

METRIC/ENGLISH

Method of Test for
THE DETERMINATION OF IN-PLACE DENSITY
DOTD Designation: TR 401

INTRODUCTION

The method of determining in-place densities shall be selected by the engineer. Although all methods (devices) specified are considered acceptable for determining in-place density and percent density for soils, aggregates and soil-aggregate mixtures, untreated, treated or stabilized, the nuclear device is hereby designated as the department's official standard for in-place density.

When using a nuclear device to conduct in-place density tests, the method corresponding to the device model number shall be used. Densities determined with the nuclear density device will normally be the average of three individual test results. However, when testing in a trench within six feet of a wall, due to the small mass of material being tested, only one test will be required. For other tests, density will be the average of three tests taken at intervals of approximately 120° around the same access hole. This method of testing is consistent with the recommendations of the manufacturer of these devices. When the sand cone is used, only one test location is required.

Table of Methods

Method A -	Nuclear Device – Troxler Model 3440
Method B -	Nuclear Device – Troxler Model 3411
Method C -	Nuclear Device – Humboldt Model HS-5001 EZ
Method D -	Sand Cone

Only an Authorized Nuclear Device Operator (operator) is to operate a nuclear device. Completion of training and the holding of a valid nuclear film badge and an operator's license issued by the Materials and Testing Section is required for authorization. This film badge is to be worn at all times when transporting, handling, or operating a nuclear device. Although there is no danger of overexposure to radiation from normal use of this equipment, improper handling, transport or operation may lead to radiation hazards. The operator's license is also to be carried at all times when an operator is transporting, handling, or operating a nuclear device.

All applicable safety precautions, outlined in the manufacturer's operations manual for the nuclear device, shall be followed. When required, cleaning of the source rod in the field will be accomplished by wiping the rod with a cloth held by a remote device, such as long tongs. Any nuclear device requiring more extensive cleaning or repairs shall be transported to the District Laboratory.

Each nuclear device, regardless of ownership, used for acceptance testing on a DOTD project shall be approved by the Materials and Testing Section prior to use and every two years thereafter. This approval includes the evaluation of calibration checks and leak tests. Leak tests are to be performed every six months. A log with the device model and department assigned number shall be kept with each device listing all moisture and density standard counts.

When asphalt cement or other asphaltic materials are present and a nuclear device is used to determine in-place density, the moisture content used to determine the dry density shall be obtained by

either stove or oven drying, in accordance with DOTD TR 403. When discrepancy occurs between a moisture content obtained with a nuclear device and a moisture content obtained in accordance with DOTD TR 403, the moisture content obtained in accordance with DOTD TR 403 shall be utilized to determine in-place density.

It will be necessary to perform moisture correction procedures on some materials, because they contain hydrogen in a form other than water. The nuclear device detects this hydrogen and computes it as water, yielding a moisture content higher than actual moisture. In most soils which occur naturally in Louisiana, this problem will not occur. However, soils or soil aggregate mixtures which contain reclaimed asphaltic concrete, recycled portland cement concrete, cement, lime, fly ash, coal, mica bearing clays, gypsum (calcium sulfates), phosphates or organic matter may cause erroneous moisture readings. Boron and cadmium will also cause the nuclear device to yield a lower than actual moisture content. Soils or soil-aggregate mixtures containing these materials will require the determination of their actual moisture content in accordance with DOTD TR 403. When a nuclear device operator encounters results which are obviously outside the normal pattern, moisture content determinations shall be performed to identify if an erroneous moisture reading is the cause of the unusual test results. When such a situation occurs, contact the District Laboratory Engineer.

