AASHTO T 191 – DENSITY IN-PLACE BY THE SAND CONE METHOD

Consult the current edition of AASHTO for procedure in its entirety and equipment specification details.

SCOPE

This method covers the determination of the in-place density of compacted soil or soil-aggregate mixtures. The in-place dry density is expressed as a percentage of the soils maximum dry density and can be compared to specification requirements.

REFERENCED DOCUMENTS

AASHTO T 265, Laboratory Determination of Moisture Content of Soils
ASTM D 4643, Determination of Moisture Content of Soil by the Microwave Oven Method
AASHTO T 19, Bulk Density (“Unit Weight”) and Voids in Aggregate

APPARATUS

Sand density apparatus and base plate
Clean, free-flowing sand consisting of -No.10 +No.200
Balance, readable to 0.1 grams
Pins, shovel, trowel, spoon, hammer, and knife
Auger, 4" diameter
Sealable container

EQUIPMENT PREPARATION

Filling the apparatus

1. Place the empty apparatus upright on a firm level surface, close the valve and fill the funnel with sand.

2. Open the valve and keep the funnel at least half full with sand during filling. When the sand stops flowing into the apparatus, close the valve sharply and empty the excess sand.

3. Determine and record the mass of the apparatus filled with sand (m_1).

Determining the mass of sand required to fill the funnel and base plate (Cone Correction)

1. Place the base plate on a clean, level, plane surface. Invert the sand cone filled with sand, and seat the funnel in the recess of the base plate.

2. Open the valve fully and allow the sand to flow until the sand stops flowing.

3. Close the valve sharply, remove the apparatus, and determine the mass of the apparatus and the remaining sand (m_2).

4. The mass of sand required to fill the cone and base plate is calculated by the difference between the initial mass and final mass. Record this mass as the cone correction: ($C_c = m_1 – m_2$).

   Where:

   C_C = Cone correction
   m_1 = Mass of the apparatus filled with sand
   m_2 = Mass of the apparatus and remaining sand

Notes:

For each container/bag of sand there will be a unique cone correction and sand calibration factor. Each sand-cone and matched base plate will also have a set of unique cone corrections and bulk sand densities. If more than one sand-cone apparatus is available, the sand-cone and base plate should be marked and the associated correction/density factors recorded.

Vibration of the sand during any mass-volume determination may increase bulk density of the sand and decrease the accuracy of the determination. Appreciable time intervals between the bulk density determination of the sand and its use in the field may result in change in the bulk density caused by a change in the moisture content or effective gradation.

Determining the bulk density of sand (D_B)

1. Replace the sand removed in the funnel determination according to the procedure for filling the apparatus, close the valve, and determine the mass of the apparatus and sand (m_3).

2. Position the calibration container on a clean, level, plane surface. Place the base plate on the calibration container. Invert the apparatus and seat the funnel in the recess of the base plate.

3. Open the valve fully and keep open until the sand stops flowing.

4. Close the valve sharply, remove the apparatus and determine the remaining mass of the apparatus and sand (m_4).

5. Calculate the mass of the sand needed to fill the container, funnel and base plate. Subtract the final mass (Step 4), from the initial mass (Step 1).

6. The mass of the sand needed to fill the container only is determined by subtracting the mass of the cone correction (Step 4) from the total mass required to fill the container with the funnel and base plate (Step 5).

7. Determine the bulk density of the calibration sand (sand calibration factor). Divide the mass of the sand needed to fill the container (Step 6), by the volume of the calibration container as determined according to T 19M/T 19.

   $$D_B = (m_3 - m_4 - C_C)/V_C$$

   Where:
   - D_B = Bulk density of the sand in g/cm^3
   - m_3 = Mass of the apparatus and sand
   - m_4 = Remaining mass of the apparatus and the sand
   - C_C = Cone correction
   - V_C = Volume of the calibration container

8. Record this factor for future reference.

PROCEDURE

All information is recorded on SFN 59725 and SFN 59724.

Fill testing apparatus with sand and record the total mass.

Select the area of compacted lift to be tested. Because the surface of a compacted area is generally loose or disturbed due to compaction operations, remove loose material and level off an area slightly larger than the base plate.

Place the base plate over the smoothed area and fasten down with the accompanying pins. Plate must stay in this position and be stable throughout the test.

Dig a test hole within base plate opening, with the auger, trowel, or other tools. Soils that are granular require extreme care and may require the digging of a conical-shaped hole. Place all of the loosened material from the hole into an aggregate balance pan, or a moisture-tight container if not weighed right away.

