METHODS OF SAMPLING AND TESTING
MT 115-04
WEIGHT PER CUBIC FOOT, YIELD, AND AIR CONTENT (GRAVIMETRIC) OF CONCRETE
(Modified AASHTO T121)

1 Scope:

1.1 This method covers determination of the weight per cubic foot (or cubic meter) 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.

1.2 The values stated in in-pound units are to be regarded as the standard.

2 Referenced Documents:

2.1 ***AASHTO:***

M 85 Portland Cement
T 121 Mass per Cubic Meter (Cubic Foot), Yield, and Air Content (Gravimetric) of Concrete
T 133 Specific Gravity of Hydraulic Cement

MT Manual:

MT-102 Air Content of Freshly Mixed Concrete by Pressure Method
MT-105 Sampling Fresh Concrete
MT-203 Unit Weight of Aggregate

3 Symbols:

A = air content (percentage of voids) in the concrete
N = actual cement content, lb/yd³ or kg/m³
N_t = mass of cement in the batch, lb or kg
R_y = relative yield
T = theoretical weight of the concrete computed on an airfree basis, lb/ft³ or kg/m³ (Note 1)
V = total absolute volume of the component ingredients in the batch, ft³ or M³
W = unit of mass of concrete, lb/ft³ or kg/m³
W_1 = total mass of all materials batched, lb or kg (Note 2)
Y = volume of concrete produced per batch, yd³ or m³
Y_d = volume of concrete which the batch was designed to produce, yd³ (m³)
Y_f = volume of concrete produced per batch, ft³

Note 1 - The theoretical weight per cubic foot or cubic meter is, customarily, a laboratory determination, the value for which is assumed to remain constant for all batches made using identical component ingredients and proportions. It is calculated from the equation:

$$T = W_1/V$$

The absolute volume of each ingredient in cubic feet is equal to the quotient of the mass of that 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 1,000 times its specific gravity. 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 Test Method T 133. A value of 3.15 may be used for cements manufactured to meet the requirements of Specification M 85.

Note 2 *-The total weight of all materials batched is the sum of the weights 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 Apparatus:

4.1 *Balance* - A balance or scale accurate to within 0.3% of the test load at any point within the range of use. The range of use shall be considered to extend from the weight of the measure empty to the weight of the measure plus its contents at 160 lb/ft³ (2,600 kg/m³).

4.2 *Tamping Rod* - A round straight steel rod, _ in. (16 mm) in diameter and approximately 24 in. (60 mm) in length, having the tamping end rounded to a hemispherical tip the diameter of which is _ in.

4.3 *Internal Vibrator* - Internal vibrators may have rigid or flexible shafts, preferably powered by electric motors. The frequency of vibration shall be 7,000 vibrations per minute or greater while in use. The outside diameter or the side dimension of the vibrating element shall be at least 0.75 in. (19 mm) and not greater than 1.50 in. (38 mm). The length of the shaft shall be at least 24 in. (600 mm).

4.4 *Measure* - A cylindrical container made of steel or other suitable metal (Note 3). It shall be watertight and sufficiently rigid to retain its form and calibrated volume under rough usage. Measures that are machined to accurate dimensions on the inside and provided with handles are preferred. The minimum capacity of the measure shall conform to the requirements of Table 1. All measures, except for measuring bowls of air meters that are used for Method T 121 tests, shall conform to the requirements of Test Method MT-203. When measuring bowls of air meters are used, they shall conform to the requirements of Test MT-102. The top rim of the air meter bowls shall be smooth and plane within 0.01 in. (0.25 mm).

Note 3 -The metal should not be readily subject to attack by cement paste. However, reactive materials such as aluminum alloys may be used in instances where as a consequence of an initial reaction, a surface film is rapidly formed which protects the metal against further corrosion.

Note 4 -The top rim is satisfactorily plane if a 0.01 in. (0.25 mm) feeler gage cannot be inserted between the rim and a piece of ¼ in. (6 mm) or thicker plate glass laid over the top of the measure.

4.5 *Strike-Off Plate* - A flat rectangular metal plate at least ¼ in. (6 mm) thick or a glass or acrylic plate at least ½ in. (12 mm) thick with a length and width at least 2 in. (50 mm) 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 in. (1.5 mm).

4.6 *Calibration Equipment* - A piece of plate glass, preferably at least ¼ in.(6 mm) thick and at least 1 in. (25 mm) larger than the diameter of the measure to be calibrated. A supply of water pump or chassis grease that can be placed on the rim of the container to prevent leakage.

4.7 *Mallet* - A mallet (with a rubber or rawhide head) weighing approximately 1.25 ± 0.50 lb (0.57 ± 0.23 kg) for use with measures of 0.5 ft.³ (14 dm³) or smaller, and a mallet weighing approximately 2.25 ± 0.50 lb (1.02 ± 0.23 kg) for use with measures larger than 0.5 ft³.

