T 19

BULK DENSITY (“UNIT WEIGHT”) AND VOIDS IN AGGREGATE FOP FOR AASHTO T 19

T 19

BULK DENSITY (“UNIT WEIGHT”) AND VOIDS IN AGGREGATE FOP FOR AASHTO T 19

BULK DENSITY ("UNIT WEIGHT") AND VOIDS IN AGGREGATE FOP FOR AASHTO T 19

02 ## Scope

This FOP describes methods for determining bulk density and void content of aggregates not exceeding five inches in nominal maximum size. Aggregates are tested in a compacted state unless loose bulk density is required by the specifying agency. The procedure yields values based on aggregates in a dry condition.

A representative aggregate sample is placed in a calibrated measure and the mass determined. The bulk density is calculated by dividing the aggregate mass by the volume of the measure. Bulk density for this FOP is expressed as pounds per cubic foot (lb/ft^3). Void content is expressed as a percentage and will require knowledge of the G_{sb}(OD) (oven-dry bulk specific gravity) of the aggregate.

03 ## Significance

Results of this test method are frequently used when materials are proportioned on a volume basis or where a minimum density is specified by the governing agency. The test is also useful in determining mass/volume relationships for purchase agreements.

Apparatus

04
- **Balance:** Of sufficient capacity and readable to 0.1% of sample mass or better. Must meet the requirements of AASHTO M 231.
- **Tamping Rod:** A round steel rod of $^5/_8$ inch diameter, approximately 24 inches in length, with one end rounded to a hemispherical tip of the same diameter as the rod.

05
- **Measure:** A cylindrical metal measure with the top and bottom parallel to each other. The height should be 80 to 150 percent of the diameter. The volume of the measure shall conform to the requirements of Table 1. The top rim shall be plane and smooth within 0.01 inch and the interior wall of the measure shall be smooth and seamless. The metal thickness of the measure shall conform to the requirements of Table 2.

06

- **Shovel or Scoop:** Of convenient size and shape for filling the measure.
- **Calibration Equipment:** A piece of plate glass at least ¼ inch thick, and at least 1 inch larger than the diameter of the measure.

Table 1 – Capacities of Measures

07

Nominal Maximum Aggregate Size	Capacity of Measure *
½”	1/10 ft^3
1”	1/3 ft^3
1½”	1/2 ft^3
3”	1 ft^3
4½”	2.5 ft^3
6”	3.5 ft^3

* The actual volume of the measure shall be at least 95% of the nominal volume indicated in this table

08

Table 2 – Requirements for Measures

Capacity of Measure	Thickness of Metal		
	Bottom	Upper 1½” of Wall *	Remainder of Wall
Less than 0.4 ft^3	0.20 in.	0.10 inch	0.10 inch
0.4 through 1.5 ft^3	0.20 in.	0.20 inch	0.12 inch
Over 1.5 through 2.8 ft^3	0.4 in.	0.25 inch	0.15 inch
Over 2.8 through 4.0 ft^3	0.5 in.	0.3 inch	0.20 inch

* The additional upper wall thickness may be achieved by attaching a reinforcing band at the top of the measure.

09

Calibration of Measure

Measures shall be calibrated annually, or whenever there is a question of accuracy, according to the following steps:

1. Determine the mass of the clean dry measure and glass plate.
2. Fill the measure with water at room temperature and cover with the glass plate in such a way as to eliminate air bubbles.
3. Leaving the glass plate in place, remove water from the exposed surfaces of the glass plate and measure and determine the mass of the measure, water and glass plate.
4. Subtract the mass of the empty measure and glass plate.
5. Remove the glass plate and determine the temperature of the water in the measure. Find the density of water corresponding to the measured temperature in Table 3, interpolating if needed.
6. Divide the mass of water in the measure by the density determined in the previous step. Express the volume of the measure to the nearest 0.001 ft^3.

Table – 3 Density of Water

Temperature (^{o} F)	Density (lb/ft^3)
60	62.366
65	62.336
70	62.301
(73.4)	(62.274)
75	62.261
80	62.216
85	62.166

Sampling

- Obtain the sample according to AASHTO T 2. Reduce to appropriate testing size according to AASHTO T 248.

Sample Preparation

16 - The test sample shall represent a volume approximately 125 to 200 percent of that required to fill the measure.
- The sample shall be handled in such a way as to prevent segregation.
- Dry the sample to constant mass in an oven regulated at 230 ±9°F according to the FOP for AASHTO T 255. Cool to room temperature prior to conducting the test.

Selection of Procedure

17 The shoveling procedure for loose bulk density shall only be permitted when the governing agency
18 requires it. Otherwise, compaction of the aggregate in the measure shall be by rodding or jigging depending on nominal maximum aggregate size.

