Method of Test for

WEIGHT PER CUBIC FOOT, YIELD, AND AIR CONTENT (GRAVIMETRIC) OF CONCRETE

DOTD Designation: TR 201

I. Scope

This method of test covers the procedure for determining the weight per cubic foot of freshly mixed concrete with slumps of: less than 1 inch, between 1-3 inches, and greater than 3 inches. In this method of test, the formulas are given for calculating the yield and volume of concrete produced from a mixture of known quantities of the component materials, the actual cement factor, and the air content of the concrete.

Note 1: *The air content calculated by this test method is for general information only, and is not to be used for job control.*

II. Apparatus

A. Balance **–** A balance or scale accurate to within 0.3% of the test load at any point within the range of use.

B. Tamping Rod **–** A round, straight steel rod, 5/8 inch in diameter and approximately 24 inches in length, having the tamping end rounded to a hemispherical tip with a diameter which is 5/8 inch.

C. Vibrator – A vibrator having a rigid or flexible shaft capable of providing 7,000 vibrations per minute or greater while in use. The outside diameter or side dimension of the vibrating head shall be at least 0.75 inch and not greater than 1.50 inches. The length of the vibrating head shall be at least 12 inches and the shaft length shall be at least 24 inches.

D. Measure **–** A cylindrical container made from metal that is not readily attacked by cement paste. It shall be watertight and sufficiently rigid to retain its form and calibrated volume under rough usage. Measures must be machined to accurate dimensions on the inside and be provided with handles. The top rim shall be smooth and plane so that a 0.02 inch feeler gauge cannot be inserted between the rim and a piece of ¼ inch or thicker plate glass laid over the top. The top shall be parallel to the bottom within 0.5 degree. Measures with a metal thickness less than 0.20 inch. shall be reinforced around the upper 1.5 inches with a steel band to provide a minimum thickness of 0.20 inch. Depending upon the nominal maximum size of coarse aggregate in the concrete, the capacity and dimensions of the measure shall conform to the limits in Table 1.

TABLE 1
Dimensions of Measures

Capacity (ft^3)	Inside Diameter (in.)	Inside Height (in.)	Minimum Thickness of Metal (in.)		Nominal Max. Size of Aggregate (in.)*
			Bottom	Wall	
1/2	10.0 ± 0.1	11.0 ± 0.1	0.20	0.12	2 or less
1	14.0 ± 0.1	11.2 ± 0.1	0.20	0.12	Over 2

**Based on sieves with square openings. Nominal maximum size is the largest sieve listed in the applicable specification, upon which any material is permitted to be retained.*

E. 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.

III. Sample

A. Determine the calibrated volume of the sample measure in accordance with DOTD Designation: TR 640.
B. Obtain the sample of freshly mixed concrete in accordance with DOTD Designation: S 301 of the Materials Sampling Manual.

IV. Procedure

A. Base the selection of the method of consolidation on the slump, unless the method is stated in the specifications under which the work is being performed. The methods of consolidation are rodding and internal vibration. Vibrate concrete with a slump of less than 1 inch. Vibrate or rod concrete with a slump between 1-3 inches. Rod concrete with a slump greater than 3 inches.
B. *Consolidation (Tamping Rod)* – Place the concrete in the measure in three (3) layers of approximately equal volume. Rod each layer with 25 strokes of the tamping rod when the 0.5 $ft.^3$ measure is used and 50 stokes when the 1 $ft.^3$ measure is used. Rod the bottom layer throughout its depth, but do not allow the rod to 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. After each layer is rodded, tap the sides of the measure smartly 10 to 15 times to close any voids left by the tamping rod and to release any large bubbles of air that may have been trapped. When adding the final layer, care should be taken not to overfill the measure.
C. *Consolidation (Vibrator)* – Place the concrete in the measure in two layers of approximately equal volume, taking care that no concrete enters the metal pipe. Immediately following the placement of each layer, insert the vibrator head into the metal pipe attached to the measure and vibrate the layer until the surface of the concrete becomes relatively smooth (20-30 seconds). The duration of vibration required will depend on the workability of the concrete and the effectiveness of the vibrator. Care shall be taken not to over-vibrate the concrete because over-vibration may cause segregation and loss of significant quantities of intentionally entrained air.
D. On completion of consolidation, the measure must not contain a substantial excess or

deficiency of concrete. An excess of concrete protruding approximately 1/8 inch above the top of the mold is optimum. If the measure contains more than 1/8 in. of concrete above the top of the mold at completion of consolidation, remove a representative portion of the excess concrete with a trowel or scoop immediately following completion of consolidation and before the measure is struck off. If the measure does not contain enough concrete at completion of consolidation, a small quantity of concrete may be added before the measure is struck off.

