Density of Soils and/or Granular Material In-place by the Sand-Cone Method

---

1. Scope:

This test is for determining the in-place density of soils and/or granular materials.

2. Apparatus:

2.1 Density apparatus consisting of a 6 1/2" diameter sand cone and a one gallon jar conforming to the requirements of AASHTO T 191.

2.2 Base plate conforming to the requirements of AASHTO T 191.

2.3 Scale or balance having the capacity to weigh any sample which may be tested utilizing this procedure and readable to the nearest 0.01 lb. An additional scale or balance that is readable to the nearest 0.1 gram will be needed for determining the moisture.

2.4 Oven capable of maintaining a temperature of 230° ± 9°F or other equipment according to SD 108.

2.5 $1/10^{th}$ cubic foot standard measure.

2.6 Sand: Clean, dry and free flowing. It must not have a variation in bulk density greater than 1%. Sand retained between the #12 and #20, or #12 and #30 sieve sizes is most suitable. To prove suitability, several bulk density determinations must be made, using the same representative sample.

2.7 Sieves: 3/4", #4, #12, and a #20 or #30 sieves conforming to AASHTO M 92.

2.8 Miscellaneous: Small pick, hammer, chisels, spoons, pans or other suitable containers for drying moisture samples, buckets, plastic bags and paint brush.

3. Procedure:

3.1 Calibration of Density Apparatus

A. Determine the weight of sand required to fill the cone and base plate.

Pour the standard sand into the density apparatus through the cone with the valve open until the jar is full. The density apparatus should be gently tapped several times (With palm of hand) during filling to ensure that the maximum amount of sand will be available for the next test. Weigh the full density apparatus and record the weight to the nearest 0.01 lb.

Place the base plate on a clean, level, plane surface (Such as a table top). The bottom of the base plate may have protrusions that prevent the base plate sitting in contact with the planar surface at the cone opening. This will allow sand to flow under the base

plate. To prevent this, use an inverted 6” mold or other planar surface that will fit inside of the base plate protrusions and allow contact with the bottom of the base plate at the cone opening. Place this mold or other similar object on a stable, level surface and place the base plate on this surface. Invert the density apparatus and seat the cone into the recess of the base plate. Open the valve to allow the sand to fill the cone and base plate. Avoid jarring or vibrating the density apparatus while the sand is flowing.

Close the valve and weigh the density apparatus and remaining sand. Subtract this weight from the weight of the density apparatus full of sand. The difference is the weight of the sand to the nearest 0.01 lb. required to fill the cone and base plate. Use DOT–87 worksheet to record weights. An average of three such tests shall be used to determine the weight of sand in the cone and base plate. Replace the sand removed in the cone and base plate weight determination and close the valve.

B. Determine the Bulk Density of the Sand.

(1) Determine the weight of sand to fill the cone.

Pour the standard sand into the density apparatus through the cone with the valve open until the jar is full. The density apparatus should be gently tapped several times (With palm of hand) during filling to ensure that the maximum amount of sand will be available for the next test. Weigh the full density apparatus and record the weight to the nearest 0.01 lb.

Invert the density apparatus and place the cone on a clean, level, plane surface (Such as a table top). Open the valve to allow the sand to fill the cone. Avoid jarring or vibrating the density apparatus while the sand is flowing.

Close the valve and weigh the density apparatus and remaining sand. Subtract this weight from the weight of the density apparatus full of sand. The difference is the weight of the sand to the nearest 0.01 lb. required to fill the cone. Use DOT–87 worksheet to record weights. An average of three such tests shall be used to determine the weight of sand in the cone. Replace the sand removed in the cone weight determination and close the valve.

(2) Determine the weight of sand to fill the cone and standard measure. Weigh the full density apparatus and record the weight to the nearest 0.01 lb. Center the density apparatus with the cone down and resting on the rim of the standard measure. Open the valve to allow the sand to fill the measure and cone. Avoid jarring or vibrating the density apparatus while the sand is flowing.

