2020 Edition

Advanced Concrete

MoDOT

Advanced Concrete

2020 – Updates

- **AUDIT NOTIFICATION SLIDE ADDED TO ALL MANUALS:** To all material testers, who work on Missouri Highways, this includes Consultants, Contractors, City, County, and MoDOT workers; you will be audited by **MoDOT IAS Inspectors** and sometimes **FHWA** personnel.
- **Added updates page**

- AASHTO T121
    - One update on equipment: **Internal Vibrator**
        - Internal Vibrator: The vibrator frequency shall be at least 9000 vibrations per min (150HZ) while the vibrator is operating in concrete. The outside diameter of a round vibrator shall be at least 19mm (0.75in) and not greater than 38mm (1.50in). Other shaped vibrator shall have a perimeter equivalent to the circumference of an appropriate round vibrator. The combined length of the vibrator shaft and vibrating element shall exceed the depth of the section being vibrated by at least 75 mm (3in.). The vibrator frequency shall be checked periodically.

Course Content

Advanced Concrete

AASHTO ASTM C138	T 121M	Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete
AASHTO ASTM C173	T 196M	Air Content of Freshly Mixed Concrete by the Volumetric Method
AASHTO ASTM C31	T 23	Making and Curing of Concrete Beam Specimens in the Field

Appendix

Glossary

AASHTO T 121M

ASTM C138

Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete

Required Audits

All testers on Federal-Aid Projects (MoDOT or Off-System) are required by the FHWA to be audited at least once per year.

Reasons:

- To ensure proper test procedures are being utilized.
- To ensure testing equipment is calibrated and operating properly.

- **Types of Audits;** procedure or comparison.
- **Be Proactive;** schedule your audit as early as possible with MoDOT Materials in district offices, do NOT wait till the end of the year.
- **Provide Proof;** when audited, present a MoDOT Certification Card, or a MoDOT Letter.

AASHTO T 121M

Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete

Rev 11/12/2019

SCOPE

- This method covers determination of the density of freshly mixed concrete and gives formulas for calculating the yield, cement content, and the air content of the concrete. "Yield" is defined as the volume of concrete produced from a mixture of known quantities of the component materials.
- Note: Unit weight was the previous terminology used to describe the property determined by this test method, which is mass per unit volume.

3

TEMINOLOGY - DEFINITIONS

Absolute Volume (V) – The absolute volume of each ingredient in cubic yards is equal to the quotient of the mass of the ingredient divided by the product of its specific gravity times 62.4.

Total Mass (M) – The total mass of all materials batched is the sum of the masses of the cement, the fine aggregate in the condition used, the coarse aggregate in the condition used, the mixing water added to the batch, and any other solid or liquid materials used.

4

SYMBOLS:

A = air content, %

C = actual cement content kg/m³ (lb./yd³)

C_b= mass of cement in the batch, kg (lb.)

D = density (unit weight) of concrete, kg/m³ (lb./ft³)

M = total mass of all materials batched, kg (lb.)

M_c= mass of the measure filled with concrete, kg (lb.)

M_m= mass of the measure, kg (lb.)

Ry = relative yield

5

T = theoretical density of the concrete computed on an air free basis, kg/m³ (lb./ft³)

V = total absolute volume of the component ingredients in the batch, m³ (ft³)

V_m = volume of the measure, m³ (ft³)

Y = yield, volume of concrete produced per batch, m³ or (yd³)

Y_d = yield, volume of concrete that the batch was designed to produce, m³ (yd³)

Y_f = yield, volume of concrete produced per batch, m³ (ft ³)

6

Theoretical Density (T) – The theoretical density is, customarily, a laboratory determination. The value for the theoretical density is assumed to remain constant for all batches made using identical component ingredients and proportions. It is calculated from the equation:

$$T = \frac{M}{V}$$

7

EQUIPMENT

- Scale
- Tamping Rod
- Internal Vibrator
- Measure
- Strike-Off Plate
- Mallet
- Scoop

8

- **Scale** – Accurate to within 45g (0.1 lb.) or 0.3 percent of the test load, whichever is greater, at any point within the range of use.
- **Tamping Rod** – A round, straight steel rod, with a 16 ± 2mm (**⅝ ± 1/16 inch**) diameter. The length shall be at least 100mm (4 inches) greater than the depth of the measure in which rodding is being performed but not greater than 610mm (**24 inches**) ± 4mm (**⅛ inch**) in overall length. The rod shall have a hemispherical (half a sphere) tip the same diameter as the rod.

Equipment

9

- **Internal Vibrator** – May have rigid or flexible shafts, preferably powered by electric motors. The frequency of vibration shall be at least 9,000 (150 Hz) vibrations per minute or greater while the vibrator is operating in concrete. The outside diameter of a round vibrator shall be at least 19mm (0.75 in.) and not greater than 35mm (1.50 in.). Other shaped vibrators shall have a perimeter equivalent to the circumference of an appropriate round vibrator. The combined length of the vibrator shaft and vibrating element shall exceed the depth of the section being vibrated by at least 75mm (3 in.) The vibrator frequency shall be checked periodically.

Equipment 10

- **Measure** – May be the bowl portion of the air meter used for determining air content under AASHTO T 152 **OR** the measure shall meet the requirements of AASHTO T 121.
- **Strike-Off Plate** – a flat rectangular metal plate at least ¼ inch thick or a glass or acrylic plate at least ½ inch thick with a length and width at least 2 inches greater than the diameter of the measure with which it is to be used. The edges of the plate shall be straight and smooth within a tolerance of $^1/_{16}$ inch.

Equipment 11

- **Mallet** – A mallet with a rubber or rawhide head.
  - Mass of 600 ± 200g (1.25 ± 0.50 lb.) for use with measures 14L (0.5 ft^3) or smaller.
  - Mass of 1000 ± 200g (2.25 ± 0.50 lb.) for use with measures larger than 0.014m^3 (0.5 ft^3).

See Table 1

Equipment 12

Table 1: Required Measure Capacity

Nominal Maximum Size of coarse Aggregate		Capacity of Measure	
mm	Inch	Liter	ft^3
25.0	**1**	6	**0.2**
37.5	**1.5**	11	**0.4**
50	**2**	14	**0.5**
75	**3**	28	**1.0**
112	**4.5**	70	**2.5**
150	**6**	100	**3.5**

13

- **Scoop** – a scoop large enough so each amount of concrete obtained from the sampling receptacle is representative and small enough so it is not spilled during placement in the measure.

Equipment

14

CALIBRATIONS, STANDARDIZATIONS, AND CHECKS

- Unless otherwise specified, follow the requirements and intervals for equipment calibrations, standardizations, and checks in AASHTO R 18.
- AASHTO R 18: States to standardize the measure every 12 months.
- **NOTE:** See the Appendix on how to standardize the measure.

15

SAMPLE

- Obtain the sample of freshly mixed concrete in accordance with AASHTO R 60.

16

PROCEDURE

- **First, Weigh** the empty dry measure on the scale and record the weight to the 0.1 lb. **(This is M_m)**

17

- **Dampen the interior** of the measuring bowl and place it on a flat, level firm surface.
  Scoop a representative sample of the concrete in the measuring bowl in 3 equal layers.

Consolidate each layer by RODDING or by VIBRATING.

Procedure

18

- **Rodding or Vibrating**
  - **Rod**
    - Slump > 3 inches
  - **Rod or Vibrate**
    - Slump 1 – 3 inches
  - **Vibrate**
    - Slump < 1 inch

Procedure 19

- **Consolidating by Rodding**
- Place the concrete in the measure in **3 layers** of approximately equal volume using the scoop. During concrete placement, move the scoop around the perimeter of the measure opening to ensure an even distribution of the concrete with minimal segregation.
- <u>**Rod each layer**</u>
  - **25 strokes** of the tamping rod when the 0.5 ft^3 **or smaller measures** are used.
  - **50 strokes** of the tamping rod when the 1 ft^3 **or larger measure** is used.

Procedure 20

- Rod the bottom layer throughout its depth but do not forcibly strike the bottom of the measure.
- Distribute the strokes uniformly over the cross section of the measure for the top two layers, penetrate about **1 inch** into the underlying layer.

Procedure 21

- After each layer is rodded, tap around the perimeter of the measure sharply, **10-15 times** with the appropriate mallet using enough force to close any voids left by the tamping rod and to release any large bubbles of air that may have been trapped.
- Add the final layer; avoid overfilling.

