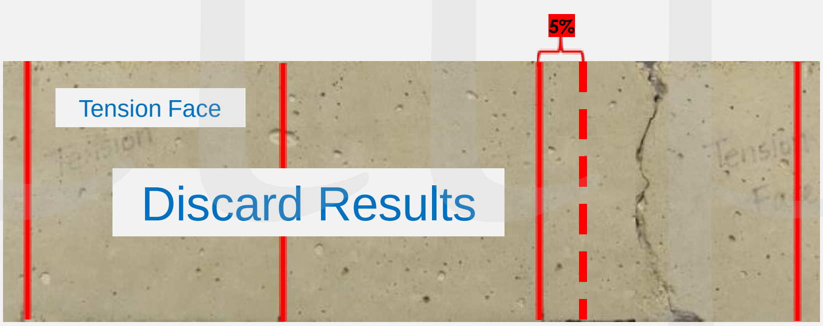
$$R = \frac{3Pa}{bd^2}$$

Maximum applied load = 10760
Distance of fracture from nearest support = 5.6”

Width 1 = 6.024”	**Depth 1 = 6.078”**
Width 2 = 6.029”	**Depth 2 = 6.083”**
Width 3 = 6.033”	**Depth 3 = 6.071”**

Calculation

- **Fracture outside middle third by more than 5% of span length:**



Report

- Id number
- Average width (to nearest 0.05”)
- Average depth (to nearest 0.05”)
- Span length
- Maximum applied load
- Modulus of rupture
- Curing history and apparent moisture at time of test
- If specimens were capped, ground, or if shims were used
- Whether sawed or molded and any defects
- Age of specimen