Close the valve and weigh the density apparatus and remaining sand. Subtract this weight from the weight of the density apparatus full of sand. The difference is the weight of the sand to the nearest 0.01 lb. required to fill the cone and standard measure. Use DOT–87 worksheet to record weights. An average of three such tests shall be used to determine the weight of the sand in the cone and standard measure. Replace the sand removed in the cone weight and standard measure determination and close the valve.

(3) Determine Bulk Density of Sand.

Subtract the average weight of the sand in the cone from the average weight of the sand in the cone and standard measure. Multiply the result by the factor on the standard measure. The results will be the bulk density of the sand in pounds per cubic foot. Use DOT–87 worksheet to record the results.

NOTE: Vibration of the sand during any sand weight-volume determination may increase the bulk density of the sand and decrease the accuracy of the determination. After the sand is calibrated it should be stored in a reasonably air tight container to prevent changes in bulk density caused by a change in moisture content.

NOTE: The calibration of the density apparatus and base plate must be done following its use for 5 density tests or each time un-calibrated sand is added to the sand jar. Ensure that the sand has been thoroughly mixed or the sand comes from the same bag when using two jars.

3.2 Density of In-Place Material.

A. Prior to traveling to the test site, weigh the full density apparatus and record the weight to the nearest 0.01 lb.

17

B. Prepare the surface of the location to be tested so that it is a level plane. Seat the base plate on the plane surface, ensuring that the edge of the hole of the base plate makes contact with the plane surface. Mark the outline of the base plate to check for movement during the test. It is recommended that the base plate be staked to the plane surface to prevent movement.

NOTE: In soils where leveling is not successful, a preliminary test must be performed to measure the volume bounded by the base plate and ground surface. This step requires balances at the test site to weigh the density apparatus after refilling. After this measurement is completed, carefully brush the sand from the prepared surface.

C. Dig the test hole through the base plate, being very careful to avoid disturbing the soil that will bound the hole. Soils that are essentially granular require extreme care. Place all loosened soil in a container, being careful to avoid losing any material or moisture.

D. If the material being tested contains + #4 or + 3/4" rock refer to section 3.3 or 3.4 before proceeding with paragraph E below.

E. Seat the density apparatus in the recess of the base plate, open the valve and after the sand has stopped flowing, close the valve. Avoid jarring or vibrating the density apparatus while the sand is flowing. Weigh the density apparatus with the remaining sand to the nearest 0.01 lb.

F. Weigh the material that was removed from the test hole to the nearest 0.01 lb.

G. Mix the material thoroughly and secure a representative sample for moisture determination.

H. Weigh the material to the nearest 0.1 gram and dry it to a constant weight as per SD 108

I. Use the suggested minimum test hole volumes and the minimum weight of the moisture content samples shown in table 1.

Table 1

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

*Nominal Maximum Particle Size Sieve	Suggested Minimum Test Hole Volume ft^3	Minimum Moisture Content Sample Grams
# 4	0.0250	100
½"	0.0500	500
¾"	0.0650	500
1"	0.0750	500
2"	0.1000	500

17

*Nominal maximum size particle is denoted by the smallest sieve opening listed above, through which 90% or more of the material will pass.

For particle size not listed in the table, use the next larger minimum sample size.

NOTE: The volume of the test hole shall be computed to the nearest 0.0001 ft^3 on the DOT-41.

3.3 When the material being tested is a soil material in which method 2 (4" mold) from SD 104 is to be used for the standard density and more than 10% rock is retained on the #4 sieve, make corrections as follows:

A. All + #4 rock must be removed from the material from the test hole.

B. Place the cone in the recess of the base plate and open the valve and release sufficient sand to cover the bottom of the hole, shut off the flow of sand and remove the density apparatus. Carefully place the rock retained on the #4 sieve in a single layer on the sand. Replace the cone in the recess of the base plate and continue the test. If a larger quantity of rock retained on the #4 sieve is encountered, place a layer of sand between the layers of rock.

C. Weigh the material taken from the hole after the rock retained on the #4 sieve has been removed to the nearest .01 lb. and report the weight on the DOT-41.

D. Mix the material thoroughly and select a representative sample for a moisture test from the minus #4 material from the test hole in accordance with table 1. Weigh the material to the nearest 0.1 g and dry it to a constant weight as per SD 108.

