Technician Certification

Concrete Strength

MoDOT

Course Content
Concrete Strength

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AASHTO	T 148	Measuring Length of Drilled Concrete Cores
AASHTO	T 231	Capping of Cylindrical Concrete Specimens
AASHTO	T 22	Compressive Strength of Cylindrical Concrete Test Specimens
GLOSSARY		Glossary of Concrete Terms
MTRAC		MTRAC (Informational Only)

AASHTO T 24

Obtaining and Testing

Drilled Cores of Concrete

AASHTO T 24

Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

Overview

- This standard method covers obtaining, preparing, and testing cores drilled from concrete for length or compressive strength or splitting tensile strength determinations.
- This method also covers sawed beams which will not be covered in this training.

2

Significance and Use

- This test method provides standard procedures for drilling, handling, curing and testing concrete cores.
- Concrete strength is affected by the location of the concrete in the structural element, with the concrete on the bottom tending to be stronger than the concrete on top. Consider these factors when planning the location of cores to be taken.

3

Significance and Use

- The strength of concrete measured by testing cores is affected by the amount and distribution of of moisture in the specimen at the time of test.

- There is no standard procedure to condition a specimen that will ensure that, at the time of test, it will be the identical moisture condition as the concrete in the structure.

4

Significance and Use

- The moisture conditioning procedures in this test method are intended to provide reproducible moisture conditions that minimize variations between parties and to reduce the effects of moisture introduced during specimen preparation.

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Significance and Use

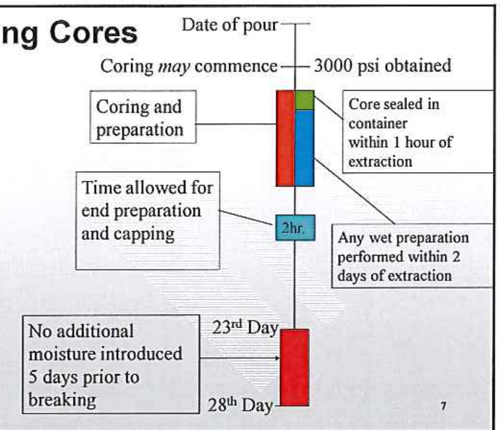
- There is no relationship between the compressive strength of a core and the corresponding compressive strength of molded cylinders. However, both are vital to evaluating performance of concrete.

- The acceptance criteria for core strength is to be established by the specifying authority. (MoDOT)

6

Curing Cores

- Time Line



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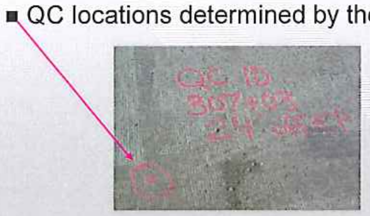
Core Locations

- All sample locations determined using random sampling procedures in accordance with ASTM D 3665
- QC locations determined by the engineer



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Random Sample Location Worksheet

CORE LOCATIONS

PROJECT ____________ ROUTE ______ MIX NO ____________

LOT NO ______ DATE ____________ TECHNICIAN ____________

SUBLOT ______ ______ ______ ______

BEGINNING STATION "STA" ______ ______ ______ ______

ENDING STATION ______ ______ ______ ______

LENGTH OF SUBLOT "L" ______ ______ ______ ______

WIDTH OF LANE ______ ______ ______ ______

RANDOM NUMBERS

	SUBLOT	SUBLOT	SUBLOT	SUBLOT
SET A				
SET B				

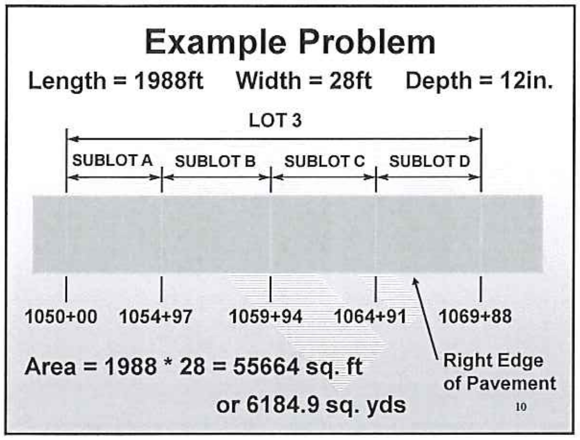
LONGITUDINAL LOCATION

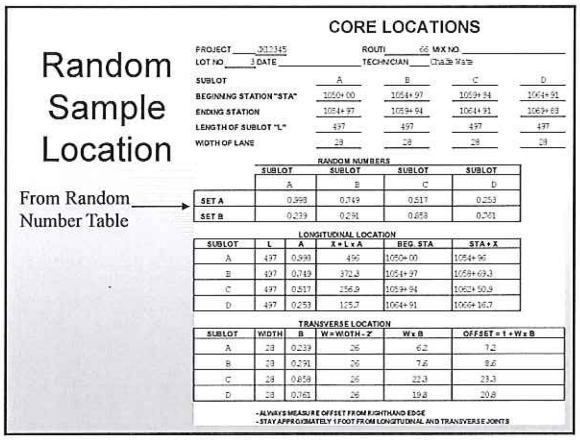
SUBLOT	L	A	X = L x A	BEG. STA	STA + X

TRANSVERSE LOCATION

SUBLOT	WIDTH	B	W = WIDTH - 2'	W x B	OFFSET = 1 + W x B

- ALWAYS MEASURE OFFSET FROM RIGHTHAND EDGE
- STAY APPROXIMATELY 1 FOOT FROM LONGITUDINAL AND TRANSVERSE JOINTS





CORE LOCATIONS

PROJECT J012345 ROUTE 66 MIX NO.
LOT NO 3 DATE TECHNICIAN Chalk Wate

SUBLOT	A	B	C	D
BEGINNING STATION "STA"	1050+00	1054+97	1059+94	1064+91
ENDING STATION	1054+97	1059+94	1064+91	1069+88
LENGTH OF SUBLOT "L"	497	497	497	497
WIDTH OF LANE	28	28	28	28

RANDOM NUMBERS

	SUBLOT A	SUBLOT B	SUBLOT C	SUBLOT D
SET A	0.998	0.749	0.517	0.253
SET B	0.239	0.291	0.858	0.761

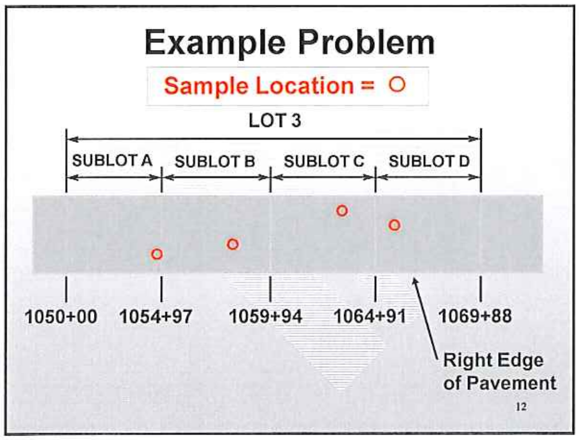
LONGITUDINAL LOCATION

SUBLOT	L	A	X = L x A	BEG. STA	STA + X
A	497	0.990	496	1050+00	1054+96
B	497	0.749	372.3	1054+97	1058+69.3
C	497	0.517	256.9	1059+94	1062+50.9
D	497	0.253	125.7	1064+91	1066+16.7

TRANSVERSE LOCATION

SUBLOT	WIDTH	B	W = WIDTH - 2'	W x B	OFFSET = 1 + W x B
A	28	0.239	26	6.2	7.2
B	28	0.291	26	7.6	8.6
C	28	0.858	26	22.3	23.3
D	28	0.761	26	19.8	20.8

- ALWAYS MEASURE OFFSET FROM RIGHTHAND EDGE
- STAY APPROXIMATELY 1 FOOT FROM LONGITUDINAL AND TRANSVERSE JOINTS



Coring

- Cores not taken until 3000psi obtained.

- Maturity Meter

- Cylinders

- Cores tested 28 days after placement.

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Sampling

- Pavement less than 12 inches, obtain a 4-inch diameter core
- Pavement 12 inches or greater, obtain a 6-inch diameter core

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Equipment

- Core Drill
- Plastic Bags
- Concrete Chop Saw
- Triangle
- Ruler
- Calipers

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Extract Core

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Core Extracting Hints

- Utilize sharp drill bit
- Ensure drill is perpendicular to surface
- Ensure drill is held steady
- Drill until base is reached
- Use plenty of water

17

Core Handling Hints

- Handle cores carefully
  - Do not throw cores
  - Do not drop cores
  - Do not allow cores to tumble while in transit
- If this occurs, compressive strength could be lowered
- Contact R.E. immediately if core is mishandled
  - Attain a replacement core

18

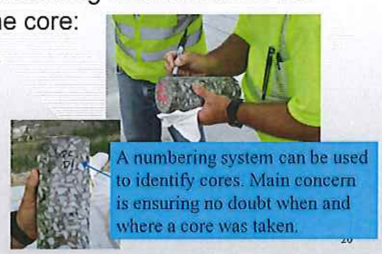
Procedure

- After the core is removed from the hole, wipe the surface water and allow the remaining surface moisture to evaporate.