THE DETERMINATION OF IN-PLACE DENSITY

DOTD Designation: TR 401

Method A – Troxler Model 3440

I. Scope

- A. This method of test is designed to determine the in-place density of soils, aggregates, or soil-aggregate mixtures, untreated, treated or stabilized, using the Troxler Model 3440 nuclear device.
- B. Reference Documents
 - 1. DOTD TR 403 – Determination of Moisture Content
 - 2. DOTD TR 415 – Field Moisture – Density Relationships
 - 3. DOTD TR 418 – Moisture – Density Relationships

II. Apparatus

- A. **Approved Troxler Model 3440 nuclear device** – with locks and keys
- B. **Operator’s manual** – for nuclear device
- C. **Transport case** – for nuclear device, **with locks and keys**
- D. **Reference standard block**
- E. **Scraper plate/drill rod guide**
- F. **19 mm (¾-inch) drill rod or 19 mm (¾-inch) auger.**
- G. **Extraction tool** (optional)
- H. **Standard Count Log**
- I. **Operator’s nuclear film badge and operator’s license**
- J. **Dry fine sand**
- K. **Hand tools** – 2 – 3 kg (4 – 6 lb) maul, shovel, straightedge
- L. **Worksheet** – Density and Moisture Content, DOTD Form No. 03-22-0750 (Figure A-1 front and back)

III. Standardization

- A. Procedure
 - 1. Turn the device on by pressing the **ON** key. The device will automatically go through a self-test routine for five minutes.

Note A-1: Do not turn the device off while the self-test display is on. Turning the device off while the self-test display is on may result in the loss of device memory.

- 2. Clean the top of the reference standard block, being sure that there is no soil or other material which would prevent a good seat between the device and the block.
- 3. With the probe retracted, clean the base of the device, being sure that there is no soil or other material which would prevent a good seat between the device and the block.
- 4. Place the reference standard block on the compacted material with a minimum density of 1600 kg/m³ (100 lb/ft³), at least 2 m (6 ft) from any large object and at least 10 m (30 ft) from any other nuclear device. When a test is to be performed in an area with less than a 2 m (6 ft) clearance from an object (e.g., near a wall, pipe, vehicle, or in a trench), the trench offset factor, as determined in Step III.C should be utilized at the

exact location as the test counts in lieu of standard counts, and shall not be entered in the Standard Count Log.

5. Place the device on the reference standard block with the source in **SAFE** position, making sure there is a good seat between the device and the block.
6. Press the **STANDARD** key to obtain the first display. The display will show the standard counts, and a question, similar to the following example.

Standard Count
MS = 640
DS = 3560
Take a new count?

7. Press the **YES** key to take a new count and obtain the second display. The display will show a question similar to the following example.

Is gauge on Std.
block and source
rod in SAFE pos?

8. If the device is on the standard block and the source rod in the SAFE position, press the YES key. A third display will appear similar to the following example.

Taking
Standard Count
240 seconds
remaining

9. When the standard count is completed, the device will beep and display the results of a four-minute standard count, similar to the following example.

MS = 660 **0.3%P**
DS = 3540 **01%P**
Do you want to
use the new STD?

Note A-2: *The P to the right of the percentage figures indicate that the new counts are within the 1% density and 2% moisture limits. If the percentages are not within these limits, an F will be displayed. If an F (Fail display) is obtained, check for the following causes and correct.*

- *Other nuclear devices nearby*
- *Device not seated solidly on the reference block*
- *Device base or top of reference block not clean*

- *Reference block not the correct one for the nuclear device*
10. If an **F** appears after the percentages, make certain all obvious possible causes of a failed percentage are considered and corrected (such as the seating of the gauge on the block, debris between the gauge and block, etc). Press **YES** to accept the failing standard count. Continue to take standard counts regardless of whether or not the cause of the failing percentage is identified. Accept each failing standard count by pressing **YES** until the counts begin to pass. Continue to take standard counts until there are **4** passing counts in the gauge memory. This process will purge the gauge of failing standards. If numerous attempts to get a passing standard fails, contact the Testing Equipment Unit at the Materials & Testing Section for assistance and evaluation. When the display indicates that the density standard counts (DS) are within passing limits, record the value displayed as DS on the worksheet. Record the value displayed for the moisture standard count, as MS on the worksheet. These counts shall also be recorded on the Standard Count Log available with each device.
 11. Press the **YES** key to accept the new standard counts and store them in the memory of the nuclear device. These standard counts will remain in the nuclear device's memory and be used for the calculation of data until a new set of standard counts is obtained and stored.