Procedure 22

- **Consolidating by Vibration**
- **Internal Vibration** – Place the concrete in the measure in **2 layers** of approximately equal volume using the scoop.
- Place all of the concrete for each layer in the measure before starting vibration of that layer.
- During concrete placement, move the scoop around the perimeter of the measure opening to ensure an even distribution of the concrete with minimal segregation.

Procedure 23

- Insert the vibrator at **3** different points of each layer.
- In consolidating the bottom layer, do not allow the vibrator to rest on or touch the bottom or side of the measure.
- In consolidating the final layer, allow the vibrator to penetrate into the underlying layer approximately **1 inch**.
- Ensure that the vibrator is withdrawn in a manner that no air pockets are left in the specimen.

Procedure 24

- The duration of vibration required will depend upon the workability of the concrete and the effectiveness of the vibrator.
- Continue vibration only long enough to achieve proper consolidation of the concrete.
- Observe a constant duration of vibration for the particular kind of concrete, vibrator, and measure involved.
- After each layer is vibrated, tap the sides of the measure sharply **10-15** times with the appropriate mallet using enough force to close any voids left by the vibrator.

Procedure 25

- **A Filled Measure**
- The filled measure must not contain a substantial excess or deficiency of concrete; **⅛ inch** above the top of the measure is optimal.
- If there is too much concrete, quickly remove a representative portion with a trowel or scoop immediately following completion of consolidation and before striking off the measure.

Procedure 26

- **Strike-Off the Measure**
- Strike off the top surface of the concrete and finish it smoothly with the flat strike off plate leaving the measure level full.
- Strike off the concrete by pressing the strike-off plate on the top surface of the measure to cover about **two thirds** of the surface and withdraw the plate towards the operator with a sawing motion to finish only the area originally covered.

Procedure 27

- Then place the plate on the top of the measure to cover the original **two thirds** of the surface and advance it with a vertical pressure and a sawing motion away from the operator to cover the whole surface of the measure.

Procedure 28

- Finally, hold the plate at an incline and apply the final strokes to produce a smooth finished surface.
- **Mass Determination –** Clean all excess concrete from the exterior of the measure and determine the net mass of the concrete in the measure with a scale.
- **Record the weight to the nearest 0.1 lb. (This is M_c)**

Procedure 29

CALCULATIONS

- **Density (Unit Mass)**
  - Calculate the net mass of the concrete in pounds by subtracting the mass of the measure (**M_m**) from the gross mass (**M_c**).
  - Calculate the *density*, (**D**), by dividing the net mass of the concrete by the volume of the measure (**V_m**) as follows:

$$D = \frac{(M_c - M_m)}{V_m}$$

30

- **Yield**, volume of concrete produced per batch, yd^3 or ft^3 .

For Yield in cubic yards

$$Y\ (yd^3) = \frac{M}{(D \times 27)}$$

For Yield in cubic feet

$$Y\ (ft^3) = \frac{M}{D}$$

D = Density (unit weight) of concrete, kg/m^3 ($lb./ft^3$)
M = total mass of all materials batched, kg (lb.)
27 = The amount of cubic feet in a yd^3

31

- **Relative Yield** – Relative yield is the ratio of the actual volume of concrete obtained to the volume as designed for the batch calculated as follows.

$$R_y = \frac{Y}{Y_d}$$

NOTE: A value for Ry greater than **1.00** indicates an excess of concrete being produced, whereas a value less than this indicates the batch to be "short' of its designed volume. In practice, a ratio of yield in cubic feet per cubic yard of design concrete mixture is frequently used, for example, 27.3 ft^3/yd^3.

32

- **Cement Content**: Calculate the actual cement content as follows:

$$C = \frac{C_b}{Y}$$

C = actual cement content kg/m^3 ($lb./yd^3$)
$\mathbf{C_b}$= mass of cement in the batch, kg (lb.)
Y = yield, volume of concrete produced per batch, m^3 or (yd^3)

33

Air Content – Calculate the air content as follows:

$$A = \frac{(T - D)}{T} \times 100$$

T = theoretical density of the concrete computed on an air free basis, kg/m^3 (lb./ft^3).

D = density (unit weight) of concrete, kg/m^3 (lb./ft^3).

(lb./ft^3) also abbreviated as **pcf** = pounds per cubic foot.

34

REPORT

- **Identification of concrete** represented by the sample.
- **Date of test**
- **Volume of density measure** to the nearest **0.001 ft^3**
- **Density** (Unit Weight) to the nearest **0.1 lb./ft^3**
- **Yield**, when requested, to the nearest **0.1 yd^3**
- **Relative Yield**, when requested to the nearest **0.01**
- **Cement Content**, when requested to the nearest **lb./yd^3**
- **Air Content**, when requested, to the nearest **0.1 %.**

35

Classroom - Exercise

- A batch design of **9.0 yd^3**, with a total of **34,850 lbs.** of materials, with a theoretical density of **142.5 lb./ft^3**, using a **0.500 ft^3** measure weighing **19.8 lbs.**, when filled with concrete the measure weighs **90.7 lbs.**
- Calculate the following:
  1. Density
  2. Yield per batch in yd^3
  3. Yield per batch in ft^3
  4. Yield per batch ft^3/ yd^3
  5. All Relative Yield calculations
  6. Air Content

36

1. Density

ANSWER

$$D = \frac{M_c - M_m}{V_m}$$

- M_c = 90.7 lbs.
- M_m = 19.8 lbs.
- V_m = 0.500 ft^3

$$D = \frac{90.7 \text{ lbs.} - 19.8 \text{ lbs.}}{0.500 \text{ ft}^3} = 141.8 \text{ lb./ft}^3$$

Density (Unit Weight) is 141.8 lb./ft^3

37

2. Yield per batch in cubic yard, yd^3

ANSWER

$$Y (yd^3) = \frac{M}{(D \times 27)}$$

- **D** = 141.8 $\frac{lbs.}{ft^3}$
- **27** = The amount of cubic feet in a yd^3
- **M** = 34,850 total weight of materials

$$Y (yd^3) = \frac{34{,}850 \text{ lbs.}}{141.8 \frac{\text{lbs.}}{\text{ft}^3} \times 27 \frac{\text{ft}^3}{\text{yd}^3}} = 9.10 = \mathbf{9.1}\ yd^3$$

38

3. Yield per batch in cubic feet, ft^3

ANSWER

$$Y (ft^3) = \frac{M}{D}$$

- D = 141.8 $\frac{lbs.}{ft^3}$
- M = 34,850 lbs.

$$Y (ft^3) = \frac{34{,}850 \text{ lbs.}}{141.8 \frac{\text{lbs.}}{\text{ft}^3}} = 245.8 \text{ ft}^3$$

39

ANSWER

4. Yield in ft^3 per yd^3

$$\text{Yield per Batch} = \frac{Y\,(ft^3)}{Y\,(yd^3)_{\text{Design}}}$$

$$\text{Yield per Batch} = \frac{245.8\ ft^3}{9.0\ yd^3} = 27.31 = 27.3\frac{ft^3}{yd^3}$$

40

ANSWER

5. All Relative Yield calculations

R_y using cubic yards

$$R_y = \frac{Y}{Y_d}$$

- $Y = 9.1\ yd^3$
- $Y_d = 9.0 yd^3$

$$R_y = \frac{9.1\ yd^3}{9.0 yd^3} = 1.01$$

R_y using cubic feet

$$R_y = \frac{Y}{Y_d}$$

- $Y = 245.8\ ft^3$
- $Y_f = 243.0\ ft^3$

$$Ry = \frac{245.8\ ft^3}{243.0\ ft^3} = 1.01$$

9 x 27 = 243

R_y using cubic feet / cubic yard

$$R_y = \frac{Y}{Y_d}$$

- $Y = 27.3\ ft^3/yd^3$
- $Y_{df} = 27.0\ ft^3/yd^3$

$$Ry = \frac{27.3\ ft^3/yd^3}{27.0\ ft^3/yd^3} = 1.01$$

41

ANSWER

6. Gravimetric Air Content

$$A = \frac{(T - D)}{T} \times 100$$

T = 142.5 pcf
D = 141.8 pcf
pcf = (lb./ft^3)

$$A = \frac{(142.5 - 141.8)}{142.5} X100 = 0.491 = 0.5\%$$

42

Calculate the Cement Content – Practice Problem

$$C = \frac{C_b}{Y}$$

- **7 yd³** (designed)
- Yield = **27.2 yd³**
- **6.5** sack mix (611 lbs/yd³)
- **4,330 lbs.** of cement batched