19

Procedure

- When the surface appears to be dried, write the following information on the side of the core:
  - Job No.
  - Route
  - County
  - Lot
  - Sublot



Curing Cores

- AASHTO T-24 has been changed. Cores are no longer soaked in lime saturated bath prior to testing

- Cores are placed in separate plastic bags or non-absorbent containers after extraction.

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Moisture Conditioning

- After labeling cores, place in an non-absorbent container and seal to prevent moisture loss.
  - This should be performed *within one hour* after the core is drilled.
- Maintain cores at ambient temperature and protect from direct sunlight.
  - For MoDOT projects, ambient temperature is defined as 60 to 80°F.

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Moisture Conditioning

- Transport cores to the testing lab as soon as practicable.
- Keep cores sealed in separate containers at all times except during measuring, end preparation and a maximum time of 2 hours to permit capping before testing.

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Determine Pavement Thickness

- Core length (pavement thickness) determined in accordance with AASHTO T 148.

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Determine Mean Diameter

- Determine the mean diameter to the nearest 0.01 in. (0.25 mm) by averaging two diameters measured at right angles to each other at about mid-height of the specimen.
- This mean diameter will be used as follows:
  - Determination of cross-sectional area
  - Reference for end diameter compliance

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Sample Preparation

- After determining core length (pavement thickness), saw cores to an Length/Diameter (L/D) ratio of 2.0.

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Length/Diameter Ratio

- The ideal L/D ratio is 2.0. However if it is less, a correction factor may be applied. Refer to AASHTO T 22 for further information.

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Procedure

- After the length is determined, the core is prepared to meet the requirements of AASHTO T22 & AASHTO T148.
  - No projections to exceed 0.2 in. (5 mm) above the end surface.
  - The end surface shall not depart from perpendicularity to the longitudinal axis by more than 0.5 degrees.
  - For cut cores, the diameter of the ends shall not depart more than 0.1 in. (2.5 mm) from the mean diameter.

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Moisture Conditioning

- If water is used during sawing or grinding of core ends, complete these operations as soon as practicable, but no later than 2 days after drilling and extraction.
  - Minimize exposure to water during end preparation.

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Moisture Conditioning

- Allow each core to remain in a sealed separate container at least 5 days after last being wetted before testing.
- Cores will be tested at 28 days of age.

30

Determine Compressive Strength

- Cap core according to AASHTO T-231
- Once the core is capped, measure it's length. Make sure the L/D ratio is between 1.94 and 2.10.

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Determine Compressive Strength

- Determine compressive strength in accordance with AASHTO T 22.

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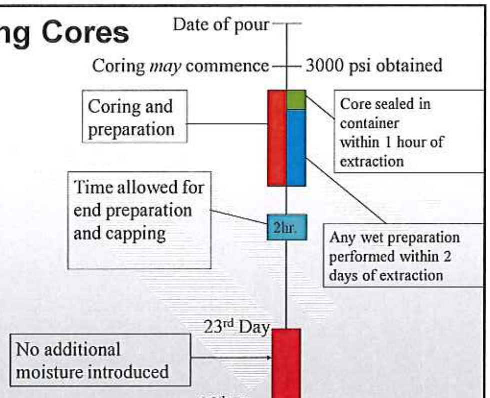
Curing Cores

- Time Line



33

Reporting

- Report thickness measurements according to AASHTO T148.
- Report the results as required by AASHTO T 22.

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Summary

- The cores are obtained by random sampling.
- The cores are used to determine pavement thickness and 28 day compressive strength.
- The cores are conditioned as outlined in the test procedures and should mimic QC/QA counterpart within test method.

35

Common Errors

- Not putting cores in separate containers.
- Not coring perpendicular to the pavement surface.
- Not checking end condition for projections or perpendicularity to sides.
- Improper L/D ratio.
- Not following conditioning procedures.

36

502.1.10.1 Coring (Sec 502.10.3)

The contractor should take care when extracting cores. The following are some hints to accomplish this:

Utilize sharp drill bit

Ensure drill is perpendicular to surface

Ensure drill is held steady

Drill until base is reached

Use plenty of water

Cores should be handled with care. Do not throw or drop cores. Secure cores while in transit to avoid tumbling. If any core has been damaged, contractor shall contact engineer and a new random sample core shall be obtained.

(Sec 502.10.3.1) Thickness Measurement Hints:

Remove underlying material with chisel

Place specimen upside down in device

Check calibration of device

Take 9 readings

1 reading at center

8 readings along circumference

Read to the nearest 0.1 in.

Compressive Strength Testing Hints:

Calibrate testing machine at least annually, not to exceed every 13 months

Make sure core is centered

Make sure core is perpendicular

Use correct loading rate (35 ± 7 psi/sec.)

Apply load till failure

Cap cores in accordance with AASHTO T-231

502.1.10.2 Outliers

Example Problem:

Placing 14-inches of PCCP

Is Lot 2, sublot D, an outlier?

Lot 2 Test Results	
A	5550
B	5500
C	5250
D	4290

Determine the average for the compressive strengths in question.

$$Average\,Compressive\,Strength = \frac{5550 + 5500 + 5250 + 4290}{4} = 5147.50\,lb/in^2$$

Second, determine the standard deviation for the compressive strengths in question.

$$\sigma_{\text{Comp.Strength}} = \sqrt{\frac{[(5550 - 5147.5)^2 + (5500 - 5147.5)^2 + (5250 - 5147.5)^2 + (4290 - 5147.5)^2]}{(4 - 1)}}$$

$$= \sqrt{\frac{[402.5^2 + 352.5^2 + 102.5^2 + (-857.5)^2]}{3}}$$

$$= \sqrt{\frac{(162006.25 + 124256.25 + 10506.25 + 735306.25)}{3}}$$

$$= \sqrt{\frac{1032075}{3}}$$

$$= \sqrt{344025}$$

$$= 586.54\,lb/in^2$$

Third, determine the T-statistic for the compressive strength in question.

$$T_{\text{Compressive Strength}} = \frac{(5147.50 - 4290)}{586.54}$$

$$= 1.46196\,rounded\,to\,1.462$$

Fourth, review Table 1 in ASTM E 178 to determine if value in question is an outlier.

n = 4

Significance Level = 5%

T-statistic = 1.462

Value to the right so NOT an outlier

If sample is identified as an outlier, a new core shall be taken at the same offset within approximately 2 feet of the original sample core. It shall be retested accordingly. A spreadsheet is available to determine outliers and is located at V:\Materials Forms.

502.2.2 Apparatus

The following material is needed for shipping cores:

(a) Plastic bag (minimum 12" x 21") (for QC cores)

(b) Tamper-proof bag (for QA cores)

(c) Felt-tip marker

(d) Strapping Tape

(e) Cardboard Box (concrete cylinder box 14" x 14" x 7")

502.2.3 Testing

Pavement thickness and compressive strength are to be determined from cores extracted from the pavement. The same core will be used to determine the pavement thickness and the compressive strength. Pavement thickness is determined by measuring the core in accordance with AASHTO T 148. After determining the pavement thickness, the core is sawed to a length/diameter (l/d) ratio of 2.0 and capped in accordance with AASHTO T 231. After 28 days, the compressive strength of the core will be tested in accordance with AASHTO T 22. Quality Assurance cores may be tested either by the Quality Assurance Inspector, using district equipment, or by the Central Laboratory. Quality Assurance cores will not to be tested using Quality Control testing equipment. Quality Control cores shall not be tested using Quality Assurance testing equipment.

502.2.4 Procedures

502.2.4.1 Sampling Cores

Cores shall not be taken until the concrete has attained a compressive strength of 3,000 psi. The location of Quality Control and Quality Assurance cores shall be determined using random sampling procedures in accordance with ASTM D 3665. The engineer will be responsible for determining the sample locations. In no case should the contractor be permitted to determine random sample locations of Quality Control cores. All cores shall be sampled in accordance with AASHTO T 24. Quality Assurance cores will be extracted by the contractor and provided to the Quality Assurance Inspector for evaluation. The QA inspector should maintain possession of the QA core from the time of extraction till it is tested.

502.2.4.2 Handling Cores

After the core is removed from the hole, wipe off the surface water and allow the remaining surface moisture to evaporate. When the surface appears to be dried, write the following information on the side of the core:

(a) Job No.

(b) Route

(c) County

(d) Lot

(e) Sublot

502.2.4.2.1 The QC inspector shall place the QC core into a separate plastic bag and seal the bag to prevent moisture lose. The QA inspector shall place and seal the QA core in a tamper-proof bag immediately after extraction and mark the bag label with the project number, lot number, location and inspector signature. This should be performed within one hour after the core is drilled.

502.2.4.2.2 If a Quality Control or Quality Assurance core is dropped, exposed to freezing temperatures, or otherwise mishandled in some fashion the Resident Engineer should be contacted immediately. A replacement core should be taken at a new random sample location as soon as possible if it is believed the core no longer represents the in-place concrete. Studies have shown the compressive strength can be reduced when a specimen is dropped.

502.2.4.2.3 Cores should be kept in an environment that has a temperature range of 60 to 80 ° F. Cores should be protected from direct sunlight.