3.4 When the material being tested is a granular material or soil material in which method 4 (6” mold) from SD 104 is to be used for the standard density, make corrections as follows:

A. All + 3/4" rock must be removed from the material from the test hole.

B. Place the cone over the hole and open the valve and release sufficient sand to cover the bottom of the hole, shut off the flow of sand and remove the density apparatus. Carefully place the rock retained on the 3/4” sieve in a single layer on the sand. Replace the density apparatus over the hole and continue the test. If a large quantity of rock is retained on the 3/4” sieve, place a layer of sand between the layers of rock.

C. Weigh the minus 3/4” material from the hole and report the weight on the DOT-41 to the nearest 0.01 lb.

D. Mix the material thoroughly and select a representative sample for a moisture test from the minus 3/4" material from the test hole in accordance with table 1. Weigh the material to the nearest 0.1 gram and dry it to a constant weight as per SD 108.

3.5 Standard Density Determination (1-point)

A. Sample the material from or adjacent to the test hole. Perform the standard density as per SD 104, method 2 or method 4.

4. Report:

4.1 Calculations

A. The procedure for calculating the in-place density, standard density, and moisture are shown on the DOT-41.

See figure 1 for an example of a test on granular material and figure 2 for an example of a test on embankment soil.

B. The maximum dry density from the family of curves established by the 1-point determination is used to compute the percent of standard obtained for the test.

4.2 Report

A. Report the moisture content to the nearest 0.1 percentage point.

B. Report densities to the nearest 0.1 lb./ft^3.

C. Report the percent of standard density obtained to the nearest whole percentage point.

5. References:

AASHTO M 92
AASHTO T 191
SD 104
SD 108
SD 110
DOT-41
DOT-87

Sample ID 2204846 **Density Report** DOT - 41

File No. 9-16

County Aurora, Ziebach PCN/PROJECT B015 PH 0066(00)15

Station 113+39 Dist. From CL 8' R Width (Gravel) 40.00

Depth _____ (from top of Subgrade or Pipe) (Hole - Gravel) Field # 06

Tested By Tester (TEST), One Checked By Tester (TEST), Two Date 04/23/2015

WORK AREA REPRESENTED (Circle what applies)

EMBANKMENT STA. TO STA. (per half mile, for each roadbed)
Zone 1(0-1ft.) Zone 2(1-3 ft.) Zone 3(3-5 ft.) Zone 4(5 ft. to base, 1 per 5 ft.)

BRIDGE END EMBANKMENT STA. TO STA.
1 per zone within plan limits 3 equal zones when backwall is less than 7 ft. 4 equal zones when backwall is 7 ft. or greater
Zone 1 Zone 2 Zone 3 Zone 4

BERM STA. TO STA. (100 ft. from Bridge End)
Zone 1(0-1ft.) Zone 2(1-3 ft.) Zone 3(3-5 ft.) Zone 4(5 ft. to base, 1 per 5 ft.)

PIPE
CROSS 24" or Smaller undercut (1/2 way up) (0-2 ft. Above)
STORM 30" to 72" undercut (Lower 1/2) (Upper 1/2) (0-2 ft. Above)
INTERSECTION 72" or more undercut (Bottom 1/3) (Middle 1/3) (Top 1/3) (0-2 ft. Above)
After Minimum for size pipe installation ☐ 1 per 3 ft. of backfill beginning at 2' above top of pipe

SUBBASE STA. TO STA. LIFT

BASE COURSE STA. TO STA. 100+00 to 126+40 LIFT 2 of 3

Curve Used	Standard Density Maximum Density	Optimum Moisture	Granular Material 4-Point Range	SPECIFICATION	% Obtained 100 X (G/U)
d	U. 133.0	8.7 %	128.1 - 134.1	97 %	100 %