43

Cement Content

ANSWER

- **7 yd³** (design)
- Yield = **27.2 yd³** = **Y**
- **6.5** sack mix (611 lbs./yd³)
- **4,330 lbs.** of cement batched = $\mathbf{C_b}$

$$C = \frac{C_b}{Y}$$

$$C = \frac{4{,}330 \text{ lbs.}}{27.2 \text{ yd}^3} = 159 \text{ lbs./yd}^3$$

44

Cement Content

ANSWER

- **7 yd³** (design)
- Yield = **27.2 yd³** = **Y**
- **6.5** sack mix (611 lbs./yd³)
- **4,330 lbs.** of cement batched = $\mathbf{C_b}$

$$C = \frac{C_b}{Y}$$

$$C = \frac{4{,}330 \text{ lbs.}}{27.2 \text{ yd}^3} = 159 \text{ lbs./yd}^3$$

45

Classroom – Exercise – on your own

- A batch design of **7.0 yd³**, with a total of **27,878 lbs.** of materials, and a theoretical density of **146.4 lb./ft³**, using a **0.500 ft³** measure weighing **19.5 lbs.**, when filled with concrete the measure weighs **91.2 lbs.**
- Calculate the following:
  1. Density
  2. Yield per batch in yd³
  3. Yield per batch in ft³
  4. Yield per batch ft³/ yd³
  5. All Relative Yield calculations
  6. Air Content

46

Answers

1. Density = 143.4 lb./ft³
2. Yield per batch in cubic yard = 7.2 yd³
3. Yield per batch in cubic feet = 194.4 ft³
4. Yield per batch in ft³ per yd³= 27.8 $\frac{ft^3}{yd^3}$
5. All yields = 1.03
6. Air Content = 2.0%

47

Calculate the Cement Content – on your own

$$C = \frac{C_b}{Y}$$

9 yd³ (designed)

Yield = **9.3 yd³**

6.5 sack mix (611 lbs./yd³)

5,499 lbs. of cement batched

48

Cement Content - Answer

$$C = \frac{C_b}{Y}$$

$$C = \frac{5{,}499 \text{ lbs.}}{9.3 \text{ yd}^3} = 591 \text{ lbs./yd}^3$$

49

Y_d T

CONCRETE UNIT WEIGHT WORK SHEET

M

A. A batch design of _______ yd³, with a total of ________lbs. of weighed materials, a theoretical density of _______ pcf, using a 0.5ft³ measure that weights _______ lbs., when filled with concrete, the measure weighs _______ lbs.

V_m M_m M_c

1. Reported answer for **Density** = ____________ lb/ft³ → **D**

2. Reported answer for **Yield per batch in yd³** = _______________ yd³ → **Y**

3. Given: **Yield per batch in ft³** = __________ft³

4. Reported answer for **Yield per batch ft³ per yd³** = _______________ ft³/yd³

5. Reported answer for **R_y: Relative Yield in yd³** = ____________

6. Reported answer for **Air Content %** (gravimetric) = ______________%

1. $\dfrac{Mc - Mm}{Vm} =$

2. $\dfrac{M}{D \times 27} =$

3. Given Yield per batch in ft³ = ____________

4. $\dfrac{Y(ft^3)}{Y_d} =$

5. $R_y = \dfrac{Y}{Y_d} =$

6. $A = \dfrac{(T - D)}{T} \times 100 =$

Y_d M T

CONCRETE UNIT WEIGHT WORK SHEET

A. A batch design of _______ yd^3, with a total of ________lbs. of weighed materials, a theoretical density of _______ pcf, using a 0.5ft^3 measure that weights _______ lbs., when filled with concrete, the measure weighs _______ lbs.

V_m M_m M_c

1. Reported answer for **Density** = ____________ **lb/ft^3** → **D**

2. Reported answer for **Yield per batch in yd^3** = _______________ **yd^3** → **Y**

3. Given: **Yield per batch in ft^3** = __________**ft^3**

4. Reported answer for **Yield per batch ft^3 per yd^3** = _______________ **ft^3/yd^3**

5. Reported answer for **R_y: Relative Yield in yd^3** = ____________

6. Reported answer for **Air Content %** (gravimetric) = ______________**%**

1. $\dfrac{Mc - Mm}{Vm} =$

2. $\dfrac{M}{D \times 27} =$

3. Given Yield per batch in ft^3 = ____________

4. $\dfrac{Y(ft^3)}{Y_d} =$

5. $R_y = \dfrac{Y}{Y_d} =$

6. $A = \dfrac{(T - D)}{T} \times 100 =$

AASHTO T 121M: Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete

PROFICIENCY CHECKLIST

Applicant_______________________________________

Employer_______________________________________

Trial #	1	2
Standardize		
1. Mass and volume of empty measure determined in yearly standardization. Note: As needed weigh the empty measure before testing.		
Sample		
2. Obtained sample in accordance with AASHTO R60.		
Procedure		
3. Determined which consolidation method to use, which size measure to use from the nominal maximum size of the aggregate, and which size mallet to use.		
4. Dampened the measure and place it on a flat, level, firm surface.		
5. Scooped representative sample of concrete into the measure, moving the scoop around the perimeter.		
Consolidation		
6. **For rodding**, measure filled in three equal layers.		
7. Rodded each layer with 25 or 50 strokes, depending on the volume of the measure used.		
8. Tapped 10 to 15 times after rodding each layer.		
9. Top layer filled to avoid overfilling.		
10. **For internal vibration**, measure filled in two equal layers.		
11. Vibrated each layer at three different points.		
12. Ensured proper consolidation achieved.		
After Consolidation is Completed		
13. Strike off top surface and finish smooth with flat cover plate.		
14. Exterior of measure cleaned, weighed, reported to nearest 0.1 lbs.		
15. Density (unit weight) calculated to nearest 0.1 lb./ft^3		
16. When requested, report: Yield, Relative Yield, Cement Content, and Gravimetric Air Content.		

PASS PASS

FAIL FAIL

Examiner: _______________________________________Date:_______________

AASHTO T 196M

ASTM C173

Air Content of Freshly Mixed Concrete by the Volumetric Method

AASHTO T 196M

Air Content

of

Freshly Mixed Concrete

by the Volumetric Method

Rev 01/07/2020

SCOPE

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

2

TERMINOLOGY

- **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.

3

SIGNIFICANCE AND USE

- This test covers the determination of the air content of freshly mixed concrete. It measures the air contained in the mortar fraction of the concrete but is not affected by air that may be present inside porous aggregate particles. Therefore, this is the appropriate test to determine the air content of concretes containing lightweight aggregates, air-cooled slag, and highly porous or vesicular natural aggregates.

4

- This test method requires the addition of sufficient isopropyl alcohol, when the meter is initially being filled with water, so that after the first or subsequent rolling, little or no foam collects in the neck of the top section of the meter.
- If more foam is present than that equivalent to **2%** air above the water level, the test is declared invalid and must be repeated using a larger quantity of alcohol. (See SLIDE 30)
- Addition of alcohol to dispel foam any time after the initial filling of the meter to the zero mark is not permitted.

Significance and Use

5

- The air content of hardened concrete may be either higher or lower than that determined by this test method.
  - Depends on the methods and amounts of consolidation effort applied to the concrete from which the hardened concrete specimen is taken
  - Uniformity and stability of the air bubbles in the fresh and hardened concrete
  - Accuracy of the microscopic examination, if used
  - Time of comparison
  - Environmental exposure

Significance and Use

6

– Stage in the delivery, placement, and consolidation processes at which the air content of the unhardened concrete is determined, that is, before or after the concrete goes through a pump
– Other factors

Significance and Use 7

APPARATUS

- Air Meter (Roll-a-Meter)
  – The top section of the meter shall be at least 20% larger than the bowl
- Funnel
- Tamping Rod
- Strike-off Bar
- Calibrated Cup
- Measuring Vessel for Isopropyl Alcohol
- Syringe
- Pouring Vessel for Water
- Scoop
- Isopropyl Alcohol
- **NOTE: See the Appendix for additional information on Apparatus**

8

CALIBRATION

- Calibrate the meter and calibrated cup initially and at three-year intervals or whenever there is reason to suspect damage or deformation of the meter or calibrated cup.
- **See the Appendix** for calibration of the Air Meter or (Roller Meter).