502.2.4.3 Shipping Cores

The plastic bag, containing the core, should be packed carefully into the cylinder box to prevent the cores from being damaged during shipment. A cylinder box will hold two 6-inch diameter cores or three 4-inch diameter cores. Do not over pack the cylinder box to avoid potentially damaging the cores or damaging the plastic bags. Packing material should be used to stabilize the cores to prevent them from moving around during shipping. Cores over 14 inches may require the use of a large cardboard box to prevent them from being damaged during shipping. The following information should placed on the side of the cylinder box:

(a) Sample Identification Number

(b) Date of Pour

(c) Lot

(d) Sublot

(e) Special Instruction

502.2.4.3.1 QA cores that are to be tested at the Central Laboratory must be shipped as soon as possible after drilling. According to AASHTO T 24, specimens need to be sawed no later than two days after extracting the cores from the pavement. The district will need to work closely with the contractor on when Quality Assurance cores will be taken. This will aid the district in arranging for the shipment of the cores. Cores must arrive at the Central Laboratory so the cores can be sawed within the allotted time.

502.2.4.3.2 Be advised that cores are to be kept in the plastic bags for at least five days after last being exposed to moisture before compressive strength testing. The purpose of the 5-day waiting period is to reduce the moisture gradient introduced when the core was drilled or wetted during sawing.

502.2.4.4 Filling Core Holes

The contractor is responsible for filling core holes after extracting the cores. The contractor shall use an approved non-shrinkage grout to fill the holes. The contractor is to fill the holes within 1 day of sampling the cores.

502.2.4.4.1 Before placing the mixture, all free water shall be removed from the bottom of the core hole. A sponge may be used for this purpose. If the hole is difficult to dry, cement may be sprinkled in the bottom. The hole shall be filled in two layers with each layer thoroughly rodded. The top layer shall be troweled to a slightly high, smooth surface.

502.2.4.4.2 Additives may be used to accelerate setting time where traffic may damage patches. Approval for additives is to be obtained from the State Construction and Materials Engineer.

AASHTO T 24 Obtaining and Testing Drilled Cores of Concrete PROFICIENCY CHECKLIST

Applicant:____

Employer:____

Trial#	1	2
1) **Cores not taken until 3000 psi. is achieved**		
2) **Size of core taken corresponds to thickness of pavement** a) For pavements less than 12" take a 4" core b) For pavements 12" or greater take a 6" core		
3) **Ensure core bit is perpendicular to the driving surface**		
4) **Extract core**, taking care not to damage or drop. a. Wipe surface water from core and allow remaining surface moisture to evaporate. **b. Mark core for identification**		
5) **Maintain the integrity of moisture** consistent with AASHTO 24. a) **Within 1 hour of extraction, place core in** plastic bag or non-absorbent **container**. b) **Maintain** ambient **temperature** of core i) 60 to 80°F c) Out of direct sunlight		
6) **Determine the length (Pavement Depth)** of core in it's original form according to AASHTO T148		
7) **Determine the mean diameter of the core,** check tolerances		
8) **Cores will be tested at 28 days of age.** a) **If water is used during preparation, complete** as soon as practicable **within 2 days of drilling and extraction** b) **Minimize exposure to water** during end preparation c) **Keep core sealed** except i) During measuring and end preparation procedure ii) A maximum of 2 hours to permit capping **d) Cores to remain sealed in container a minimum of five days after last being wetted**		
9) **Reporting** a) Report the length and direction of load b) Report the results of the compressive strength		

Pass Pass

Fail Fail

Examiner:__________________________________ Date:__________________

AASHTO T 148

Measuring Length Of Drilled Concrete Cores

AASHTO T 148

Measuring Length of Drilled Concrete Cores

Overview

- This test method is used to determine the average thickness of the core taken from a concrete pavement.

AASHTO T 148 2

Equipment

- Measuring Device
- Measuring Rod
- Flat Steel Plates
- Calibration 1" x 2" x 3" Blocks
- Tape Measure
- Caliper (for measuring diameter)

AASHTO T 148 3

Equipment

- The measuring device will meet the following requirements:
  - It will measure along the axis of the core.
  - The lower end will hold the core vertical by use of three symmetrically spaced supports. These supports will be made of hardened steel with the ends which bear against the core rounded to a radius of not less than ¼" and not more than ½".

AASHTO T 148 4

Equipment

Measuring Device

AASHTO T 148 5

Equipment

- The device will be capable of measuring cores which are the full depth of the concrete pavement.
- The device will measure a length at the center of the core and at eight additional points spaced at equal intervals along the circumference of a circle which has it's center point at the center of the core.
- The radius of the circle will be not less than 50%, nor more than 75% of the radius of the core being measured.

AASHTO T 148 6

Equipment

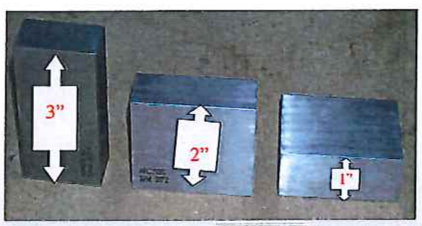
- Measuring Rod

- The measuring rod or rods will be rounded to a radius of 1/8" for the end which contact the core.
- The measuring rod on one end is divided into tenths of an inch. (It is a good idea to color in the grooves to make it easier to read and giving the 1/2" and 1" marks a different color.
- The 0.1" marks on the measuring rod will be verified.

AASHTO T 148 7

Equipment

Calibration Blocks



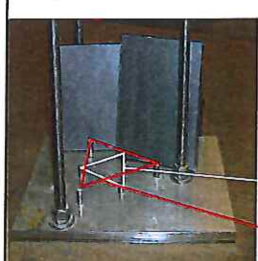
Each block is 1"x 2" x 3".

AASHTO T 148 8

Equipment

Flat steel plates

One is 1/2"thick by 4 1/2" square & Two are 1/4" thick and 4" square.

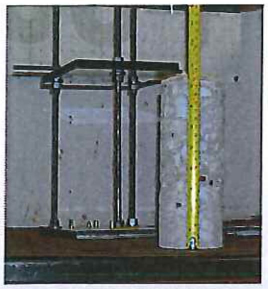


- 4" cores, you will use the 1/4" plate on the inner three studs.
- 6" cores, you will use the 1/2" plate on the outer three studs.
- Core diameter determines which stud set you use to set up the measuring device.
- Inner three studs are for 4" diameter cores.
- Outer three studs are for 6" diameter cores.

AASHTO T 148 9

Equipment Calibration

Using a tape measure take a rough measurement to the tallest point then add 1/2" and round up to the nearest inch and record as "Calibration Height of Measuring Device"



AASHTO T 148 10

Equipment Calibration

- Place the appropriate plate for the core size in the measuring device.
- Notice the 4" square by ¼" thick plate on the inner three studs for a 4" core

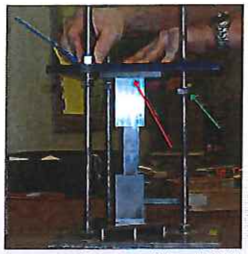
AASHTO T 148 11

Equipment Calibration

Using the calibration 1" x 2" x 3" blocks, stack up on the flat plate the amount to achieve a height slightly more than the core.

AASHTO T 148 12

Equipment Calibration



Bring down the Plexi-glass plate to rest on top of the plate at the top of your 1,2,3 blocks.

Run down the nuts on top of the Plexi-glass to just snug by the hand.

Bring up the nuts from the bottom and hand tighten against the bottom of the Plexi-glass.

Remove all the 1,2,3 blocks and the plates.

Your measuring device is calibrated.

AASHTO T 148 13

Procedures

- The cores will be representative of the pavement they are taken from.
- Cores that show abnormal defects or have been damaged will be replaced.
- Any particles of the base material that are attached to the bottom of the core shall be removed, may use a wire brush or chisel.
- Care should be exercised not to remove any of the concrete when removing attached particles.

AASHTO T 148 14

Procedures

Insert the core, placing the driving surface down onto the studs.

AASHTO T 148 15

Procedures

On the top plexi-glass plate there is one hole in the middle and then two sets of eight holes in a small circumference around it. The inside are used when measuring 4" diameter cores. The outside are used when measuring 6" diameter cores. (It is a good idea to label the center hole #1, then continue on with the other holes 2-9 for both set of holes.)

AASHTO T 148 16

Procedures

- Insert the measuring rod into hole #1 and bring to rest on the core.
- Take the calibrated set height of the device and from the core surface start counting the tenths of an inch on the rod backwards from that number, interpolating the nearest .05".
- Record this as the height for that hole.
- Repeat process for the remaining 8 holes.

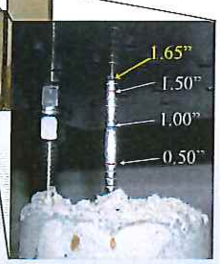
AASHTO T 148 17

Example

- From the top of the core count backwards each tenth of an inch mark up to the bottom of the plexi-glass.
- Interpret to the nearest .05"
- The core shown would be 13.35"
- The individual observations shall be recorded to the nearest 0.05".
- Average the nine measurements expressed to the nearest 0.1".