E. *Strike-off, Cleaning and Weighing* – After consolidating the concrete, strike off and finish the top surface with the flat strike-off plate taking care to leave the measure just level full. All excess concrete shall then be cleaned from the exterior and the filled measure weighed to an accuracy consistent with the requirements of II(A).

V. Calculations

A. *Weight Per Cubic Foot* – Calculate the net of the measure from the gross weight. Calculate the weight per cubic foot by dividing the net weight by the calibrated volume of the measure used, determined as described in Section III.

Example: Assume that a measure weighing 18.4 lbs. and having a calibrated volume of 0.5005 ft.^{3} was used to obtain a gross weight of 88.6 lbs. (weight of measure filled with concrete). The net weight of the concrete is therefore equal to 88.6 - 18.4 = 70.2 lbs. The weight per cubic foot is then equal to 70.2 ÷ 0.5005 ft.^{3} = 140.3 lbs./ft.^{3}.

B. *Yield* – Calculate the yield (volume of concrete produced per batch) as follows:

$$Y = \frac{W_c + W_{fa} + W_{ca} + W_w}{W}$$

Where:

Y = Yield, (ft^3)
W_c = Total Weight of Cement in the Batch, (lb.)
W_{fa} = Total Weight of Fine Aggregate in Batch in Condition Used, (lb.)
W_{ca} = Total Weight of Coarse Aggregate in Batch in Condition Used, (lb.)
W_w = Total Weight of Mixing Water Added to Batch, (lb.)
W = Weight of Concrete, (lb/ft.^{3})

Note 2: *To convert yield to cubic yards, divide Y by 27.*

Example:

W_c = 4,277 lbs
W_{fa} = 7,826 lbs
W_{ca} = 12,425 lbs
W_w = 1,970 lbs
W = 140.3 lbs/ft.^{3}

$$Y = \frac{(4{,}277 + 7{,}826 + 12{,}425 + 1{,}970)lbs}{140.3\ lbs/ft^3} = 188.9 ft^3$$

C. *Cement Factor* – Calculate the "actual" cement factor as follows:

$$N = \frac{KW_c}{Y}$$

Where:
N = Number of bags of cement per yd^3 of concrete produced (actual cement factor)
K = A constant factor equal to 0.2872
W_c = Total weight of cement in the batch, (lb.)
Y = Yield, (ft^3)

Example: Using the example shown in paragraph V(B), the cement factor can be calculated as:

$$N = \frac{0.2872\ x\ 4{,}277\ lbs}{188.9\ ft^3} = 6.5\ bags/yd^3$$

D. Volume – Calculate the volume of each concrete component as follows:

Note 3: *The specific gravities for the fine and coarse aggregates are assumed to be 2.62 and 2.53, respectively, for this example only. The specific gravity of cement is 3.15 and is a standard value used in calculating absolute volumes. The specific gravity of water is also standard and a value of 1 is used.*

Example: The absolute volume of component ingredients can be calculated by dividing the weight of the components by the product of its specific gravity and 62.4. Therefore, the absolute volumes of the component materials shown in the example in paragraph V(B) are as follows:

$$Cement = \frac{4{,}277\ lbs}{3.15\ x\ 62.4\ lbs/ft^3} = 21.8\ ft^3$$

$$Fine\ Aggregate = \frac{7{,}826\ lbs}{2.62\ x\ 62.4\ lbs/ft^3} = 47.9\ ft^3$$

$$Coarse\ Aggregate = \frac{12{,}425\ lbs}{2.53\ x\ 62.4\ lbs/ft^3} = 78.7\ ft^3$$

$$Water = \frac{1{,}970\ lbs}{1\ x\ 62.4\ lbs/ft^3} = 31.6\ ft^3$$

Using the absolute volumes, the total absolute volume of the component ingredients can be calculated as:

V = CEMENT + FINE AGGREGATE + COARSE AGGREGATE + WATER

$$V = 21.8 + 47.9 + 78.7 + 31.6 = 180.0 \text{ ft}^3$$

E. Air Content – Calculate the air content as follows:

$$A = \frac{Y - V}{Y}$$

Where:
A = Air content (percentage of voids) in the concrete
Y = Yield, (ft^3)
V = Total absolute volume of the component ingredients in the batch, (ft^3)

The air content can then be calculated as follows:

$$A = \frac{188.9 - 180.0}{188.9} x\ 100 = 4.7\%$$

VI. Report

Report the unit weight as calculated in V(A) to the nearest 0.1 lb/ft^3.

Note 4: *Normal Testing Time is 15 minutes.*