9

Roller Meter Video

10

SAMPLING

- Obtain a sample of freshly mixed concrete in accordance with AASHTO R 60.
- If the concrete contains coarse aggregate particles that would be retained on a **1½** inch sieve, wet-sieve a representative sample over a **1** inch sieve to yield somewhat more than enough material to fill the measuring bowl.
- **NOTE:** Wet-sieving procedure is described in AASHTO R 60.

11

PROCEDURE

- **Rodding and Tapping**
  - Wet the inside of the bowl and dry it to a damp, not shiny, appearance.

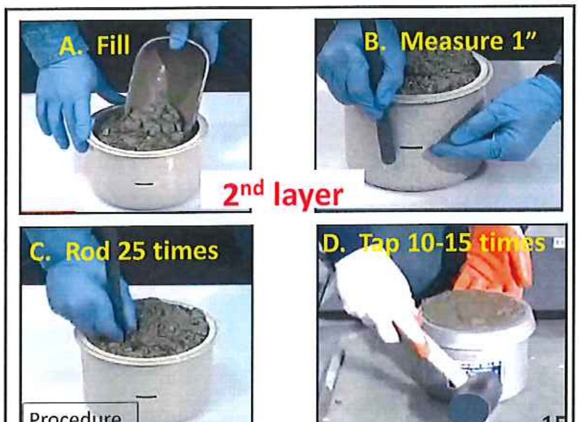
12

- Using the scoop, fill the bowl in **2** equal layers with fresh concrete.
- Rod each layer **25 times** uniformly over the cross section with the tamping rod.
- Do not forcibly strike the bottom of the bowl on the first layer, on the second layer rod into the first layer by **1** inch.
- Tap the sides of the measure **10-15** times with a mallet; after rodding each layer.

Procedure 13

1st layer

Procedure 14



Procedure 15

– After tapping the final layer, a slight excess of concrete about ⅛ inch or less above the rim is acceptable, adjust by adding or subtracting concrete to or from the bowl as necessary.

Procedure 16

- **Striking Off**
  – After rodding and tapping of the 2nd layer, strike off the excess concrete with the strike-off bar until the surface is flush with the top of the bowl.

Procedure 17

– Wipe the flange of the bowl clean. Wet the top portion of the Roll-a-Meter and gasket, and clamp the top on to the bowl for a water tight seal.

Procedure 18

- **Adding Water**
- Insert the funnel through the top, and add at least **0.5 L (1 pint)** of water.

Procedure 19

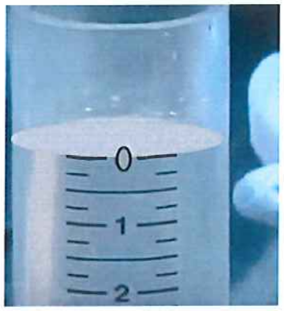
- **Add 70% Isopropyl Alcohol.**
- Add a selected amount of isopropyl alcohol. Record the amount of alcohol added. **(see Note)**

Procedure 20

- **NOTE:** Add the amount of isopropyl alcohol necessary to obtain a stable reading and a minimum of foam at the top of the water column.
- Many concretes made with less than 500 lb/yd^3 of cement and air contents less than 4% may require less than 200mL (0.5 pint) of alcohol.
- Some high-cement mixes made with silica fume that have air contents of 6% or more may require more than 1400mL (3 pints) of alcohol.
- A typical amount is 1,000ml or 2 pints.
- Larger amounts will need less initial water added.

Procedure 21

- Then add the **2nd** amount of water up to the zero mark, pull out the funnel and fine tune the liquid level (adding or subtracting liquid) with a syringe until the bottom of the meniscus is on the zero mark.



Procedure 22

- Put the cap on and tighten.

Procedure 23

- **Displace the volume of air in the concrete specimen using the following procedures:**

- **Free the Concrete from the Base**
  - After tightening the lid, quickly invert the meter, shake the base **horizontally**, and return the meter to the upright position.

Procedure 24

Step 1- Invert shake 5 seconds

- To prevent aggregate from lodging in the neck of the unit, do not keep the meter inverted for more than **5 seconds at a time**.

Step 2 – Return to upright position

- Repeat the inversion and shaking process for a minimum of **45 seconds** until the concrete is free from the base and can be heard moving in the meter as it is inverted.

Repeat

Procedure 25

- **Rolling**
  - Place one hand on the neck of the meter and the other on the flange. Using the hand on the neck, tilt the top of the meter approximately **45 degrees** from the vertical position with the bottom edge of the base of the meter resting on the floor or on a work surface.
  - Maintain this position through the procedure.

Procedure 26

- Using the hand on the flange to rotate the meter, vigorously roll the meter ¼ to ½ turn forward and back several times, quickly starting and stopping the roll.
- Turn the base ⅓ turn and repeat the rolling procedure as stated previously.

First Rolling Procedure

Continue the turning and rolling procedures for approximately **1 minute**. The aggregate must be heard sliding in the meter during this process.

Procedure 27

- If, at any time, during the inversion and rolling procedure liquid is found to be leaking from the meter, the test is considered **invalid**, and a new test shall be started on a new sample.

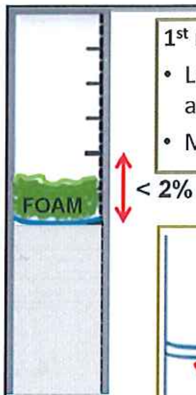
Procedure 28

- Set the unit upright and loosen the top to allow any pressure to stabilize.
- Allow the meter to stand while the air rises to the top and until the liquid level stabilizes.
- The liquid level is considered stable when it does not change more than **0.25%** air within a **2 minute** period.

Procedure 29

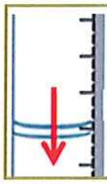
- If it takes more than **6 minutes** for the liquid level to stabilize or if there is more foam than that equivalent to **2** full percent air content divisions on the meter scale over the liquid level, discard the trial and start a new test on a new sample of concrete.
  - Use a larger addition of alcohol than used in the initial testing.
- If the level is stable without excessive foam, read the bottom of the meniscus to the nearest **0.25%** and record the initial meter reading.

Procedure 30



1st reading:

- Less than **2%** increments of foam above water line.
- Must be stable within **6** minutes.



Stable Reading:

Drops <¼% in 2 minutes.

¼ % = 0.25%

Procedure 31

- If the air content is greater than the **9%** range of the meter, the water level will not appear in the graduated neck of the meter. To fix this, add a sufficient number of calibrated cups of water to bring the liquid level within the graduate range.
- Record the number of cups added to get the water up into the graduated neck of the meter.
- Read the bottom of the meniscus to the nearest **0.25%.**

Procedure 32

- Record the number of calibrated cups of water to be added to the final meter reading.

Procedure 33

Confirmation of the Initial Meter Reading

- When an initial meter reading is obtained, retighten the top and repeat the **1-minute** rolling procedure.

Second Rolling Procedure

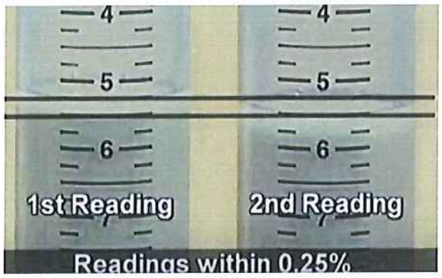
Procedure 34

- When the liquid level is stable on the 2nd rolling, make a direct reading to the bottom of the meniscus and estimate to **0.25%** air.
- If this reading has not changed more than **0.25%** from the initial meter reading, record it as the final meter reading of the sample tested.
- However if the reading has changed from the initial meter reading by more than **0.25%** air, record this reading as the NEW "initial reading" and repeat the 1-minute rolling for a 3rd time.

Procedure 35

- Read the indicated air content. If this reading has not changed by more than **0.25%** air from the NEW "initial reading" record it as the final meter reading.
- If the reading has changed by more than **0.25%**, discard the test and start a new test on a new sample of concrete using more alcohol.

Procedure 36



1st reading is 5.25%, 2nd reading is 5.50%
readings are within 0.25%
therefore the 2ND reading is the final reading
5.50% = Air Content

Procedure 37

- Take the cap off and pour out the liquid.
- Disassemble the apparatus and examine the contents to be sure that there are no portions of undisturbed, tightly packed concrete in the base.