- The set height is 15.00"

15.00-1.65=13.35"

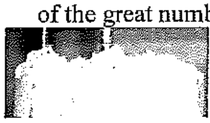


AASHTO T 148

Procedures

- If there is one or more of the eight locations on the circle for the measurements that are found not to be representative of the plane of the core, the core shall be rotated slightly and nine new measurements made.

  NOTE: Pavements on open-graded aggregate cannot use this provision because of the great number of projections or voids.



AASHTO T 148 19

Reporting

- Record each measurement to the nearest 0.05".
- Average the nine measurements and report to the nearest 0.1".

AASHTO T 148 20

Common Errors

- Not verifying the measuring rod.
- Misreading the measuring rod.
- Adding when you should be subtracting or subtracting when you should be adding.
- Improperly setting the height of the upper plate.
- Not centering the core.
- Not removing attached foreign particles.
- Removing some of the concrete when removing foreign particles.

AASHTO T 148: Measuring Length of Drilled Concrete Cores
PROFICIENCY CHECKLIST

Applicant:____

Employer:____

Trial#	1	2
1. Remove any base particles from the core		
2. Place core in callipering device, orient core with the top (pavement surface) on the base		
3. Center core in callipering device		
4. Measure length at the 9 locations to the nearest 0.05"		
5. Subtract the measurements from the set height of the top plate		
6. Record the calculated lengths to nearest 0.05"		
7. Average the 9 measurements and report average length to 0.1"		

Pass Pass

Fail Fail

Examiner:____Date:____________________

AASHTO T 231 &
AASHTO T 22

Capping of Concrete Cores & Compressive Strength of Cylindrical Concrete Test Specimens

AASHTO T 231
&
AASHTO T 22

Capping Cylindrical Concrete Specimens

&

Compressive Strength of Cylindrical Concrete Specimens

Background & Overview

The compressive strength of cylindrical concrete specimens is determined for contract control or department information. Field cylinders are broken for contract control and typically range in age of a few hours to several days depending on the field conditions to be monitored.

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Capping Cylindrical Concrete Specimens

Capping Materials

- Capping may be accomplished using the following materials as allowed:
  - Sulfur Mortar
  - Neoprene Rubber

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Specimen Preparation

- Specimens will be prepared as defined in AASHTO T23 & T24 prior to capping.
- Core measured per AASHTO T 148.
- If necessary, reduce the length of a core to L/D ratio of 2.0.

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Specimen Preparation

- No projections to exceed 0.2 in. (5 mm) above the end surface.
- The end surface shall not depart from perpendicularity to the longitudinal axis by more than 0.5 degrees.
- ***For cut cores,*** the diameter of the ends shall not depart more than 0.1 in. (2.5 mm) from the mean diameter.

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Specimen Preparation

- Saw the ends to square
- Smooth ends to meet perpendicularity and planeness requirements,
- Or cap the ends.
- Specimens de-burred using masonry brick.

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Capping Equipment

- Capping Plates
- Alignment Device
- Melting Pot for Sulfur Mortar
- Ladle
- Ruler
- Feeler Gauge 0.002 in.
- Masonry stone - used to remove concrete protrusions on cylinders by rubbing.

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Equipment Verification

- The capping plates, alignment device, and capping material will be verified as meeting the specified requirements.
  - Capping plates – planeness, thickness, diameter
  - Alignment device – perpendicularity
  - Capping materials – strength

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Capping with Sulfur Mortar

- Plug sulfur pot in **WITHOUT** the use of an extension cord.
- Prepare sulfur mortar for use by heating to about 265°F (130°C).
- Wear an apron or other suitable protective clothing before using hot melted sulfur.
- Fill sulfur pot 2/3 full of flake sulfur and stir periodically.

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Sulfur Capping

- Check the temperature of the material periodically to ensure setting on melting pot will heat the material to the required temperature [265°F (130°C) maximum].
- Any material which has been heated 5 times must be discarded.
- When adding fresh sulfur mortar ensure it is dry.

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Sulfur Capping

Select size of alignment device, make sure it is clean and the alignment blocks are adjusted to the proper height.

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Sulfur Capping

The bottom alignment block should be approximately one and a half inches (1 ½") up from the top of the capping plate, regardless of the core size.

The top alignment block is placed approximately two-thirds of the way between the bottom block and the top of the core.

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Sulfur Capping

Practice aligning and setting the core in the alignment device to familiarize yourself with how it sets in the device.

This will help ensure that you won't drop the core into hot sulfur and splash it on you. (Wear protective clothing).

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Sulfur Capping

When sulfur is melted and has reached temperature, lightly oil the base of the alignment device. This should be done before each cap.

Use oil or a non-stick cooking spray.

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Sulfur Capping

Sulfur mortar heated to about 265°F (130°C).
Be sure to stir the sulfur before each cap.
The sulfur separates and develops an oily film.

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Sulfur Capping

Fill the capping plate to warm the plate. Do not insert a specimen at this time.

Warming the capping plate keeps the sulfur from curing too quickly while placing specimen.
The sulfur dries and builds up on the ladle. Clean it periodically by striking it with the rawhide mallet.

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Sulfur Capping

- Let the sulfur harden and cool.
- Hit the capping plate with a rawhide mallet on both sides to remove sulfur from the plate.
  - Note: If a tool is used to facilitate getting the sulfur cap loose, be careful not to gouge the plate.

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Sulfur Capping

- Ensure that the ends of the specimen are free of moisture.
- Lightly oil the capping plate.
- Stir the sulfur, ladle into the capping plate.
- Quickly set the specimen into the sulfur, being sure to keep it against the alignment blocks.

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Sulfur Capping

Continue to hold against the alignment blocks for approximately 45 seconds till sulfur hardens.(The edges of the sulfur will turn flat or dull as it cools.)

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Sulfur Capping

After sulfur has hardened, tap the plate with the rawhide mallet on both sides of the specimen.

Gently twist the specimen and pull straight up, being careful not to hit the cap against the bottom alignment blocks.

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Checking Finished Caps

- –Soundness Check
- –Perpendicularity Check
- –Planeness Check

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Soundness Check

Using a metal object lightly tap or rub the cap. If a hollow sound is produced, an unsatisfactory cap is indicated.

Remove the sulfur cap and recast.

The bad cap can be removed from the end of the specimen using taps from the mallet.

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Perpendicularity Check

Check for perpendicularity to ensure that the cylinder or core is within 0.5 degrees or 0.125" in 12" or 0.083" in 8".

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Planeness Check

Using a straight edge and feeler gage, check to ensure the cap is within 0.002 in. of planeness at three different diameters.

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Core Specimen Final Measurements

After capping place the core into the measuring device and take the final length measurements.

The individual observations shall be recorded to the nearest 0.05" (1.3 mm) and the average of the nine measurements expressed to the nearest 0.1" (2.5mm) shall be reported as the length of the concrete core after capping.

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Core L/D Results

Final Length(L)/Diameter(D) Ratio will be determined after capping:

$$\frac{Average\ \ Length}{Average\ \ Diameter}$$

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Length/Diameter Ratio

- Specimens shall be corrected to a L/D ratio of 2.0 when practical.
- If specimen L/D ratio is 1.75 or less correct the results obtained by multiplying by the appropriate correction factor listed below. Interpolate as necessary.

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

Refer to test method for further guidance.

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Neoprene Caps

- On molded specimens only, in lieu of sulfur capping, neoprene pads may be used.
- Cut cores require capping other than neoprene.
- QC/QA specimens should mimic their counterpart, i.e.. If QC is sulfur capping, QA should also sulfur cap.

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Neoprene Caps

- Concrete specimens tested with neoprene caps rupture more intensely than comparable cylinders tested with sulfur caps. Use both the cylinder wrap and the protective cage of the test machine to protect operator from flying fragments.

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Equipment

- **Neoprene pads** - should meet the requirements of the ASTM C1231. Each neoprene pad is limited to no more than 100 tests.
  - The pads can be lubricated with a small amount of furniture spray wax or cornstarch to help the cylinder seat itself on the pads. *EPG Section 501.*
- **Extrusion controllers** - will be dimensioned and in the condition as required in the ASTM C1231.

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Equipment

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Neoprene Caps

- Lubricate neoprene pad with either a small amount of furniture spray wax or cornstarch.
- The lubricated neoprene pads are placed in the extrusion controller and placed on each end of the cylinder.

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Compressive Strength of Cylindrical Concrete Specimens

Equipment

- **Testing machine -** device which applies continuous load to the cylinder. It must be capable of registering loads as specified in the test method at the rates specified. It must be calibrated annually not to exceed 13 months. The testing machine includes a protective cage to protect the operator from flying particles as the cylinder is broken.

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Equipment

Cylinder wrap - made of canvas with velcro attachments to encase the cylinder during breaking.

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Sample Preparation

- Any imperfections found not to meet the test method will be corrected prior to testing.

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Sample Preparation

- Cylinders shall be broken within the tolerances given below based on age.