Minimum Test Hole Volumes and Moisture Content Samples Based on Maximum Size

Maximum Particle Size	Minimum Test Hole Volume	Minimum Sample Size for Moisture Content
No. 4 (4.75 mm)	0.025 ft^3	100 g
1/2" (12.5 mm)	0.050 ft^3	250 g
1" (25.0 mm)	0.075 ft^3	500 g
2" (50.0 mm)	0.100 ft^3	1000 g

Place testing apparatus on the base plate and open valve. After the sand has stopped flowing, close the valve; remove apparatus, and record final mass.

Weigh the wet soil or soil-aggregates removed from the hole to the nearest 0.01 lb. and record.

Use a representative portion of the soil for moisture determination. Do not use material containing particles large enough to be retained on the No. 4 (4.75 mm) sieve. Moisture can be determined by the use of AASHTO T 265 or ASTM D 4643. Calculate moisture to nearest 0.1%.

CALCULATIONS

Complete calculations as follows:

- (V_H) Volume of Test Hole = (Initial Mass - Final Mass - C_C)/D_B

  Calculate the volume of test hole to the nearest 0.0001 ft^3.

- (M_{DS}) Dry Mass of Material removed from test hole = (Moist Mass removed from test hole/ (1 + (% moisture /100))

  Calculate dry mass of material to the nearest 0.01 lbs.

- (D_D) Dry Density = M_{DS}/V_H

  Calculate in-place dry density to the nearest 0.1 lbs/ft^3.

CALIBRATION

All new devices should be calibrated prior to being used. A calibration check should be performed annually as a minimum, or whenever damage or repair occurs.

SAND CONE CORRECTION FACTOR

North Dakota Department of Transportation, Materials and Research Division
SFN59724 (03-2011)

Project Number	PCN	Date	Tested By

Trial	1	2	3
A Wt. of jar, cone, and sand (before) lbs.			
B Wt. of jar, cone, and sand (after) lbs.			

Trial	C^1	C^2	C^3
C Wt. of sand in cone and ring (A - B)			

Cone Correction Factor (Cc) = $\frac{(C^1 + C^2 + C^3)}{3}$

Cc =

Note: all weights shall be recorded to the nearest .001 lbs. Three weights should not vary by more than 0.01 lbs.

SAND BULK DENSITY DETERMINATION

Trial	1	2	3
D Wt. of jar, cone, and sand (before) lbs.			
E Wt. of jar, cone, and sand (after) lbs.			
F Wt. of sand in cone, ring, and density apparatus (D - E)			
G Wt. of sand in density apparatus (F - Cc)			

Trial	D^1	D^2	D^3
Bulk Density = (G ÷ Density apparatus volume)			

Bulk Density Sand (Db) = $\frac{(D^1 + D^2 + D^3)}{3}$

Db =

DENSITY TEST WORKSHEET - SAND CONE METHOD

North Dakota Department of Transportation, Materials and Research Division
SFN59725 (01-2011)

Project Number	PCN	Date	Tested By

TEST IDENTIFICATION		**Test Number**					
		Time					
		Station					
		Offset from centerline					
		Lane					
		Depth below finished grade ft.					

IN-PLACE DRY DENSITY DETERMINATION	a	Unit Weight of Sand (pcf) SFN 59724					
	b	Wt. material removed from test hole (lbs.)					
	c	Initial sand weight (lbs.)					
	d	Final sand weight (lbs.)					
	e	Wt. sand in funnel and hole = c - d					
	f	Cone calibration factor (lbs.) SFN 59724					
	g	Wt. sand in hole = e - f (lbs.)					
	h	Volume of Test hole = g/a (cu. ft.)					
	i	Wet Density - b/h/(lbs./cu. ft.)					
	j	Dry Density = i/(100 +p) x 100 (lbs./cu. ft.)					
		Moisture Determination					
	k	Wet weight + container					
	l	Dry weight + container					
	m	Moisture loss= k - i					
	n	Tare weight of container					
	o	Dry weight of soil = l - n					
	p	Moisture Percentage = (m/o) x 100 (%)					

MOISTURE-DENSITY RELATIONSHIP TEST		AASHTO Procedure					
		Test Number (Proctor Test)					
		Station					
		Offset from centerline					
		Depth below finished grade					
	q	Maximum Dry Density					
		Optimum Moisture					

REQUIRED MOIS-DENS.		Required % maximum Dry Density					
		% Maximum Dry Density = (j/q) x 100					
		Required Moisture					
		Moisture = p					

Remarks