Balloon Method		Sand Density			Nuclear Method
		A. Std. Sand PCF		96.4	Meter No.
B. Wt. Undried Matl. from Hole		B. Wt. Undried Matl. from Hole		11.98	Test Mode
C. Volumeter Reading in Hole		C. Initial Wt. Sand		16.96	A. Wet Density from Gauge ± Corr. * =
D. Initial Volumeter Reading		D. Final Wt. Sand	5.35		
		Plus Cone Sand	3.66	9.01	B. Dry Density A / (100 + M-Field) x 100
E. Volume of Test Hole (C - D)		E. Volume of Test Hole (C - D) / A		0.0825	
F. Wet Density (B / E)		F. Wet Density (B / E)		145.2	
G. Dry Density F / (100 + M) x 100		G. Dry Density F / (100 + M) x 100		133.5	

1-Point Density Determination			Moisture Determinations	1-Point	Field	Rock Determination
O. Weight of Mold & Specimen		25.64				A. Total Sample Weight
			H. Wt. of Wet Matl. and Container	523.1	829.9	
P. Weight of Mold		14.95	I. Wt. of Dry Matl. and Container	484.3	762.7	B. Weight of Material Retained on 3/4" Sieve
Q. Wet Wt. of Molded Specimen (O- P)		10.69	J. Wt. of Moisture (H - I)	38.8	67.2	C. Percent Retained On 3/4" Sieve (B x 100)/A
R. Factor of Mold No.	2-36					
Used in Test		13.29	K. Wt. of Container			
			L. Wt. of Dry Matl. (I - K)	484.3	762.7	
S. Wet Density (Q x R)		142.1				
T. Dry Density S / (100 + M [1-PT]) x 100		131.6	M. Percent Moisture Field (J x 100) / L	8.0	8.8	

* Correction from DOT-39. If there is no correction or, if the correction has been applied to the meter show "NA".

Figure 1

Sample ID 2204843 **Density Report** DOT - 41
File No. 9-16

County Aurora, Ziebach PCN/PROJECT B015 PH 0066(00)15
Station 115+30 Dist. From CL 7' R Width (Gravel)
Depth 12' (from top of Subgrade or Pipe) (Hole - Gravel) Field # E09
Tested By Tester (TEST), One Checked By Tester (TEST), Two Date 04/23/2015

WORK AREA REPRESENTED (Circle what applies)

EMBANKMENT STA. TO STA. 104+00 to 130+00 (per half mile, for each roadbed)
Zone 1(0-1ft.) Zone 2(1-3 ft.) Zone 3(3-5 ft.) Zone 4(5 ft. to base, 1 per 5 ft.)

BRIDGE END EMBANKMENT STA. TO STA.
1 per zone within plan limits 3 equal zones when backwall is less than 7 ft. 4 equal zones when backwall is 7 ft. or greater
Zone 1 Zone 2 Zone 3 Zone 4

BERM STA. TO STA. (100 ft. from Bridge End)
Zone 1(0-1ft.) Zone 2(1-3 ft.) Zone 3(3-5 ft.) Zone 4(5 ft. to base, 1 per 5 ft.)

PIPE
CROSS 24" or Smaller undercut (1/2 way up) (0-2 ft. Above)
STORM 30" to 72" undercut (Lower 1/2) (Upper 1/2) (0-2 ft. Above)
INTERSECTION 72" or more undercut (Bottom 1/3) (Middle 1/3) (Top 1/3) (0-2 ft. Above)
After Minimum for size pipe installation ☐ 1 per 3 ft. of backfill beginning at 2' above top of pipe

SUBBASE STA. TO STA. LIFT
BASE COURSE STA. TO STA. LIFT

Curve Used: Q
Standard Density: Maximum Density U. 102.4; Optimum Moisture 20.3 %
Granular Material 4-Point Range: -
SPECIFICATION 95 %
% Obtained 100 X (G/U) 96 %

Balloon Method		Sand Density			Nuclear Method
		A. Std. Sand PCF		96.4	Meter No.
B. Wt. Undried Matl. from Hole		B. Wt. Undried Matl. from Hole		3.91	Test Mode
C. Volumeter Reading in Hole		C. Initial Wt. Sand		13.68	A. Wet Density from Gauge ± Corr. * =
D. Initial Volumeter Reading		D. Final Wt. Sand Plus Cone Sand	6.86 3.66	10.52	B. Dry Density A / (100 + M-Field) x 100
E. Volume of Test Hole (C - D)		E. Volume of Test Hole (C - D) / A		0.0328	
F. Wet Density (B / E)		F. Wet Density (B / E)		119.2	
G. Dry Density F / (100 + M) x 100		G. Dry Density F / (100 + M) x 100		98.4	