Procedure 38

The bowl should empty with no clumps left behind for a valid test.

If portions of undisturbed concrete are found, the test is invalid!

Procedure 39

CALCULATIONS

- The final meter reading tends to be slightly higher than the actual air content of the sample when 1.2L (2.5 pints) or more of isopropyl alcohol is used.
- When less than 1.2L (2.5 pints) of isopropyl alcohol is used, the final meter reading is the air content of the sample of concrete tested except as modified in **SLIDE 43**
- When 1.2L (2.5 pints) or more of isopropyl alcohol is used, subtract the correction from Table 1 from the final meter reading to obtain the air content of the concrete sample tested, except as modified in **SLIDE 43.**

40

Table 1: Correction for the Effect of Isopropyl Alcohol on Air Meter Reading

Pints of Alcohol	Ounces of Alcohol	Liters of Alcohol	Correction (subtract)[a]
0.5	8	0.2	0.0[b]
1.0	16	0.5	0.0[b]
1.5	24	0.7	0.0[b]
2.0	32	0.9	0.0[b]
3.0	48	1.4	0.3
4.0	64	1.9	0.6
5.0	80	2.4	0.9

41

70% Isopropyl Alcohol is Used

Table 1 added information:

- **a** = Subtract from final meter reading.
- **b** = Corrections less than 0.125 are not significant and are to be applied only when 1.2L (2.5 pints) or more alcohol is used.
- The values given are for air meters with a bowl volume of 2.1L (0.075ft^3) and a top section that is 1.2 times the volume of the bowl.

Calculation

42

- If it was necessary to add calibrated cups of water to obtain a reading, add the number of cups recorded to the air content.
- When the sample tested represents that portion of the mixture obtained by **wet-sieving** over a 1 inch sieve, calculate the air content of the mortar or of the full mixture using the formulas given in AASHTO T 152.
- Use appropriate quantities coarser or finer than the 1 inch sieve instead of the 1½ inch sieve specified in AASHTO T 152.

Calculation

43

REPORT

- Report the air content to the nearest **0.25** percent air.

44

Class - Example Calculation

Notes:
%Air = Report to nearest 0.25%
− Alcohol Correction (if 2-½ pints or more of alcohol used)
+ Calibrated Cups of Water (If initially over 9% on meter)

Example:

Added 1.5 pints of alcohol (0.0% correction)
Initial meter reading is readable at 7.00%
Did not need to add calibrated cups of water
Continued rolling operation. . .
Final meter reading is 6.75%

%Air = 6.75% ANSWER

45

Class - Example Calculation

Notes:
%Air = Report to nearest 0.25%
– Alcohol Correction (if 2-½ pints or more of alcohol used)
+ Calibrated Cups of Water (If initially over 9% on meter)

Example:

Added 3 pints of alcohol = – **0.3** correction (see table)
Initial meter reading > 9% = not able to read
Added 4 calibrated cups of water to bring water level up to a readable level. = **+ 4**
Now the initial reading is at 6.00%.
Continued rolling operation. . .
Final meter reading is 6.00%

ANSWER

%Air = 6.00 – 0.3 + 4 = 9.70% report to: 9.75%

46

Class – On your own Calculation

Notes:
%Air = Report to nearest 0.25%
– Alcohol Correction (if 2-½ pints or more of alcohol used)
+ Calibrated Cups of Water (If initially over 9% on meter)

Example:

Added 4 pints of alcohol (see table)
Initial meter reading > 9% = not able to read
Added 1 calibrated cups of water to bring water level up to a readable level. = **+ 1**
Now the initial reading is at 8.50%.
Continued rolling operation. . .
Final meter reading is 8.00%

Your Answer:

47

AASHTO T 196M: Air Content of Freshly Mixed Concrete by the Volumetric Method

PROFICIENCY CHECKLIST

Applicant____

Employer____

Trial #	1	2
Sample		
1. Obtained sample in accordance with AASHTO R60		
Procedure		
2. Bowl filled in 2 layers		
3. Each layer rodded 25 times		
4. Bowl tapped (sharply) 10-15 times after rodding each layer		
5. Used funnel, water added, then alcohol added, then final water added until liquid level close to zero		
6. Funnel removed, adjusted the water to where the bottom of the meniscus is on zero		
7. Screw cap attached and tightened		
Initial Reading		
1. Unit inverted and agitated at 5 second intervals for a minimum of 45 seconds and until concrete is free from the base		
2. Unit vigorously rolled ¼ to ½ turn forward and back several times with base at a 45° angle, then turn base about ⅓ turn and rolling process resumed		
3. Meter checked for leaks; if leaking, test started over with a new sample		
4. Apparatus placed upright, cap loosened and allowed to stand until air rises to the top a. Less than 0.25% change in 2 minutes (without excessive foam), initial reading recorded to the nearest 0.25% b. More than 6 minutes to stabilize or observed excessive foam, test discarded and new test ran		
Confirmation of Initial Meter Reading		
1. One-minute rolling repeated and liquid level checked		
2. Confirmation reading is greater than 0.25% of initial, new meter reading recorded as new initial reading, repeat 1-minute rolling		
3. Level of liquid read less than 0.25% change, final meter reading recorded to nearest 0.25%		
4. Apparatus disassembled and checked for undisturbed concrete		
Calculations		
1. Correction factor from Table 1 subtracted for use of 2.5 pints or more of alcohol		
2. If required, number of calibration cups of water added to air content		
3. Air content reported to the nearest 0.25% air		

PASS PASS

FAIL FAIL

Examiner: ____Date:______________

AASHTO T 23

Making and Curing
Of
Concrete Beam Specimens
in the Field

MoDOT

AASHTO T 23

Making and Curing
of
Concrete Beam
Test Specimens in the Field

Revised 01/07/2020

SCOPE

- This method covers procedures for making and curing **beam specimens** from representative samples of fresh concrete for a construction project.
- The concrete used to make the molded specimens shall be sampled after all on-site adjustments have been made to the mixture proportions, including the addition of mix water and admixtures.
- This practice is not satisfactory for making specimens from concrete not having a measurable slump or requiring other sizes or shapes of specimens.

2

SIGNIFICANCE AND USE

- This method provides standardized requirements for making, curing, protecting, and transporting concrete test specimens under field conditions.

3

- If the specimens are made and ***STANDARD CURED***, as stipulated herein, the resulting strength test data where the specimens are tested are able to be used for the following purposes:
  - Acceptance testing for specified strength.
  - Checking the adequacy of mixture proportions for strength.
  - Quality Control.

Significance and Use 4

- If the specimens are made and ***FIELD CURED***, as stipulated herein, the resulting strength test data when the specimens are tested are able to be used for the following purposes:
  - Determination of whether a structure is capable of being put in service.
  - Comparison with test results of standard cured specimens or with test results from various in-place test methods.
  - Adequacy of curing and protection of concrete in the structure or form or shoring removal time requirements.

Significance and Use 5

EQUIPMENT

- Tamping Rod (size determined by the size of specimen being made)
- Beam Molds (see the Appendix for specifics)
- Scoop
- Marker
- Trowel or Straight-Edge
- Vibrator
- Mallet (rubber or rawhide weighing 0.75-1.75 lb)
- Personal Protective Equipment (Safety Vest, Gloves, Hard Hat etc.)

See Appendix for additional equipment information.
6

TESTING REQUIREMENTS

- **Beam specimens**
  - When the nominal maximum size of the coarse aggregate exceeds 2 inches the concrete sample shall be treated by **wet sieving** through a 2 inch sieve as described in AASHTO R 60.
- **Self Consolidating Concrete**
  - Cast specimens without layers or consolidation.

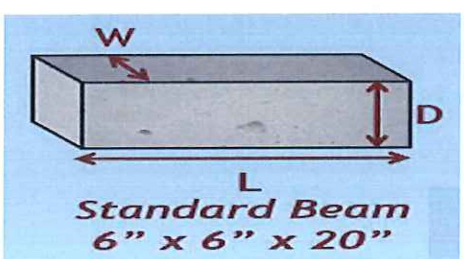
7

- **Beam Specimens**
  - Flexural strength specimens shall be beams cast and hardened in the horizontal position.
  - The length shall be at least **2 inches** greater than **3 times** the depth as tested.
  - The ratio of width to depth as molded shall not exceed **1.5**.
- **The Minimum Cross–Sectional dimension** of the beam shall be as stated in **Table 2**. ***The standard beam shall be 6x6 inches in cross section*** (unless otherwise specified by **MoDOT**).

