METHODS OF SAMPLING AND TESTING
MT 203-04
TEST FOR UNIT WEIGHT OF AGGREGATE
(*Modified AASHTO T 19*)

1 Scope

1.1 This method covers the determination of unit weight in a compacted or loose condition, and calculated voids in fine, coarse, or mixed aggregates based on the same determination. The method is applicable to aggregates not exceeding 6 in. [150 mm] in nominal maximum size.

Note 1 - Unit weight is the traditional terminology used to describe the property determined by this test method. Some believe the proper term is unit mass or density or bulk density, but consensus on this alternate terminology has not been obtained.

1.2 The values stated in either inch-pound units or acceptable metric units are to be regarded separately as standard, as appropriate for a specification with which this test method is used. An exception is with regard to sieve sizes and nominal size of aggregate, in which the metric values are the standard as stated in AASHTO M 92. Within the text, metric units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system must be used independently of the other, without combining values in any way.

2 Referenced Documents

AASHTO

M 92 Wire Cloth and Sieves for Testing Purposes
T 2 Sampling Aggregates
T 19 Bulk Density ("Unit Weight") and Voids in Aggregate
T 84 Specific Gravity and Absorption of Fine Aggregate
T 85 Specific Gravity and Absorption of Coarse Aggregate
T 121 Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete

MT Materials Manual

MT 204 Absorption of Fine Aggregate
MT 205 Specific Gravity and Absorption of Coarse Aggregate
MT 405 Specification for Wire-Cloth Sieves for Testing Purposes
MT 607 Procedure for Reducing Field Samples of Aggregate to Testing Size

3 Apparatus

3.1 *Balance* - A balance or scale accurate within 0.3 percent 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 100 pounds per cubic foot (1600 kilograms per cubic meter).

3.2 *Tamping Rod* - A round, straight steel rod, 3/8 in. (16 mm) in diameter and approximately 24 in. (600 mm) in length, having one end rounded to a hemispherical tip of the same diameter as the rod.

3.3 *Measure* - A cylindrical metal measure preferably provided with handles. It shall be watertight, with the top and bottom true and even, and sufficiently rigid to retain its form under rough usage. The measure should have a height approximately equal to the diameter, but in no case shall the height be less than 80% nor more than 150% of the diameter. The capacity of the measure shall conform to the limits in Table 1 for the aggregate size to be tested. The thickness of metal in the measure shall be as described in Table 2. The top rim shall be smooth and plane within 0.01 in. [0.25 mm] and shall be parallel to the bottom within 0.5° (Note 2).

TABLE 1 Capacity of Measures			
Nominal Maximal Size of Aggregate		**Capacity of Measure[A]**	
in.	**mm**	**ft³**	**L(m³)**
1/2	12.5	1/10	2.8 (0.0028)
1	25.0	1/3	9.3 (0.0093)
1½	37.5	1/2	14 (0.014)
3	75	1	28 (0.028)
4½	112	2½	70 (0.070)
6	150	3½	100 (0.100)

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

TABLE 2 Requirements of Measures			
Capacity of Measure	**Thickness of Metal, min**		
	Bottom	**Upper 1½ in. or 38 mm of Wall[A]**	**Remainder of Wall**
Less than 0.4 ft³	0.20 in.	0.10 in.	0.10 in.
0.4 ft³ to 1.5 ft³, incl	0.20 in.	0.20 in.	0.12 in.
Over 1.5 to 2.8 ft³, incl	0.40 in.	0.25 in.	0.15 in.
Over 2.8 to 4.0 ft³, incl	0.50 in.	0.30 in.	0.20 in.
Less than 11 L	5.0 mm	2.5 mm	2.5 mm
11 to 42 L, incl	5.0 mm	5.0 mm	3.0 mm
Over 42 to 80 L, incl	10.0 mm	6.4 mm	3.8 mm
Over 80 to 133 L, incl	13.0 mm	7.6 mm	5.0 mm

[A]The added thickness in the upper portion of the wall may be obtained by placing a reinforcing band around the top of the measure.

Note 2 – 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 measure. The top and bottom are satisfactorily parallel if the slope between pieces of plate glass in contact with the top and bottom does not exceed 0.87 percent in any direction.

3.3.1 If the measure may also be used for testing for unit weight of concrete according to T 121, the measure should be made of steel or other suitable metal not readily subject to attack by cement paste.

Note 3 – Reactive materials such as aluminum alloys may be used where, as a consequence of an initial reaction, a surface film is formed which protects the metal against further corrosion. Measures larger than nominal 1-ft³ (28-L) capacity should be made of steel for rigidity, or the minimum thicknesses of metal listed in Table 2 should be suitably increased.

3.4 *Shovel or Scoop*--A shovel or scoop of convenient size for filling the measure with aggregate.

3.5 *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 Sampling

4.1 Sampling should generally be accomplished in accordance with MT 607, Procedure for Reducing Field Samples of Aggregate to Testing Size.

5 Sample

5.1 The size of sample shall be approximately 125 to 200% of the quantity required to fill the measure, and shall be handled in a manner to avoid segregation. Dry the sample of aggregate to essentially constant mass, preferably in an oven at 230 ± 9°F (110 ± 5°C).

6 Calibration of Measure

6.1 Fill the measure with water at room temperature and cover with a piece of plate glass in such a way as to eliminate bubbles and excess water.

6.2 Determine the mass of water in the measure using the balance described in 5.1.

6.3 Measure the temperature of water to determine its density from Table 3, interpolating if necessary.

6.4 Calculate the volume, V, of the measure by dividing the mass of water required to fill the measure by its density. Alternately, calculate the factor for the measure (1/volume) by dividing the density of the water by the mass required to fill the measure.