Note 1: For this FOP, Nominal Maximum Size is one specification sieve size larger than the first sieve to cumulatively retain more than 10 percent.

Rodding: Compact the aggregate in the measure by rodding when the nominal maximum aggregate size is less than or equal to 1½ inch.

Jigging: Compact the aggregate in the measure by jigging for nominal maximum aggregate sizes larger than 1½ inch.

Procedure, General

19 - Record all masses to the nearest 0.1 lb (50 g). (This does not preclude mass determinations of greater accuracy).
- Determine the mass of the clean, empty measure.
- Select the appropriate procedure from the following.

Rodding Procedure

20 1. Fill the measure approximately 1/3 full and level the layer with the fingers. Compact the layer with 25 strokes of the tamping rod taking
21 care to not forcibly strike the bottom of the measure.

2. Fill the measure approximately 2/3 full and level that layer with the fingers. Compact the layer with 25 strokes of the tamping rod, penetrating to the underlying layer if possible.

Note 2: When rodding large or angular aggregate pieces it may not be possible to completely penetrate the layer being compacted. Vigorous effort used in rodding the material is considered sufficient to achieve the proper degree of compaction.

3. Fill the measure to overflowing and rod again as in step 2 above. After rodding, level the surface with the fingers or with a straightedge such that slight projections above the top of the measure compensate for the depressions in the surface below the top of the measure.
4. Determine the mass of the measure and aggregate. Subtract the mass of the empty measure. Record mass in pounds.

Jigging Procedure

1. Fill the measure in three approximately equal layers, compacting each layer by alternately lifting opposite sides of the measure approximately 2 inches and allowing it to fall in a manner that results in a sharp slapping blow. Each layer shall be compacted by applying 50 blows (25 per side).
2. When full, the measure shall be leveled with the fingers or a straightedge such that slight projections above the top of the measure compensate for the depressions in the surface below the top of the measure.
3. Determine the mass of the measure and aggregate. Subtract the mass of the empty measure. Record mass in pounds.

Shoveling Procedure

1. Using a shovel or scoop, carefully fill the measure to overflowing. Do not allow aggregate particles to fall from a height more than 2 inches above the top of the measure. Do not allow vibration or any movement of the measure that will compact the aggregate beyond the loose state. Prevent segregation of the aggregate as the measure is filled.

31 2. When full, the measure shall be leveled with the fingers or a straightedge such that slight projections above the top of the measure compensate for the depressions in the surface below the top of the measure.

3. Determine the mass of the measure and aggregate. Subtract the mass of the empty measure. Record mass in pounds.

Calculations

32 Calculate values for bulk density and voids to the nearest 0.1, but round to the whole number for reporting.

33 **Bulk Density:** Calculate the bulk density for the rodding, jigging, or shoveling method according to the following formula:

$$M = \frac{(G - T)}{V}$$

where:

M = bulk density of aggregate (lb/ft^3)

G = mass of aggregate plus measure (lb)

T = mass of measure (lb)

V = volume of measure (ft^3)

Void Content: Calculate the percentage of voids according to the following formula:

34

$$\text{Voids, \%} = \frac{100\left(\left(S \times W\right) - M\right)}{S \times W}$$

where:

M = bulk density of aggregate (lb/ft^3)

S = dry bulk specific gravity (G_{sb}) as determined by AASHTO T 84 or AASHTO T 85

W = density of water (62.3 lb/ft^3)

Sample Worksheet for Test Method AASHTO T 19

Date: _____ Project: _____

Material: 1½ inch Nominal Maximum Size Coarse Aggregate

Source: _____ Tested By: _____

I – Calibration of Measure

Line	Description	Data Source or Formula	No. 1	No. 2	Average
A	Measure + Plate + Water (lb)	Balance	48.10	48.09	
B	Dry Measure + Plate (lb)	Balance	16.87	16.87	
C	Water (lb)	A – B	31.23	31.22	
D	Water Temperature (° F)	Thermometer	75	73	
E	Water Density (lb/ft^3)	Table No. 3	62.261	62.277	
F	Volume of Measure (ft^3)	C/E	0.5016	0.5013	0.501

II – Aggregate Bulk Density and Void Content 35

Procedure Used: **RODDING** Jigging Shoveling

Line	Description	Data Source or Formula	No. 1	No. 2	Average
G	Measure + Aggregate (lb)	Balance	74.07	74.68	
H	Empty Measure (lb)	Balance	14.83	14.83	
J	Aggregate (lb)	G – H	59.24	59.85	
K	Volume of Measure (ft^3)	Avg. from "F"	0.501	0.501	
L	Aggregate Bulk Density (lb/ft^3)	J/K	118.2	119.5	118.8 *
M	Oven-Dry Bulk Specific Gravity, G_{sb}(OD)	T 84 or T 85			2.628
N	Density of Water	Constant			62.3 lb/ft^3
O	Voids, %	See Below			27.4 *