Apparatus: (continued)

TABLE 1 - Capacity of Measures

Nominal Maximum Size of Coarse Aggregate [a]		Capacity of Measure [a]	
in.	mm	ft^3	L
1	25.0	0.2	6
1½	37.5	0.4	11
2	50	0.5	14
3	75	1.0	28
4½	112	2.5	70
6	150	3.5	100

[a] *The indicated size of measure shall be used to test concrete containing aggregates of a nominal maximum size equal to or smaller than that listed. The actual volume of the measure shall be at least 95 percent of the nominal volume listed.*

5 Calibration of Measure:

5.1 Calibrate the measure and determine the factor used to convert the mass in pounds (or kilograms) contained in the measure to mass in pounds per cubic foot (or kilograms per cubic meter). Follow the procedure outlined in MT-203. Measures shall be recalibrated at least once a year or whenever there is reason to question the accuracy of the calibration.

6 Sample:

6.1 Obtain the sample of freshly mixed concrete in accordance with MT-105.

7 Procedure:

7.1 The methods of consolidation are rodding and internal vibration. Rod concretes retain with a slump greater than 3 in. (75 mm). Rod or vibrate concrete with a slump of 1 to 3 in. (25 to 75 mm). Consolidate concretes with a slump less than 1 in. (25 mm) by vibration.

Note 5 - The non-plastic concrete, such as is commonly used in the manufacture of pipe and unit masonry, is not covered by this method.

7.2 *Rodding* - Place the concrete in the measure in three layers of approximately equal volume. Rod each layer with 25 strokes of the tampering rod when the 0.5 $ft.^3$ (14 dm^3) or smaller measures are used and 50 strokes when the 1 ft^3 (28 dm^3) measure is used. Rod the bottom layer throughout its depth but the rod shall not forcibly strike the bottom of the measure. Distribute the strokes uniformly over the cross section of the measure and for the top two layers, penetrate about 1 in. (25 mm) into the underlying layer. After each layer is rodded, tap the sides of the measure smartly 10 to 15 times with the appropriate mallet (see 3.7) 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 so as to avoid overfilling.

7.3 *Internal Vibration* - Fill and vibrate the measure in two approximately equal layers. Place all of the concrete for each layer in the measure before starting vibration of that layer. Insert the vibrator at three different points of each layer. In compacting the bottom layer, do not allow the vibrator to rest on or touch the bottom or sides of the measure. In compacting the final layer, the vibrator shall penetrate into the underlying layer approximately 1 in. (25 mm). Take care that the vibrator is withdrawn in such a manner that no air pockets are left in the specimen. The duration of vibration required will depend upon the workability of the concrete and the effectiveness of the vibrator (Note 6). Continue vibration only long enough to achieve proper consolidation of the

concrete

7 Procedure: (continued)

(Note 7). Observe a constant duration of vibration for the particular kind of concrete, vibrator, and measure involved.

Note 6 - Usually, sufficient vibration has been applied as soon as the surface of the concrete becomes relatively smooth.

Note 7 – Over vibration may cause segregation and loss of appreciable quantities of intentionally entrained air.

7.4 On completion of consolidation the measure must not contain a substantial excess or deficiency of concrete. An excess of concrete protruding approximately 1/8 in. (3 mm) above the top of the mold is optimum. A small quantity of concrete may be added to correct a deficiency. If the measure contains a great excess of concrete 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.

7.5 *Strike-Off* - After consolidation, strike-off the top surface of the concrete and finish it smoothly with the flat strike-off plate using great care to leave the measure just level full. The strike-off is best accomplished by pressing the strike-off plate on the top surface of the measure to cover about two-thirds of the surface and withdrawing the plate with a sawing motion to finish only the area originally covered. 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 to cover the whole surface of the measure. Several final strokes with the inclined edge of the plate will produce a smooth finished surface.

7.6 *Cleaning and Weighing* - After strike-off, clean all excess concrete from the exterior of the measure and determine the net mass of the concrete in the measure to an accuracy consistent with the requirements of 4.1.

***Note 8** - A value for R_y 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.*

8 Calculations:

8.1 *Unit Weight* - Calculate the net mass of the concrete in pounds or kilograms by subtracting the mass of the measure from the gross mass. Calculate the unit mass, *W*, by multiplying the net mass by the calibration factor for the measure used, determined according to Test Method MT-203.

8.2 *Yield* - Calculate the yield as follows:

$$Y_f(ft^3) = W_1/W$$

or,

$$Y(yd^3) = W_1/27\ W$$

or,

$$Y(m^3) = W_1/W$$

8.3 *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:

$R_y = Y/Y_d$

8 Calculations: (continued)

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

$N = N_t/Y$

8.5 *Air Content* - Calculate the air content as follows:

$A = [(T - W)T] \times 100$

or,

$A = [(Y_f - V)Y_f] \times 100$ (Inch-pound units)

or,

$A = [(Y - V)/Y] \times 100$ (SI units)