Test Age	Permissible Tolerance
12 h	±0.25 h or 2.1 percent
24 h	±0.5 h or 2.1 percent
3 days	±2 h or 2.8 percent
7 days	±6 h or 3.6 percent
28 days	±20 h or 3.0 percent

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Sample Preparation

- The diameter of the cylinder will be measured at the middle to the nearest 0.01".
- Two measurements at right angles to each other will be taken across the diameter and averaged.

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Sample Preparation

- Record measurements for later calculations.
- These 2 diameter measurements will be compared to each other to ensure they are within 2% for out-of-roundness compliance.
  - Diameter measurements may be performed prior to capping when roundness is suspect.

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Procedure

Place the wrap around the cylinder and secure the velcro attachments.

Center the cylinder under the upper bearing block.

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Procedure

Reset ultimate load indicator to zero.

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Procedure

Initially load specimen.

Gently rotate the upper bearing block as it is brought to bear on the specimen.

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Procedure

Secure the protective cage.

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Procedure

- Apply load at a rate of 35 ± 7 psi/sec uniformly and without shock until the specimen has failed.
  - NOTE: Machine speed of travel for 4" specimens differs from 6" substantially.
  - As a general rule,use the following load rates:
    - » 4" specimens, approx. 450 lbs/force/sec.
    - » 6" specimens, approx. 1000 lbs/force/sec.
      - Actual ranges:
        - 4"→ 352-528 lbs/force/sec
        - 6" →792-1187 lbs/force/sec

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Procedure

- After breaking the specimen, remove from the testing machine.

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Procedure

Place the cylinder on it's side so that the wrap may be removed and the type of fracture determined (see diagram in written material for examples of breaks).

The specimen can now be disposed of in accordance with office practice.

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Calculations

The two diameters (d) in inches are averaged (Da).

$$\frac{d1 + d2}{2} = \text{Average} = \text{Da}$$

(d) - reported to the nearest 0.01 inch

The diameter average (Da) is used to calculate the cross-sectional area (A).

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Calculations

$$\frac{\pi(Da)x(Da)}{4} = area\ (A) sq. in.$$

$\pi = 3.14159$

(Da) – reported to the nearest 0.01 inch
(A) – reported to the nearest 0.0001 sq. inch

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Calculations

The compressive strength is calculated by dividing the ultimate load (L) in pounds by the cross-sectional area (A) in sq. in.

$$\frac{L}{A} = \text{Compressive Strength (psi)}$$

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Documentation

- The ultimate load in psi and type of fracture are recorded.
- The types of fractures are presented pictorially later in the manual.
- The value is rounded to the nearest 10 psi for reporting.

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Common Errors

- Improper shape of specimen not corrected
- Neoprene pads used beyond acceptable wear limits
- Steel extrusion controllers have excessive surface imperfections
- Testing machine load indicator not reset to zero

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Common Errors

- Testing machine loading rate other than 35 ± 7 psi/sec
- Not cleaning neoprene pad and controller prior to use
- Not centering the specimen under the upper bearing block
- Un-calibrated testing machine

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Sample Calculations for Determining the Compressive Strength Of a Concrete Test Cylinder

Data

d_1 (diameter measurement #1) = 6.03 inches

d_2 (diameter measurement #2) = 5.99 inches

Ultimate Load (reading from cylinder breaking machine) = 114,500 lbs

Out-of-roundness = (6.03 – 5.99) / 5.99 x 100 = 0.7% < 2% maximum

Da = Average Diameter

$$Da = \frac{d_1 + d_2}{2}$$

$$Da = \frac{6.03 + 5.99}{2}$$

$$Da = \frac{12.02}{2}$$

$$Da = 6.01$$

A = Cross-sectional area of cylinder

$$A = \frac{\Pi Da^2}{4} \qquad \Pi = 3.14159$$

$$A = \frac{3.14159 x (6.01)^2}{4}$$

$$A = \frac{3.14159 x 36.1201}{4}$$

$$A = \frac{113.4745}{4}$$

A = 28.3686 sq. inches

$$\text{Compressive Strength (psi)} = \frac{\text{L (Ultimate Load)}}{\text{A (Area)}}$$

$$PSI = \frac{114{,}500}{28.3686}$$

PSI = 4036

PSI = 4040 (rounded to nearest 10 psi)

NOTE: If we assumed this cylinder to be a 6.00 inch diameter,
We would use A = 28.27

$$PSI = \frac{114{,}500}{28.27} = 4050$$

This is a 10 psi difference and is only 0.01 inches different in diameter (average).

AASHTO T 22

Sample Calculations for Determining the Compressive Strength Of a Concrete Test Cylinder

Data

d_1 (diameter measurement #1) = __________

d_2 (diameter measurement #2) = __________

Out-of-roundness = $(d_1 - d_2) / d_2 \times 100$ =

(_______ - _______) / ________ x 100 = ___________% < less than or equal 2%

d_2 should be the smaller of the 2 diameters measured.

Da = Average Diameter

$$Da = \frac{d_1 + d_2}{2}$$

Da = $\frac{\_\_\_\_\_\_\_\_\_\_}{2}$

Da =

A = Cross-sectional area of cylinder

$$A = \frac{\Pi Da^2}{4} \qquad \Pi = 3.14159$$

A = $\frac{3.14159 \times \_\_\_\_\_ \times \_\_\_\_\_}{4}$

A =

Ultimate Load (reading from cylinder breaking machine) = ___________________

Compressive Strength (psi) = $\frac{L \text{ (Ultimate Load)}}{A \text{ (Area)}}$

PSI = ________________

PSI =

PSI (rounded to nearest 10 psi) =

501.1.3.5 Compressive Strength

Compressive tests are performed both in the field and in the laboratory on cylindrical specimens of concrete, 6 in. diameter and 12 in. tall (6x12) or 4 in. diameter and 8 in. tall (4x8). The Standard Specifications require use of compressive specimens for job control of concrete production.

All concrete for air and slump tests as well as preparation of the specimens should be secured from a single batch of concrete. Air and slump tests should always be made on samples of concrete used for preparation of compressive specimens.

Cylinder forms shall be filled with fresh concrete in accordance with the instructions provided by AASHTO T 23 (ASTM C 31). Care should be taken when placing the caps on the molds to avoid damage to the surface of the concrete. The lids should be kept on tight to prevent moisture loss.

501.1.3.5.1 Curing

Curing of compressive specimens will depend on whether they are for standard cure or field cure.

Standard Cure is defined as 1) specified strength for 28-day testing; 2) Check of mixture proportions or design strength; 3) Quality control (i.e. monitoring mix variability) or 4) Maturity meter curve.

Standard curing involves two phases of curing: initial and final.

Each set of compressive test specimens for standard cure consists of two 6x12 cylinders or three 4x8 cylinders. Standard Cure specimens shall be cured in accordance with AASHTO T23 (ASTM C31) for initial and final curing.

Standard Cure – Initial

If specimens cannot be molded at the place where they will receive initial curing, immediately after finishing move the specimens to an initial curing place for storage. Recommended method for initial curing is keeping the specimen in the plastic mold covered with a plastic lid or place in a damp sand pit for a maximum of 48 hours in a temperature range from 60° F to 80° F and an environment preventing moisture loss.

Standard Cure - Final

Upon completion of initial curing and within 30 minutes of removing the molds, cure specimens with free water maintained on their surfaces at all times at a temperature of 70° F to 77° F using water storage tanks or moisture room per AASHTO M201 (ASTM C511).

Storage Tanks When water tanks are used for final curing the temperature shall be maintained at 70° F to 77° F. Method of recording temperature is required. Transportation of Specimens Specimens may be transported to the Central Laboratory for final curing. To transport, after the initial cure period, the specimen shall be removed from the mold and placed in a plastic bag to maintain free moisture during shipping. Specimens should not be transported to begin final cure until at least 8 hours after final set.

During transporting, use suitable material to prevent damage from jarring and use suitable insulation material during cold weather. Show shipper's name and address on the outside of the box. The box comes with the address of Central Laboratory printed on the side and a preprinted form that provides basic information about the cylinders. If the box does not have the form preprinted, contact the Central Laboratory for copies of the self stick form. SiteManager Sample ID number should be written on the side of cylinders or cylinder molds. Necessary boxes, cardboard liners, polyethylene bags, wire ties and rolls of strapping tape are stock items available by requisition.

Field Curing

Field cure is defined as 1) Opening to traffic strength or staged construction; 2) Comparison with test results of standard cure to in place methods, such as maturity method verification; 3) Adequacy of curing and protection of concrete in the structure, such as cold weather placement or 4) Form removal.

Field curing shall be in accordance with AASHTO T23 (ASTM C 31). Store cylinders in or on the structure as near as practical to the represented concrete. Protect all surfaces of the cylinders from the elements, and ensure a temperature and moisture environment similar to the formed work. To meet these conditions specimens made for the purpose of determining when a structure is capable of being put in service shall be removed from the molds at the time of removal of form work.

Compressive test specimens for field cures may consist of one or more for either 6x12 cylinders 4x8 cylinders. Specimens prepared to determine when forms may be removed will be cured as described in above except for bridge decks or heated concrete. Specimens representing bridge decks are to be cured on the deck under wet mats until the cylinders are to be broken or wet curing is discontinued. If cylinders remain after wet curing has ended, they shall be cured in plastic molds under field conditions until they are to be broken.