Testing Requirements

8

- <u>**Standard Beam Dimensions**</u>



Specimen

9

- The specifier of tests (MoDOT) shall specify the specimen size and the number of beam specimens to be tested to obtain an average test result .
- The same specimen size shall be used when comparing results, for mixture qualification, and acceptance testing.

Specimen

10

SAMPLING CONCRETE

- The samples used to fabricate test specimens shall be obtained in accordance with AASHTO R 60.

(See the Concrete Field Manual for AASHTO R 60)

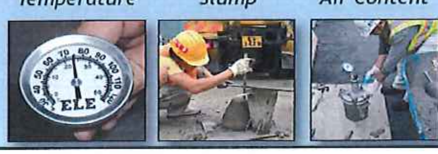
11

Temperature, Slump, and Air Content

- Three tests to complete before molding beams
  - Note: unit weight may be requested
  - See the Concrete Field Manual for test methods

- **Within 5 minutes of obtaining the final portion of the composite sample, start tests for :**

Temperature *Slump* *Air Content*



12

- ***TEMPERATURE*** – Determine and record the temperature in accordance with MoDOT TM 20.
- ***SLUMP*** – Measure and record the slump of each batch of concrete, from which specimens are made, immediately after remixing in the receptacle as required in AASHTO T 119M/T 119.
- ***AIR CONTENT*** – Determine and record the air content in accordance with either AASHTO T 152 or T 196M/T 196. the concrete used in performing the air content test shall not be used in fabricating test specimens.

13

- **Place for Molding Specimens**
- Mold specimens promptly on a level, rigid, horizontal surface, free from vibration and other disturbances, at a place as near as practicable to the location where they are to be stored.

14

CASTING BEAMS

- Choose size mold 4"x 4" or standard **6"x 6"** (Table 2)*
- Need to know slump result (Table 3)*
- Determine method of consolidation (Table 3)*
  - If rodding, (Table 4)*
  - If vibrating, (Table 5)*
- Select tamping rod (Table 1)*, or vibrator
- Use a scoop or shovel to place the concrete uniformly in the mold to the required height for each layer

*Note: Tables are at the end of the slides.

15

- Consolidate as required (Table 4 or Table 5)
- Final layer; over fill the mold after consolidation to less than ¼ inch
- Finish using a handheld float or trowel, level to a flat, even surface with no depressions or projections larger than ⅛ inch
- Identify the beam and the concrete

Casting Beams 16

Consolidation Quick Chart for Beams	
Rodding ⅜ inch Rod (4 inch in width) ⅝ inch Rod (6-8 inch in width)	**Vibration** Do not touch mold with Vibrator
2 Lifts	1 Lift (avoid over filling >¼")
Rod once every 2 inch^2 of surface area Penetrate previous layer by 1 inch	1 insertion per lift Insert full depth at intervals ≤ 6" along center line. 4 insertions standard beam Beams wider than 6", use alternating insertions along 2 lines
Tap 10-15 times with a mallet per lift	Tap 10-15 times with a mallet per lift
Spade each layer with trowel Sides and ends	Do not spade

17

Consolidation by Rodding

- Place the concrete in the mold, in the required number of layers of approximately equal volume.
- Rod each layer uniformly over the cross section with the rounded end of the rod. Rod once for each ***2 in^2 of surface area*** of the beam. (Table 4)
- Rod the bottom layer throughout its depth without damaging the bottom of the mold.

18

- After each layer, tap the outsides of the mold lightly 10-15 times with the mallet, to close any holes left by rodding and to release any large air bubbles that may have been trapped.
- After tapping, spade each layer of the concrete along the sides and ends of beam molds with a trowel or other suitable tool.

Rodding 19

- For each upper layer, rod the layer to penetrate through the layer below approximately **1 inch**, then tap 10-15 times.
- Underfilled molds shall be adjusted with representative concrete during consolidation of the top layer.
- Overfilled molds shall have excess concrete removed.
- When placing the final layer, avoid overfilling by more than ¼ inch.

Rodding 20

Rodding 21

Consolidation by Vibration

- Maintain a uniform time period for duration of vibration.
- Sufficient vibration is when the surface of the concrete has become relatively smooth and large air bubbles cease to break through the top surface.
- Vibration time should rarely have to exceed 10 seconds per insertion.
- Fill the molds and vibrate in the required number of approximately equal layers. (Table 5)

22

- Do not allow the vibrator to rest on the bottom or sides of the mold.
- Slowly withdraw the vibrator so that no large air pockets are left in the specimen.
- Insert the vibrator at intervals not exceeding 6 inches along the center line of the long dimension of the specimen.
- When placing the final layer, avoid overfilling by more than ¼ inch.

Vibration

23

- For specimens wider than 6 inches, use alternating insertions along two lines.
- After vibrating, tap the outsides of the mold sharply **10 to 15 times** with a mallet, to close any holes left by vibrating and to release entrapped air voids.

Vibration

24

Finishing

- Perform all finishing with the minimum manipulation necessary to produce a flat, even surface which has no depressions or projections larger than ⅛ inch, and that is level with the rim or edge of the mold.

Use a handheld float or trowel to strike off the top surface to the required tolerance.

25

Identification

- Mark the specimens to positively identify them and the concrete they represent without altering the top surface of the concrete.

26

Standard Curing Beams

- Beams are to be cured the same as cylinders, except that they shall be stored in water saturated with calcium hydroxide at 70 to 77° F at least 20 hours prior to testing.
  - **NOTE:** See your Concrete Field Manual for additional information on curing.
- Drying of the surfaces of the beam shall be prevented between removal from water storage and completion of testing.

27

Field Curing Beams

- As nearly as practicable, cure beams in the same manner as the concrete in the structure.
- At the end of 48 ± 4 hours after molding, take the molded specimens to the storage location and remove from the molds.
- Store specimens representing pavements of slabs on grade by placing them on the ground as molded, with their top surfaces up.
- Bank the sides and ends of the specimens with earth or sand that shall be kept damp, leaving the top surfaces exposed to the specified curing treatment.

28

- Store beam specimens representing structure concrete as near the point in the structure they represent as possible, and afford them the same temperature protection and moisture environment as the structure.
- At the end of the curing period, leave the specimens in place exposed to the weather in the same manner as the structure.

Field Curing Beams 29

- Remove all beam specimens from field storage and store in water saturated with calcium hydroxide at 70 to 77°F immediately before time of testing to ensure uniform moisture condition from specimen to specimen.
- Guard against drying between time of removal from curing to testing.

Field Curing Beams 30

Transporting Beams

- Prior to transporting, cure and protect specimens as required.
- During transporting, protect the specimen with suitable cushioning materials to prevent damage from jarring.
- During cold weather, protect the specimens from freezing with suitable insulation material.

31

- Prevent moisture loss during transportation by wrapping the specimens in plastic, wet burlap, by surrounding them with wet sand, or in plastic molds with tight-fitting caps.
- Transportation time shall not exceed 4 hours.

Transporting

32

REPORTING

- Identification number.
- Location of concrete represented by the samples.
- Date, time, and name of individual molding specimens.
- Slump, air content, concrete temperature, test results and results of any other tests on the fresh concrete, and any deviations from the standard test methods.

33

- **Curing Method**
  - **Standard Curing**
    - Report the initial curing method with max and min temperatures and final curing method.
  - **Field Curing**
    - Report the location where stored, manner of protection from the elements, temperature, moisture environment, and time of removal from molds.

Reporting

34

TABLES

35

AASHTO Table 1

Tamping Rod Requirements		
	Rod Dimensions[a]	
Diameter of cylinder or Width of Beam mm (inch)	Diameter mm (inch)	Length of rod mm (inch)
< 150 (6)	10 (⅜)	300 (12)
150 (6)	16 (⅝)	500 (20)
225 (9)	16 (⅝)	650 (26)

[a]Rod tolerances length ± 100mm (4 inches) and diameter ±2mm (1/16 inch).

36

- **Note**

  A rod length of 16 – 24 inches meets the requirements of the following: AASHTO methods T 119, T 121, T 152 and T 196.