* Note: These values are calculated to the nearest 0.1 but must be rounded to the whole number for reporting purposes. 36

Voids in Aggregate

37

Formula:

$$\text{Voids,\%} = \frac{100((M \times N) - L)}{M \times N}$$

Example:

$$\frac{100((2.628 \times 62.3) - 118.8)}{2.628 \times 62.3} = 27.4, \text{ say } 27\%$$

38

Report

- Report on standard agency forms
- Project description and location
- Material source and description, including nominal maximum size
- Method used: rodding, jigging, or shoveling
- Bulk density by rodding, jigging, or loose bulk density to the nearest 1 lb/ft^3
- Void content of aggregate compacted by rodding, jigging, or loose bulk density to the nearest 1 percent

39

Tips

- Make sure the aggregate is dry
- Calibrate the volume of the measure at least annually or whenever there is a question of accuracy
- Use rodding or jigging method based on nominal maximum aggregate size, unless the governing agency specifically calls for the shoveling method.
- Obtain G_{sb}(OD) (oven-dry bulk specific gravity) according to AASHTO T 84 or AASHTO T 85 for void content calculation.
- Calculate values for bulk density and voids to the nearest 0.1 but round to the whole number for reporting.

40

REVIEW QUESTIONS

1. According to this FOP, aggregate up to _____ in Nominal Maximum Size may be tested.

2. Summarize requirements for volume of the measure.

3. The _____ method should be used to fill the measure when nominal maximum size of aggregate is 1 inch.

4. What approximate volume of aggregate is used for conducting this test?

5. To what degree of accuracy is the volume of the measure determined?

6. When is the shoveling method allowed?

7. Given the following, the bulk density of the aggregate as reported is _____.

   Mass of Measure and Aggregate: 36.24 lb.
   Mass of Measure: 8.47 lb.
   Volume of Measure: 0.248 ft^3
   Dry Bulk Specific Gravity (G_{sb}): 2.649
   Density of Water: 62.3 lb/ft^3

8. Given the data from question 7, the void content as reported is _____.

PERFORMANCE EXAM CHECKLIST

BULK DENSITY ("UNIT WEIGHT") AND VOIDS IN AGGREGATE FOP FOR AASHTO T 19

Participant Name:_____ Exam Date:_____

Procedure

Calibration of Measure

1. All masses determined to 0.1% of sample mass or better? _____
2. Clean dry mass of measure and glass plate determined? _____
3. Measure filled with water at room temperature and glass plate placed to eliminate air bubbles? _____
4. Exterior of measure and glass plate dried and mass determined? _____
5. Mass of water determined? _____
6. Temperature of water measured and density of water determined? _____
7. Volume of measure correctly determined to 0.001 ft^3? _____

Sample Preparation

1. Sample obtained by AASHTO T 2 and reduced by AASHTO T 248? _____
2. Aggregate dried to constant mass at 230 ±9° F? _____
3. Aggregate quantity 125 to 200 percent of that needed to fill measure? _____
4. Sample handled so as to avoid segregation? _____

Procedure

1. All masses determined to 0.1 lb or 50 g or better? _____
2. Mass of clean, empty measure determined? _____
3. Correct method of filling measure selected based on agency requirements and nominal maximum aggregate size? (1½ inch or less by rodding; greater than 1½ inch by jigging; shoveling only when required by agency) _____
4. Rodding performed in 3 layers, leveling first two layers with fingers; 25 rods per layer but not forcibly striking bottom of measure on first layer; penetrating depth of layer if possible; third layer filled to overflowing? _____
5. Jigging performed in 3 layers; 50 drops per layer (25 per opposite side); last layer filled to overflowing? _____

6. Shoveling performed by carefully filling in loose state; not dropping aggregate more than 2 inches; avoiding vibration or movement of measure? _____
7. For all procedures, final layer leveled with fingers or straightedge such that projections above top of measure compensate for depressions? _____
8. Mass of aggregate and measure determined properly? _____
9. Mass of aggregate determined by subtracting empty measure from total? _____
10. Bulk density correctly calculated? _____
11. Dry bulk specific gravity of aggregate obtained? _____
12. Void content correctly determined? _____

Comments: First attempt: (Pass/Fail) ___ Second attempt: (Pass/Fail) ___

Signature of Examiner_____.