Specimens representing heated concrete are to be left in the enclosure subject to the same protection as concrete they represent until they are to be broken. Cylinders should be left in molds and covered with wet burlap for 48 hours. If cylinders remain after the heating period has ended they shall be cured in plastic molds under field conditions until they are to be broken.

Curing of bridge decks shall be in accordance with Standard Specification 704, wet curing shall be maintained for 7 days and until the concrete has reached a minimum of 3000 psi

Test Procedures

A calibrated testing machine must be used by a certified technician. The SiteManager sample record must be completed documenting the testing. Testing is to be done in the hydraulically operated compressive testing machine. If there is doubt as to the 28-day strength of the cylinder, relative to the working capability of the available testing machine, send the cylinders to the Central Laboratory. All specimens are to be loaded to failure.

All cylinders are to be tested using a neoprene cap in a steel extrusion controller placed on each end of the cylinder. The neoprene caps have 6 1/8 in. diameters and are 1/2 in. thick. The caps are made from neoprene and no substitution of material or cap is to be made. A 50 durometer neoprene cap is used for concrete with a cement factor of less than 7.5 sacks per yard. Otherwise, a 60 durometer neoprene cap is used. The caps should be replaced if worn or after a maximum of 100 cylinder breaks.

The steel extrusion controller's outside bearing surface is to be maintained free of gouges, dents or protrusions greater than 0.03125 in. or 0.0625 sq. in. surface area. The inside bearing surface is to be maintained to within 0.002 in. of plane.

Care should be taken when molding the specimen since irregularities can result in poor test results. Specimens should be tested using neoprene pads per ASTM C1231 or capped in accordance to AASHTO T231.

Projections on the ends of test specimens should not be higher than 0.20 inches, and corrected as necessary before testing.

Neither end of the concrete cylinder is to depart from perpendicularity to the axis of more than 0.5 degrees or 0.12" in 12"(0.08" in 8"). Neither end of the cylinder is to be marked by scratching in the date, cylinder number, etc. Cylinders not meeting these conditions shall not be tested unless the irregularity is first corrected.

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A sufficient amount of ordinary corn starch is used to completely fill any void between the edge of the neoprene pad and the steel extrusion controller and to lubricate the face of the neoprene pad that contacts the concrete cylinder. In lieu of corn starch, Pledge spray wax has been used with good results.

The same surface of the neoprene cap is to bear on the concrete cylinder for all tests performed with that cap.

Place a steel extrusion controller containing a neoprene cap on the top and bottom surface of the concrete surface. As the upper bearing block is lowered, carefully align the cylinder's axis with the center of thrust of the upper block. The upper block should be carefully seated to obtain uniform bearing. No loose particles are allowed between the concrete cylinder and the neoprene caps or between the bearing surfaces of the extrusion controllers and the bearing surfaces of the test machine.

Concrete cylinders tested with neoprene caps rupture more intensely than comparable cylinders tested with sulfur-mortar caps. The test machine is to be equipped with a protective cage to protect the operator from flying fragments.

Once the cylinder is carefully seated, load shall be carefully and uniformly applied. The last half of the anticipated maximum load must be applied at a constant rate which falls within the range of 35 ± 7 (that is, 28 to 42) psi per second or between 352 and 528 pounds force per second for 4 in. diameter cylinders and between 792 and 1187 pounds force per second for 6 in. diameter cylinders on the gauge dial. The first half of load may be applied at a faster rate. Load is to be increased until the specimen fails. Needle travel or digital load readout will usually slow, or even stop, just before visible failure. The maximum distance of ram movement is 2 inches.

On digital readout machines, total load is captured automatically. On dial readout machines, although the red needle is supposed to indicate total load, it should be watched carefully to be sure it does not spring back at failure of the specimen. As soon as the specimen fails, the pressure should be released allowing the upper block to return to the unloaded position.

All test data shall be recorded in SiteManager. Results of the tests are to be reported to the nearest 10 psi.

AASHTO T 231 Capping Cylindrical Concrete Specimens & AASHTO T 22 Compressive Strength of Cylindrical Concrete Specimens
PROFICIENCY CHECKLIST

Applicant:____

Employer:____

Trial#	1	2
Specimen Preparation		
1) **Reduce the length of the core to achieve a Length/Diameter (L/D) ratio of 2 to 1**		
2) **Perform end preparation as necessary** to meet the following: a) No projections to exceed 0.2" (5mm) b) Perpendicularity to the longitudinal axis not to exceed 0.5° c) The diameter of the ends shall not depart more than 0.1" (2.5mm) from the mean diameter of the core		
Capping Concrete Cylindrical Specimens		
3) **Compressive Strength** a) Cap according to AASHTO T 231. **b) Sulphur Only** **i)** Is the mortar stirred at the beginning of the operation **ii)** Is the capping plate lightly oiled prior to use **iii)** Are cylinder ends dried prior to capping **c) All Capping Materials** **i)** Are perpendicularity guides or leveling devices used effectively **ii)** Are caps checked for planeness If yes, how often **iii)** Are cylinders kept moist after capping		
	Pass Fail	Pass Fail

Examiner:____________________________________Date:________________

Compression Testing of Concrete Cylindrical Specimens		
1) Is the **diameter** of the cylinder **recorded** to **the nearest 0.01 inch** by **averaging two diameters** taken at about mid-height		
2) Are lower and upper **bearing surfaces wiped clean**		
3) Is the axis of **the specimen centered under the upper bearing block**		
4) **Zero setting checked** prior to testing and adjusted when necessary		
5) **Is the spherical block rotated as it contacts the cylinder**		
6) Is the **load applied** continuously and without shock **at the specified rate 35 ± 7 psi/sec**		
7) **Is no rate adjustment made while the cylinder is yielding**		
8) **Is the maximum load recorded**		
9) Are cylinders tested to failure and the **type of fracture recorded**		
	Pass Fail	Pass Fail

Examiner:____________________________________Date:________________

Glossary of Terms

AASHTO
American Association of State Highway and Transportation Officials

Aggregate Correction Factor
An easily run test that accounts for air in the aggregate structure which fills with water under pressure. It is determined on inundated fine and coarse aggregate in approximately the same moisture condition, amount and proportions occurring in the concrete sample under test.

Air Content
The amount of air in mortar or concrete, exclusive of pore space in the aggregate particles, usually expressed as a percentage of total volume of mortar or concrete.

Air Void
A space in cement paste, mortar, or concrete filled with air, and entrapped air void is characteristically 1mm (0.04 in.) or more in size and irregular in shape; an air entrained air void is typically between 10µm and 1mm in diameter and spherical (or nearly so).

Batch Weights
Quantity of concrete or mortar mixed at one time.

Central Mixed Concrete
A stationary concrete mixer from which the fresh concrete is transported to the work.

Compression Test
Test made on a specimen of mortar or concrete to determine the compressive strength; unless otherwise specified, compression tests of mortars are made on 50mm (2 in.) cubes, and compression tests of concrete are made on cylinders either 4 inches in diameter and 8 inches in height or 6 inches in diameter and 12 inches in height.

Compressive Strength
The measure resistance of a concrete or mortar specimen to axial loading; expressed as pounds per square inch (psi) of cross-sectional area.

Concrete
A composite material that consists essentially of a binding medium in which is embedded particles or fragments of relatively inert material filler. In Portland cement concrete, the binder is a mixture of Portland cement and water; the filler may be any of a wide variety of natural or artificial aggregates.

Consistency
The relative mobility or ability of fresh concrete or mortar to flow. The usual measures of consistency are slump or ball penetration for concrete and flow for mortar.

Consolidation
The process of inducing a closer arrangement of the solid particles in freshly mixed concrete or mortar during placement by the reduction of voids, usually by vibration, centrifugation, tamping, or some combination of these actions; also applicable to similar manipulation of other cementitious mixtures, soils, aggregates, or the like.

Core
A cylindrical specimen of standard diameter drilled from a structure or rock foundation to be bested compression or examined petrographically.

Entrained Air
Round, uniformly distributed, microscopic, non-coalescing air bubbles entrained by the use of air-entraining agents; usually less than 1mm (.04 in.) in size.

Entrapped Air
Air in concrete that is not purposely entrained. Entrapped air is generally considered to be large voids (larger than 1mm [.04 in.]).

Field Cured Cylinders
Test cylinders cured as nearly as practicable in the same manner as the concrete in the structure to indicate when supporting forms may be removed, additional loads may be imposed, or the structure may be placed in service.

Finishing
Leveling, smoothing, compacting, and otherwise treating surfaces of fresh or recently placed concrete or mortar to produce desired appearance and service.

Gradation
The distribution of particles of granular material among various sizes, usually expressed in terms of cumulative percentages larger or smaller than each of a series of sizes (sieve openings) or the percentages between certain ranges of sizes (sieve openings).

Length Measurement
The longitudinal measurement taken along the specimen axis.

Plasticity
The property of fresh concrete or mortar which determines its resistance to deformation or its ease of molding.

PSI
Pounds per square inch; a measurement of the compressive, tensile or flexural strength of concrete as determined by appropriate test.