37

AASHTO Table 2

Minimum cross-Sectional Dimensions of Beams	
Nominal Maximum Aggregate Size (NMAS)	**Minimum Cross-Sectional Dimension**
≤ 25mm (≤ 1 inch)	100 by 100mm (4 x 4 inches)
25mm (1 inch) < NMAS ≤ 50mm (2inch)	152 by 152 mm (6 by 6 inches)

38

AASHTO Table 3

Method of Consolidation Requirements	
Slump, mm (in)	**Method of Consolidation**
≥25mm (≥ 1 inch)	**Rodding or Vibration**
≤25mm (≤1 inch)	**Vibration**

39

AASHTO Table 4

Molding Requirements by Rodding

Specimen Type and Size	Number of Layers of Approximately Equal Depth	Number of Roddings per Layer
Beams:		
Width, mm (inch)		
100 (4 inch) to 200 (8 inch)	2	Once every 2 inch^2 of surface area
Over 200 (8 inch)	3 or more equal depths, each not to exceed 150mm (6 inch)	Once every 2 inch^2 of surface area

40

AASHTO Table 5

Molding Requirements by Vibration

Beam Width	Number Layers	Number of Vibrator Insertions per Layer	Approximate Depth of Layer
6 to 8 inches	1	*	Depth of specimen as near as practicable
> 8 inches	2 or more	*	Depth of specimen as near as practicable

•Vibrator inserted at intervals not exceeding 6 inches, use alternating insertions along two lines

41

501.1.3.4 Protection of sample

After the sample has been obtained, it must be protected from direct sunlight and wind until it is used, which must not be more than 15 minutes after sampling. When the sample has been moved to the place where the test is to be made or specimens are to be molded it should be mixed with a shovel if necessary to assure uniformity of the mixed sample.

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.

AASHTO T 23 Making and Curing of Concrete BEAM Specimens In the Field PROFICIENCY CHECKLIST

Applicant: ______________________________

Employer: ______________________________

Trial#	1	2
Sample concrete per AASHTO R60		
Conducted Slump, Air Content, and Temperature Procedures a. Reported all results of these tests		
Molding Beams – 6" x 6" Standard Size		
1. Each layer properly consolidated per results of slump, AASHTO T 119		
2. Mold filled in 2 approximately equal layers (Vibrated = 1 layer)		
3. Rodded each layer every 2 square inches of surface area, into 1 inch of the layer below it a. If vibrator used, 1 insertion per layer, insert full depth at intervals of approximately 6 inches along the center line of the length of the mold alternating insertions between 2 lines		
4. Mold tapped lightly 10 to 15 times after each layer was rodded		
5. Beam finished using either a tamping rod, handheld float, or a trowel so that the specimen was level with the rim of the mold		
6. Identification, information written on the mold		
7. Beams cured the same as cylinders, except they are stored in water saturated with calcium hydroxide at 70-77°F at least 20 hours prior to testing		
8. Reported all beam information, temperatures, and curing information		
Transportation		
1. Waited at least 8 hours after final set to transport, protected specimens from the cold, moisture maintained, and did not exceed 4 hours of transport time		
	PASS	PASS
	FAIL	FAIL

Examiner: ______________________________ Date: ____________________

APPENDIX

Standardization of AASHTO T121mMeasure

Measure the inside diameter, the inside height, and the minimum thicknesses for the measure, see Table 1 below. Record these measurements in a lab quality manual.

Table 1
Dimensions of Measures

Capacity m^3 (ft^3)	Inside Diameter mm (in.)	Inside Height mm (in.)	Minimum Thicknesses mm (in.) Bottom	Minimum Thicknesses mm (in.) Wall	Nominal Maximum Size of Coarse Aggregate** mm (in.)
0.0071	203 ±2.54	213 ±2.54	5.1	3.0	25
(1/4)*	(8.0 ±0.1)	(8.4 ±0.1)	(0.20)	(0.12)	(1)
0.0142	254 ±2.54	279 ±2.54	5.1	3.0	50
(1/2)	(10.0 ±0.1)	(11.0 ±0.1)	(0.20)	(0.12)	(2)
0.0283	356 ±2.54	284 ±2.54	5.1	3.0	76
(1)	(14.0 ±0.1)	(11.2 ±0.1)	(0.20)	(0.12)	(3)

* ***Note:*** Measure may be the base of the air meter used in the FOP for AASHTO T 152.
** Nominal maximum size: One sieve larger than the first sieve to retain more than 10 percent of the material using an agency specified set of sieves based on cumulative percent retained. Where large gaps in specification sieves exist, intermediate sieve(s) may be inserted to determine nominal maximum size.

Standardization of Measure

Standardization is a critical step to ensure accurate test results when using this apparatus. Failure to perform the standardization procedures as described herein will produce inaccurate or unreliable test results.

1. Determine the mass of the dry measure and strike-off plate.
2. Fill the measure with water at a temperature between 16°C and 29°C (60°F and 85°F) and cover with the strike-off plate in such a way as to eliminate bubbles and excess water.
3. Wipe the outside of the measure and cover plate dry, being careful not to lose any water from the measure.
4. Determine the mass of the measure, strike-off plate, and water in the measure.
5. Determine the mass of the water in the measure by subtracting the mass in Step 1 from the mass in Step 4.
6. Measure the temperature of the water and determine its density from Table 2, interpolating as necessary.
7. Calculate the volume of the measure, V_m, by dividing the mass of the water in the measure by the density of the water at the measured temperature, from Table 2.

$$\boxed{V_m = \frac{Mass\ of\ Water}{Density\ of\ Water}}$$

See **table 2** on the next page

Example: at 23°C (73.4°F)

$$V_m = \frac{7.062\,kg}{997.54\,kg/m^3} = 0.007079m^3 \qquad V_m = \frac{15.53lb}{62.274\,lb/ft^3} = 0.2494ft^3$$

Table 2

Unit Mass of Water

15°C to 30°C

°C	(°F)	kg/m³	(lb/ft³)	°C	(°F)	kg/m³	(lb/ft³)
15	(59.0)	999.10	(62.372)	23	(73.4)	997.54	(62.274)
15.6	(60.0)	999.01	(62.366)	23.9	(75.0)	997.32	(62.261)
16	(60.8)	998.94	(62.361)	24	(75.2)	997.29	(62.259)
17	(62.6)	998.77	(62.350)	25	(77.0)	997.03	(62.243)
18	(64.4)	998.60	(62.340)	26	(78.8)	996.77	(62.227)
18.3	(65.0)	998.54	(62.336)	26.7	(80.0)	996.59	(62.216)
19	(66.2)	998.40	(62.328)	27	(80.6)	996.50	(62.209)
20	(68.0)	998.20	(62.315)	28	(82.4)	996.23	(62.192)
21	(69.8)	997.99	(62.302)	29	(84.2)	995.95	(62.175)
21.1	(70.0)	997.97	(62.301)	29.4	(85.0)	995.83	(62.166)
22	(71.6)	997.77	(62.288)	30	(86.0)	995.65	(62.156)

Apparatus for Air Meter – Volumetric

Air Meter – The air meter consists of a bowl and a top section (See Figure 1) conforming to the following requirements:

The bowl and the top sections shall be of sufficient thickness and rigid enough to withstand rough field use. The material shall not be marked by high pH cement paste, deformed from high temperatures or brittle or cracked from low temperatures. The apparatus must have a watertight seal when assembled.

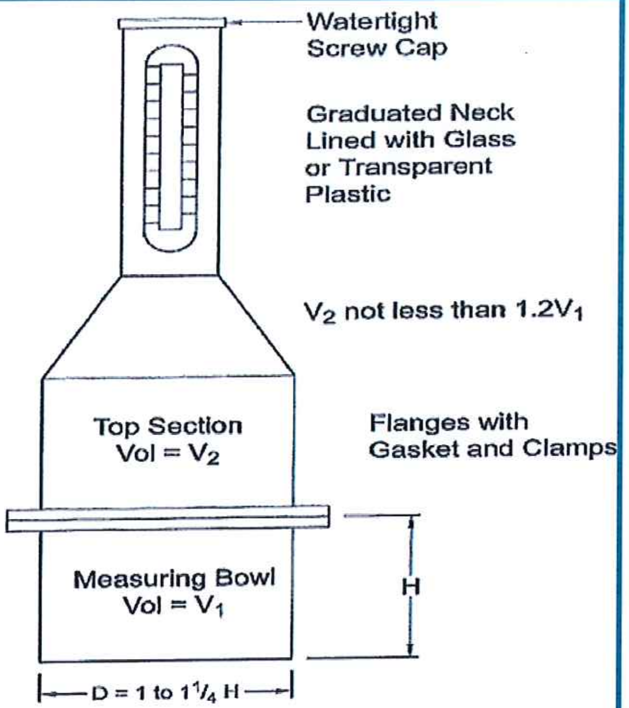


Figure 1

Bowl- The bowl diameter is equal to 1 to 1.25 times the height and constructed with a flange at or near the top surface. Bowls shall not have a capacity of less than 2.0 Liters.