1-Point Density Determination			Moisture Determinations	1-Point	Field	Rock Determination
O. Weight of Mold & Specimen		13.27	H. Wt. of Wet Matl. and Container	143.1	156.4	A. Total Sample Weight
P. Weight of Mold		9.22	I. Wt. of Dry Matl. and Container	119.3	129.2	B. Weight of Material Retained on 3/4" Sieve
Q. Wet Wt. of Molded Specimen (O- P)		4.05	J. Wt. of Moisture (H - I)	23.8	27.2	C. Percent Retained On 3/4" Sieve (B x 100)/A
R. Factor of Mold No. Used in Test	4-73	30.12	K. Wt. of Container			
S. Wet Density (Q x R)		122.0	L. Wt. of Dry Matl. (I - K)	119.3	129.2	
T. Dry Density S / (100 + M [1-PT]) x 100		101.8	M. Percent Moisture Field (J x 100) / L	19.9	21.1	

* Correction from DOT-39. If there is no correction or, if the correction has been applied to the meter show "NA".

Figure 2

Sample ID 2225659

Calibration of Sand Cone and Base Plate and Determination of Sand Bulk Density
SD 105 and SD 110

DOT-87
9-15

INFO.

PROJECT PH 0066(00)15 COUNTY Aurora, Ziebach PCN B015

Calibrated by: Tester, One Date: 09/08/2015

SAND CONE AND BASE PLATE: SD 105

A.	Initial weight of sand, cone, and jar.	(1)	16.05	(2)	12.38	(3)	8.72	0.01 lb (1 g)
B.	Final weight of sand, cone, and jar.	(1)	12.38	(2)	8.72	(3)	5.06	0.01 lb (1 g)
C.	Weight of sand in cone and base plate. (A - B)	(1)	3.67	(2)	3.66	(3)	3.66	0.01 lb (1 g)
D.	Average weight of sand in cone and base plate.				3.66			0.01 lb (1 g)

SAND CONE AND MODIFIED BASE PLATE: SD 110

E.	Initial weight of sand, cone, and jar.	(1)		(2)		(3)		0.01 lb (1 g)
F.	Final weight of sand, cone, and jar.	(1)		(2)		(3)		0.01 lb (1 g)
G.	Weight of sand in cone and plate. (E - F)	(1)		(2)		(3)		0.01 lb (1 g)
H.	Average weight of sand in cone and modified base plate.							0.01 lb (1 g)

SAND BULK DENSITY

I.	Initial weight of sand, cone, and jar.	(1)	15.98	(2)	12.66	(3)	9.35	0.01 lb (1 g)
J.	Final weight of sand, cone, and jar.	(1)	12.66	(2)	9.35	(3)	6.03	0.01 lb (1 g)
K.	Weight of sand in cone. (I - J)	(1)	3.32	(2)	3.31	(3)	3.32	0.01 lb (1 g)
L.	Average weight of sand in cone.				3.32			0.01 lb (1 g)
M.	Initial weight of sand, cone, and jar.	(1)	15.98	(2)	15.98	(3)	15.98	0.01 lb (1 g)
N.	Final weight of sand, cone, and jar.	(1)	3.03	(2)	3.04	(3)	3.03	0.01 lb (1 g)
O.	Weight of sand in cone and measure. (M - N)	(1)	12.95	(2)	12.94	(3)	12.95	0.01 lb (1 g)
P.	Average Weight of sand in cone and measure.				12.95			0.01 lb (1 g)
Q.	Average weight of sand in measure. (P - L)				9.63			0.01 lb (1 g)
R.	Factor of measure No. P-1881				10.01			
	Sand Bulk Density (Q x R) =				96.4			0.1 lb/ft^3 (1 kg/m^3)

Figure 3