Pumping
The forceful displacement of a mixture of soil and water that occurs under slab joints, cracks, cracks and pavement edges which are depressed and released quickly by high-speed heavy vehicle loads; occurs when concrete pavements are placed directly on fine-grained, plastic soils or erodible sub base materials.

Quality Assurance
Planned and systematic actions by an owner or his representative to provide confidence that a product or facility meet applicable standards of good practice. This involves continued evaluation of design, plan specification development, contract advertisement and award, construction, and maintenance, and the interactions of these activities.

Quality Control
Actions taken by a producer or contractor to provide control over what is being done and what is being provided so that the applicable standards of good practice for the work are followed.

Rebar
Abbreviation for "Reinforcing Bar." Bars, wires, strands, and other slender members embedded in concrete in such a manner that the reinforcement and the concrete act together in resisting forces.

Rod, Tamping
A straight steel rod of circular cross section having one or both ends rounded to a hemispherical tip.

Rodding
Compaction of concrete by means of a tamping rod.

Sample
A group of units, or portion of material, taken from a larger collection of units or quantity of material, which serves to provide information that can be used as a basis for action on the larger quantity or the production process; the term is also used in the sense of a sample of observations.

Slump
A measure of consistency of freshly mixed concrete, equal to the subsidence measured to the nearest 6mm (¼ in.) of the molded specimen immediately after removal of the slump cone.

Standard Cure
The curing method used when specimens are intended for acceptance testing for specified strength, checking the adequacy of mixture proportions for strength, quality control.

Strike off
To remove concrete in excess of that required to fill the form evenly or bring the surface to grade; performed with a straight edged piece of wood or metal by means of forward sawing movement or by a power operated tool appropriate for this purpose; also the name applied to the tool.

Tamping
The operation of compacting freshly placed concrete by repeated blows or penetrations with a tamping device.

Thickness Measurement
The length measurement of a core taken perpendicular to the driving surface of a pavement.

Three Point Caliper
A device used to determine the length of a cylindrical shaped specimen consisting of three resting points and a means of evenly measuring nine different points on the opposite end.

Truck-Mixed Concrete
Concrete, the mixing of which is accomplished in a truck mixer.

COMPRESSIVE STRENGTH OF CYLINDRICAL CONCRETE SPECIMENS
AASHTO T 22
ASTM C 39

FHWA SPONSORED

Developed by
Multi-Regional Training & Certification Group
2006

NOTE

Successful completion of the following training materials, including examination and performance evaluation is a prerequisite for this training package.

- AASHTO T 23, Making and Curing Concrete Test Specimens in the Field
- AASHTO T 231, Capping Cylindrical Concrete Specimens

COMPRESSIVE STRENGTH OF CYLINDRICAL CONCRETE SPECIMENS

This procedure covers determination of the compressive strength of cylindrical concrete specimens in accordance with AASHTO T 22. The cylinder should be molded, cured, and stored according to AASHTO T 23 and capped according to AAHSTO T 231. Testing concrete may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices.

CAUTION !

Concrete specimens will rupture suddenly, so a method to contain concrete fragments will need to be provided. The tendency for sudden rupture increases with increasing concrete strength.

Concrete cylinders tested with neoprene caps rupture more intensely than comparable cylinders tested with sulphur-mortar caps. As a safety precaution, the cylinder testing machine should be equipped with a protective cage.

Common Testing Errors

- Improper Load Rate
- Uneven Cylinder Ends
- Calculations

SUMMARY OF TESTING

The technician will apply a compressive axial load to molded cylinders or cores at a rate which is within a prescribed range until failure occurs.

Apparatus

- Testing Machine: The testing machine shall be of a type having sufficient capacity and capable of providing the proper rates of loading. The machine must be power-operated and must apply the load continuously rather than intermittently, and without shock. If the machine has only one loading rate, it must be provided with a supplemental means for loading at a rate suitable for verification. The machine must conform to the specifications in AASHTO T 22.
- Testing Machine when using neoprene caps: When neoprene caps are used the above description, as well as, two steel extrusion controllers shall be used.

Specimen Preparation

1. Specimens can't be tested if any individual diameter of a cylinder differs from any other diameter of the same cylinder by more than 2%.

2. The ends of the specimen can't depart from perpendicularity to the axis by more than 0.5 degrees. This would approximately be equivalent to 3mm in 300mm (0.12 in. in 12 in.). The ends of the test specimens that are not plane within 0.050mm (0.002 in.) will need to be sawed, ground, or capped in accordance with T 231 to meet the tolerance. The diameter used for calculating the cross-sectional area of the test specimen shall be determined to the nearest 0.25mm (0.01 in.) by averaging two diameters measured at right angles to each other at about mid-height of the specimen.

3. The number of cylinders measured for determination of the average diameter may be reduced to one for each ten specimens or three specimens per day, whichever is greater, if all cylinders are known to have been made from a single lot of reusable or single-use molds which consistently produce specimens with average diameters within a range of 0.5mm (0.02 in.). When the average diameters do not fall within the rage 0.5mm (0.02 in.) or when cylinders are not made from a single lot of molds, each cylinder tested must be measured and the value used in calculation of the unit compressive strength of that specimen. When the diameters are measured at the reduced frequency, the cross-sectional areas of all cylinders tested on that day shall be computed from the average of the diameters of the three or more cylinders representing the group test that day.

4. If required, determine the density of the test specimen before capping. Remove any surface moisture with a towel and measure the mass of the specimen using a balance or scale that is accurate to within 0.3 percent of the mass being measured. Measure the length of the specimen to the nearest 1 mm (0.05 in.) at three locations spaced evenly around the circumference. Compute the average length and record to the nearest 1mm (0.05 in.). An alternate method would be to determine the density by weighing the cylinder in air and then submerged under water at 23.0 ± 2.0°C (73.5 ± 3.5°F), and computing the volume.

Procedure

1. Specimens shall be kept moist during the time between removal from moist storage and testing. They also need to be tested in the moist condition.

2. The test specimen needs to be broken within the permissible time tolerances which are shown in the table below.

Test Age	Permissible Tolerance
12 h	±0.25 h or 2.1 %
24 h	±0.5 h or 2.1 %
3 days	2 h or 2.8 %
7 days	6 h or 3.6 %
28 days	20 h or 3.0 %
56 days	40 h or 3.0%
90 days	2 days or 2.2%

3. Place the lower bearing block, with its hardened face up, on the table of the testing machine directly under the upper bearing block. Wipe clean the bearing faces of the upper and lower bearing blocks and of the test specimen. Place the test specimen on the lower bearing block.

4. Check the load indicator and make sure it is set at zero. If the load indicator is not set to zero, adjust the indicator. The technique used to verify and adjust a load indicator to zero will depend on the machine manufacturer. Consult the owner's manual or compression machine calibrator for the proper technique.

5. The load needs to be applied continuously and without shock. During the first half of the anticipated loading phase, a higher rate of loading will be

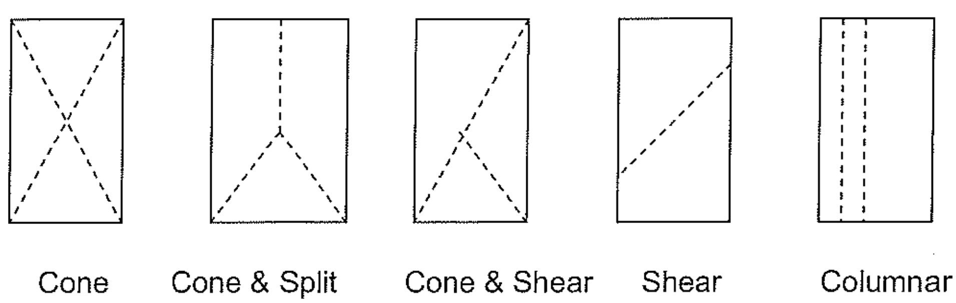
permitted. The higher loading rate will need to be applied in a controlled manner so that the specimen isn't subjected to shock loading. For the last half of the loading process, a designated rate will be maintained. The load shall be applied at a rate of movement corresponding to a stress rate on the specimen of 0.25 ± 0.05 MPa/s (35 ± 7 psi/s). **Note**: For a screw driven or displacement-controlled testing machine, preliminary testing will be necessary to establish the required rate of movement to achieve the specified stress rate. The required rate of movement will depend on the size of the test specimen, the elastic modulus of the concrete, and the stiffness of the testing machine.

Don't adjust the rate of movement as the ultimate load is being approached and the stress rate decreases due to cracking in the specimen.

Apply the compressive load until the load indicator shows that the load is decreasing steadily and the specimen displays a well-defined fracture pattern. When using a testing machine equipped with a specimen break detector, automatic shut-off of the testing machine is prohibited until the load has dropped to a value that is less than 95 percent of the peak load. When unbonded caps are used, a corner fracture may occur before the ultimate capacity of the specimen has been attained. If this happens, continue compressing the specimen until the user is certain that the ultimate capacity has been attained.

6. Record the maximum load carried by the specimen during the test, and note the type of fracture pattern. If the fracture pattern is not one of the typical patterns shown below, sketch and describe the fracture pattern. If the measured strength is lower than expected, examine the fractured concrete and note the presence of large air voids, evidence of segregation, whether fractures pass predominantly around or through the coarse aggregate particles, and verify end preparations were in accordance with T 231.