Top Section – the top shall have a capacity at least 20% larger than the bowl and equipped with a flexible gasket with a device to attach the top section to the bowl to create a water tight connections. The top section shall be have a transparent scale, graduated in increments not greater than 0.5% from zero at the top, to 9% or more of the volume of the bowl. Graduations shall be accurate to ±0.1% by volume of the bowl. The upper end of the neck shall have a watertight cap that will maintain a seal when the meter is inverted and rolled.

Funnel – A funnel with a spout of a size permitting it to be inserted through the neck of the top section and long enough to extend to a point just above the bottom of the top section. The discharge end of the spout shall be constructed so when water is added to the container there will be very little disturbance of the concrete.

Tamping Rod – a round, straight steel rod, with a 16±2-mm (5/8 inches ± 1/16 inch) diameter. The rod length shall be 100mm (4 inches) greater than the depth of the measure in which rodding is being performed but not greater than 600mm (24inches) in overall length. The length tolerance for the tamping rod shall be ±4mm (±1/8 inch). The rod shall have the tamping end or both ends rounded to a hemispherical tip of the same diameter as the rod.

NOTE 1 – A rod length of 400mm. (16 inches) to 600mm (24 inches) meets the requirements of the following AASHTO Test Methods: T23, T119M/T 119, T121M/T 121, T152, and T196M/T 196.

Strike-Off Bar – A flat, straight steel bar at least 3 by 20 by 300mm (0.125 by 0.75 by 12 inch), or a flat, straight, high-density polyurethane bar, or other plastic of equal or greater abrasion resistance, at least 6 by 20 by 300mm (1/4 by ¾ by 12 inch).

Calibrated Cup – A metal or plastic cup either having a capacity of or being graduated in increments equal to 1.0 ± 0.04 percent of the volume of the bowl of the air meter. The calibrated cup is only to be used to add water when the concrete air content exceeds 9% or the calibrated range of the meter.

Measuring Vessel for Isopropyl Alcohol – a vessel with a minimum capacity of 500mL (1pt) with graduations not larger than 100ml (4oz) for measuring a quantity of isopropyl alcohol.

Syringe – A rubber syringe having a capacity of at least 50mL (2oz).

Pouring Vessel for Water – A container of approximately 1L (1qt) capacity.

Scoop – Of a size large enough so each amount of concrete obtained from the sampling receptacle is representative and small enough so it is not spilled during placement in the bowl.

Isopropyl Alcohol – Use 70% by volume isopropyl alcohol (approximately 65%by mass). Other foam-dispersing agents are permitted if tests demonstrate that he use of the agent does not change the indicated air content, in the amounts being used, by more than 0.1% or if correction factors are developed similar to those in table 1. When other dispensing agents are used, a copy of the records documenting the testing or calculations shall be available in the laboratory.

Note 2 – Seventy % isopropyl alcohol is commonly available as rubbing alcohol. More concentrated grades can be diluted with water to the required concentration.

Mallet – A mallet (with a rubber or rawhide head) with a mass of approximately 600 ± 200g (1.25 ± 0.5lb.).

Calibration

Calibrate the meter and calibrated cup initially and at three-year intervals or whenever there is reason to suspect damage or deformation of the meter or calibrated cup.

Determine the volume of the bowl, with an accuracy of at least 0.1%, by determining the mass of water required to fill it at room temperature and dividing this weight by the density of water at the same temperature. Follow the calibration procedure outlined in AASHTO T19M/T19.

Determine the accuracy of the graduations on the neck of the top section of the air meter by filling the assembled measuring bowl and top section with water to a preselected air content graduation and then determining the quantity of 21.1°C water required to fill the meter to the zero mark. The quantity of water added shall equal the preselected air content graduation within ±0.1 volume percent of the measuring bowl. Repeat the procedure to check a minimum of three gradations within the expected range of use.

Add water in increments of 1.0 percent of the volume of the bowl to check accuracy throughout the graduated range of air content. The error at any point throughout the graduated range shall not exceed 0.1% of air.

Determine the volume of the calibrated cup using water at 21.1°C by the method outlined in Section 5.2., a quick check can be made by adding one or more calibrated cups of water to the assembled apparatus and observing the increase in the height of the water column after filling to a given level.

Apparatus

Beam Molds – beam molds shall be of the shape and dimensions required to produce the specimens that are at least 2 inches greater in length than three times the depth as tested. The ratio of width to depth as molded shall not exceed 1.5. The minimum cross setional dimension of the beam shall be as stated in Table 2. Unless otherwise specified by MoDOT, the standard beam shall be 6 X 6 inches cross section.

TABLE 2	
TABLE 2Nominal Maximum Aggregate Size (NMAS)	**Minimum Cross-Sectional Dimension**
≤1 inch	4 x 4 inches
≤1 inch < NMAS ≤2 inches	6 X6 inches

The inside surfaces of the beam molds shall be smooth. The sides, bottom, and ends shall be at right angles to each other and shall be straight and true and free of warpage. Maximum variation from the nominal cross section shall not exceed 3.2mm (1/8 inch) for molds with depth or breadth of 6 inches or more, or 1/16th inch for molds of smaller depth or breadth. Except for flexure specimens, molds shall not vary from the nominal length by more than 1/16th inch of the required length. NOTE: Greater lengths are allowed.

Tamping Rods – A round, smooth, straight, steel rod with a diameter conforming to the requirements in Table 1. The length of the tamping rod shall be at least 100mm (4inch) greater than the depth of the mold in which rodding is being performed, but got greater than 600mm (24inch) in overall the rod shall have the tamping end or both ends rounded to a hemispherical tip of the same diameter at the rod.

Table 1—Tamping Rod Requirements

Diameter of Cylinder or Width of Beam, mm (in.)	Rod Dimensions[a]	
	Diameter, mm (in.)	Length of Rod, mm (in.)
<150 (6)	10 ($^3/_8$)	300 (12)
150 (6)	16 ($^5/_8$)	500 (20)
225 (9)	16 ($^5/_8$)	650 (26)

[a] Rod tolerances length ±100 mm (4 in.) and diameter ±2 mm ($^1/_{16}$ in.).

Vibrators – An Internal vibrator shall be used. The vibrator frequency shall be at least 9000 vibrations per minute (150Hz) while the vibrator is operating in the concrete. The diameter of a round vibrator shall be no more than ¼ of the diameter of the cylinder mold or ¼ the width of the beam mold. Other shaped vibrators shall have a perimeter equivalent to the circumference of an appropriate round vibrator. The combined length of the vibrator shaft and vibrating element shall exceed the depth of the section being vibrated by at least 75mm (3inches). The vibrator ferequency shall be checked periodically.

Air content apparatus – The apparatus for measureing air content shall conform to the requirements of T196M/T196 or T152

Temperature Measureing Devices – the temperature mesureing devices shall conform to the applicable requirements of MT 20.

Glossary

Glossary of Terms

AASHTO
American Association of State Highway and Transportation Officials

Absolute Volume (V)
The absolute volume of each ingredient in cubic yards is equal to the quotient of the mass of the ingredient divided by the product of its specific gravity times 62.4. The absolute volume of each ingredient in cubic meters is equal to the mass of the ingredient in kilograms divided by 1000 times its specific gravity.

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.

Bulk Specific Gravity and Mass
For the aggregate components, the bulk specific gravity and mass should be based on the saturated surface-dry condition. For cement, the actual specific gravity should be determined by T133. A value of 3.15 may be used for cements manufactured to meet the requirements of M85.

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.

Total Mass (M)
The total mas of all materials batched is the sum of the masses of the cement, the fine aggregate in the condition used, the coarse aggregate in the condition used, the mixing water added to the batch, and any other solid or liquid materials used.

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

Volumetric Method

Air is removed from a known volume of concrete by agitation in an excess of water. It may be used with any type of aggregate including light weight and porous material. The test is not affected by atmospheric pressure and the specific gravity of the material need not be known.