TABLE 3. Density of Water

Temperature			
°F	**°C**	**lb/ft³**	**kg/m³**
60	15.6	62.366	999.01
65	18.3	62.336	998.54
70	21.1	62.301	997.97
(73.4)	(23.0)	(62.274)	(997.54)
75	23.9	62.261	997.32
80	26.7	62.216	996.59
85	29.4	62.166	995.83

Note 4 – For the calculation of unit weight, the volume of the measure in acceptable metric units should be expressed in cubic meters, or the factor as 1/m³. However, for convenience the size of the measure may be expressed in liters (equal to m³/1,000).

6.5 Measures shall be recalibrated at least once a year or whenever there is reason to question the accuracy of the calibration.

7 Selection of Procedure

7.1 The shoveling procedure for loose unit weight shall be used only when specifically stipulated. Otherwise, the compact unit weight shall be determined by the rodding procedure for aggregates having a nominal maximum size of 1½ in. [37.5 mm] or less, or by the jigging procedure for aggregates having a nominal maximum size greater than 1½ in. [37.5 mm] and not exceeding 6 in. (150 mm).

8 Rodding Procedure

8.1 Fill the measure one-third full and level the surface with the fingers. Rod the layer of aggregate with 25 strokes of the tamping rod evenly distributed over the surface. Fill the measure two-thirds full and again level and rod as above. Finally, fill the measure to overflowing and rod again in the manner previously mentioned. Level the surface of the aggregate with the fingers or a straightedge in such a way that any slight projections of the larger pieces of the coarse aggregate approximately balance the larger voids in the surface below the top of the measure.

8.2 In rodding the first layer, do not allow the rod to strike the bottom of the measure forcibly. In rodding the second and third layers, use vigorous effort, but not more force than to cause the tamping rod to penetrate to the previous layer of aggregate.

Note 5 – In rodding the larger sizes of coarse aggregate, it may not be possible to penetrate the layer being consolidated, especially with angular aggregates. The intent of the procedure will be accomplished if vigorous effort is used.

8.3 Determine the mass of the measure plus contents, and the mass of the measure alone and record the values to the nearest 0.1 lb (0.05 kg).

9 Jigging Procedure

9.1 Fill the measure in three approximately equal layers as described in 10.1 compacting each layer by placing the measure on a firm base, such as a cement-concrete floor, raising the opposite sides alternately about 2 in. (50 mm), and allowing the measure to drop in such a manner as to hit with a sharp, slapping blow. The aggregate particles, by this procedure, will arrange themselves in a densely compacted condition. Compact each layer by dropping the measure 50 times in the manner described, 25 times on each side. Level the surface of the aggregate with the fingers or a straightedge in such a way that any slight projections of the larger pieces of the coarse aggregate approximately balance the larger voids in the surface below the top of the measure.

9.2 Determine the mass of the measure plus contents, and the mass of the measure alone, and record the values to the nearest 0.1 lb (0.05 kg).

10 Shoveling Procedure

10.1 Fill the measure to overflowing by means of a shovel or scoop, discharging the aggregate from a height not to exceed 2 in. (50 mm) above the top of the measure. Exercise care to prevent, so far as possible, segregation of the particle sizes of which the sample is composed. Level the surface of the aggregate with the fingers or a straightedge in such a way that any slight projections of the larger pieces of the coarse aggregate approximately balance the larger voids in the surface below the top of the measure.

10.2 Determine the mass of the measure plus contents, and the mass of the measure alone, and record the values to the nearest 0.1 lb (0.05 kg).

11 Calculations

11.1 *Unit Weight*--Calculate the unit weight for the rodding, jigging, or shoveling procedure as follows:

$$M = (G - T)/V \quad (1)$$

or

$$M = (G - T) \times F \quad (2)$$

where:

M = unit weight of aggregate, lb/ft³ [kg/m³]

G = mass of aggregate plus the measure, lb [kg]

T = mass of the measure, lb [kg]

V = volume of measure, ft³ [m³]

F = factor for measure, ft^{-3} [m^{-3}]

11.1.1 The unit weight determined by this method is for aggregate in an ovendry condition. If the unit weight in terms of saturated-surface-dry (SSD) condition is desired, use the exact procedure in this method, and then determine the SSD unit weight by the following formula:

$$M_{SSD} = M[1 + (A/100)] \quad (3)$$

where:

M_{SSD} = unit weight in SSD condition, lb/ft³ [kg/m³]

A = absorption, %, determined in accordance with AASHTO T84 or T 85.

11.2 *Void Content*--Calculate the void content in the aggregate using the unit weight determined by either the rodding, jigging, or shoveling procedure, as follows:

$$Voids, \% = \frac{100[(S \times W) - M]}{S \times W} \quad (4)$$

where:

M = unit weight of aggregate, lb/ft³ [kg/m³]

S = bulk specific gravity (dry basis) as determined in accordance with AASHTO T 84 or T 85.

W = density of water, 62.3 lb/ft³ [998 kg/m³]

12 Report

12.1 Report the results for unit weight to the nearest 1 lb/ft³ [10 kg/m³] as follows:

12.1.1 Unit weight by rodding, or

12.1.2 Unit weight by jigging, or

12.1.3 Loose unit weight.

12.2 Report the results for void content to the nearest 1% as follows:

12.2.1 Voids in aggregate compacted by rodding, % or

12.2.2 Voids in aggregate compacted by jigging, %, or

12.2.3 Voids in loose aggregate, %.

13 Reproducibility of Results

13.1 Results by an operator using the sample and procedure check within one percent.