Type of fractures:



Procedure Using Neoprene Caps

The procedure when using neoprene caps is the same as the main test method with the following modifications:

Place an extrusion controller, containing a neoprene cap, on the top and bottom surfaces of the concrete cylinder. Once you have the caps in place, carefully align the axis of the specimen with the center of thrust of the spherically seated block. Bring the bearing blocks of the machine in contact with both of the extrusion controllers.

Be sure that no loose particles are trapped between the concrete cylinder and the neoprene caps or between the bearing surfaces of the extrusion controllers and the bearing blocks of the test machine.

The same surface of the neoprene cap shall be against the concrete cylinder for all tests performed with that cap. Each cap shall not be used to test more than 100 cylinders. The life of alternate pads must be verified by the agency (or purchaser) in accordance with AASHTO T 22.

Calculation

Calculate the compressive strength of the specimen by dividing the maximum load carried by the specimen during the test by the average cross-sectional area. The cross-sectional area is determined by averaging two diameters measured at right angles to each other at about mid-height of the specimen.

Area of the cylinder would be calculated by the following formula:

$A = \pi r^2 L$

A = area
π = 3.14
r = radius (1/2 diameter)
L = length

Compressive strength would be calculated by the following formula:

$C = L/A$

C = compressive strength
L = maximum load
A = area

If the specimen length-to-diameter ratio is 1.75 or less, correct the compressive strength by multiplying the appropriate correction factor shown in the following table:

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

Use interpolation to determine correction factors for L/D values between those given in the table.

Consult AASHTO T 22 for more information on correction factors.

If density determination of the specimen is necessary, calculate to the nearest 10kg/m^3 (1 lb/ft^3) as follows:

$$\text{Density} = \frac{W}{V}$$

W = mass of specimen, kg (lb)

V = volume of specimen computed from the average diameter and average length or from weighing the cylinder in air and submerged, m^3 (ft^3)

When the volume is determined from submerged weighing, calculate the volume as follows:

$$V = \frac{W - W_s}{Y_w}$$

W_s = apparent mass of submerged specimen, kg (lb)

Y_w = density of water at 23°C (73.5°F) = 997.5kg/m^3 (62.27 lbs/ft^3)

Report

- Report on standard agency form
- Identification number
- Diameter (and length, if outside the range of 1.8D to 2.2D), in inches or millimeters
- Cross-sectional area, in square inches or square centimeters
- Maximum load, in pounds-force or kilonewtons

- Compressive strength calculated to the nearest 0.1 MPa (10psi)
- Type of fracture
- Defects in either specimen or caps
- Age of specimen
- When determined, record the density to the nearest 10 kg/m^3 (1 lb/ft^3)

TESTING METHODOLOGY

METHOD OF DETERMINING THE COMPRESSIVE STRENGTH OF CYLINDRICAL CONCRETE SPECIMENS

Specimens being cured in a controlled moist environment according to AASTHO M201.

Load Testing Machine

Significance

Concrete is specified primarily on the basis of strength. Standard specimens are made and subsequently tested to determine the acceptability of concrete. Concrete strength test specimens are made in accordance with a standard procedure to produce results that are reliable and tests that can be reproduced by someone else with the same concrete, following the same procedures.

Specimens are molded according to standard procedures and then cured under proper temperature and moisture conditions. The specimens are then tested to determine the compressive strength of the concrete.

This test method pertains to specimens cast for the purpose of acceptance. Neoprene caps may be used if certain modifications to the test method are followed.

Scope

This procedure covers the method for determining the compressive strength of cylindrical concrete specimens according to AASHTO T 22.

Apparatus and Specimen Preparation

- Testing Machine: The testing machine shall be of a type having sufficient capacity and capable of providing the proper rates of loading. The machine must be power-operated and must apply the load continuously rather than intermittently, and without shock. If the machine has only one loading rate, it must be provided with a supplemental means for loading at a rate suitable for verification. The machine must conform to the specifications in AASHTO T 22.

- Testing machine when using neoprene caps: When neoprene caps are used the above description, as well as, two steel extrusion controllers shall be used.

Extrusion controllers and caps

Test Age	Permissible Tolerance
12 h	±0.25 h or 2.1%
24 h	±0.5 h or 2.1%
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56 days	40 h or 3.0%
90 days	2 days or 2.2%

Cylinder set on bearing block

Load Indicator at Zero

Procedure – Making Cylinders – Internal Vibration

1. Make and cure the specimens according to AASHTO T 23.
2. Specimens shall be kept moist during the time between the removal from moist storage and testing. They also need to be tested in the moist condition.
3. The test specimen needs to be broken within the permissible time tolerances, which are shown in the table.
4. Place the lower bearing block, with it hardened face up, on the table of the testing machine directly under the upper bearing block. Wipe clean the bearing faces of the upper and lower bearing blocks and of the test specimen. Place the test specimen on the lower bearing block.
5. Check the load indicator and make sure it is set at zero. If the load indicator is not set to zero, adjust the indicator. The technique used to verify and adjust a load indicator to zero will depend on the machine manufacturer. Consult the owner's manual or compression machine calibrator for the proper technique.
6. The load needs to be applied continuously and without shock. During the first half of the anticipated loading phase, a higher rate

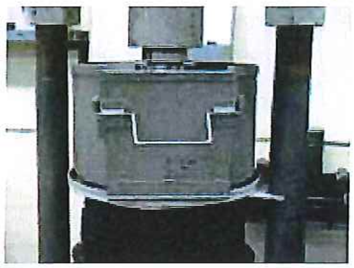
of loading will be permitted. The higher loading rate will need to be applied in a controlled manner so that the specimen isn't subjected to shock loading. For the last half of the loading process, a designated rate will be maintained. The load shall be applied at a rate of movement corresponding to a stress rate on the specimen of 0.25 ± 0.05 MPa/s (35 ± 7 psi/s). **Note**: For a screw driven or displacement-controlled testing machine, preliminary testing will be necessary to establish the required rate of movement to achieve the specified stress rate. The required rate of movement will depend on the size of the test specimen, the elastic modulus of the concrete, and the stiffness of the testing machine.

Don't adjust the rate of movement as the ultimate load is being approached and the stress rate decreases due to cracking in the specimen.

Apply the compressive load until the load indicator shows that the load is decreasing steadily and the specimen displays a well-defined fracture pattern. When using a testing machine equipped with a specimen break detector, automatic shut-off of the testing machine is prohibited until the load has dropped to a value that is less than 95 percent of the peak load. When unbonded caps are used, a corner fracture may occur before the ultimate capacity of the specimen has been attained. If this happens, continue compressing the specimen until the user is certain that the ultimate capacity has been attained.

7. Record the maximum load carried by the specimen during the test, and note the type of fracture pattern. If the fracture pattern is not one of the typical patterns shown, sketch and describe the fracture pattern. If the measured strength is lower than expected, examine the fractured concrete and note the presence of large air

Applying the Load

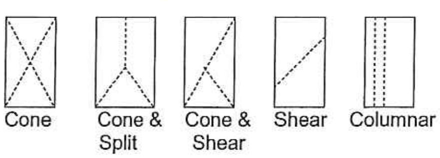


Specimen During Testing

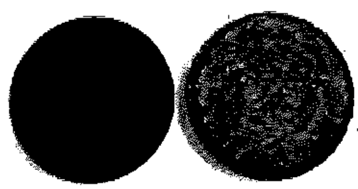
Load Indicator at Maximum Load

Fractured Specimen

Type of Fractures



voids, evidence of segregation, whether fractures pass predominantly around or through the coarse aggregate particles, and verify end preparations were in accordance with T 231.



New and Worn Neoprene Caps

Procedure Using Neoprene Caps

1. The procedure when using neoprene caps is the same as the test method above with the following modifications.
2. Modification: Place an extrusion controller, containing a neoprene cap, on the top and bottom surfaces of the concrete cylinder. Once you have the caps in place, carefully align the axis of the specimen with the center of thrust of the spherically seated block. Bring the bearing blocks of the machine in contact with both of the extrusion controllers.

   Be sure that no loose particles are trapped between the concrete cylinder and the neoprene caps or between the bearing surfaces of the extrusion controllers and the bearing blocks of the test machine.

   The same surface of the neoprene cap shall be against the concrete cylinder for all tests performed with that cap. Each cap shall not be used to test more than 100 cylinders. The life of alternate pads must be verified by the agency (or purchaser) in accordance with AASHTO T 22.

Calculation

Calculate the compressive strength of the specimen by dividing the maximum load carried by the specimen during the test by the average cross-sectional area. The cross-sectional area is determined by averaging two diameters measured at right angles to each other at about mid-height of the specimen.

Area of the cylinder would be calculated by the following formula:

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- Maximum load, in pounds-force or kilonewtons
- Compressive strength calculated to the nearest 0.1 MPa (10 psi)
- Type of fracture
- Defects in either specimen or caps
- Age of specimen
- When determined, record the density to the nearest 10 kg/m^3 (1 lb/ft^3)

Tips!

- Be careful when applying load.
- Check cylinder ends for evenness
- Check measurements for accuracy
- Check calculations for errors