B. Frequency

1. Take standard counts at least once each day when the nuclear device has been idle for 4 hours or more and when test results are suspected of being in error.
2. If tests are to be taken where the nuclear device must be placed less than 2 m (6 ft) from an object (e.g., near a wall or in a trench) determine the density and moisture standard counts at each test location, using the trench offset factor procedure, outlined in Step III.C. These counts shall not be entered in the Standard Count Log.
3. If the day-to-day shift in standard count is greater than 2% for moisture or 1% for density as compared to the average of the previous four sets, there is a possibility of a device malfunction or operator error in placing the device on the standard block. Since the radiation source may cause this degree of shift, a second attempt to acquire usable standard counts is permissible. If instability is suspected, four or five sets of standard counts may be performed. If the highest and lowest counts are different by more than 25 for density or 12 for moisture, the device is to be returned to the Materials and Testing Section for a complete stability check. If over a period of several months, the cumulative shift in standard counts exceeds 4% for moisture or 2% for density, the calibration of the device is to be checked.

C. Trench Offset Factor

Note A-3: *Prior to determining the trench offset factor, the standard count should be determined in accordance with Step III.A.1 - 12.*

1. Select a random test location at the area where the actual test will be taken.

2. Arrange the reference standard block and device in accordance with Step III.A.1 – 5, except that the reference standard block will be set at the exact location as selected for the test.
3. Press the **OFFSET** key to obtain the first display. The display will show the offset selections, similar to the following example.

Method A

OFFSET – Select:

- 1 – Dens. –OFF**
- 2 – Moist –OFF**
- 3 – Trench - OFF-**

4. Press the **3** key to select the trench offset. The resulting display will be similar to the following example.

**Trench Offset
DISABLED
Want to use
Trench Offset?**

5. Press the **YES** key to obtain the following display:

**Trench Offset
constant =
Want to change?**

6. Press the **YES** key to obtain the following display:

**Rod -> SAFE pos.
Press START for
1 min. STD cnt.
in trench.**

7. Press the **START** key to begin a one minute count. After counting down to zero, the display will be similar to the following example.

**New TR. Offset
constant =
Want to change?**

8. Press the **YES** key. The device will return to the **(READY)** mode.

Note A-4: *The trench offset factor must be changed for each new test location where the factor is required by repeating the preceding procedure.*

Note A-5: *Once enabled, the trench offset factor is retained in memory and will affect all future test results until the gauge is turned off or the function is disabled from the device keypad. Therefore, the trench offset must be disabled prior to performing the next test. Disable the trench offset factor by following Steps III.C.3 – 5, except that the **NO** key should be pressed in Step 5.*

IV. Procedure

A. Site Location

1. Select a test location greater than 2 m (6 ft) from an object. If the test location must be within 2 m (6 ft) of an object, standard moisture and density counts utilizing the trench offset procedure, outlined in Step III.C, shall be taken at each test location before density testing and shall not be entered in the Standard Count Log.
2. When it is not necessary to match the exact location at which the maximum dry weight density was determined, select the test site randomly in accordance with the Materials Sampling Manual.

Note A-6: *When in-place density is to be compared with moisture-density relationships determined in accordance with DOTD TR 415 for percent compaction, the test site for in-place density shall be the same location as the original site that material was obtained for the moisture-density relationships.*

B. Testing

Note A-7: *The nuclear device shall be set to obtain a one minute test count. The time for which the nuclear device is set will be displayed when it is in the (READY) mode. If the nuclear device does not indicate a one minute count, the Manual of Operation and Instruction shall be consulted for the method of resetting the time of the test count.*

1. Enter the maximum dry density, obtained from DOTD TR 418 or DOTD TR 415, into the nuclear device by pressing the **PROCTOR?MARSHALL** key. The display will show the last theoretical dry densities entered and a question, similar to the following example.

MA = 132.5
PR = 110.2
KD = 0.0
Do you want to
Make a change?

2. Press the **YES** key to make a change in the PR. The display will ask which one to change, similar to the following example.

**Which one to
change?**

1 – MA

2 – PR

3 – VOIDLESS

3. Select **2** and press ENTER, if required. The display will read similar to the following example.

PR = 110.2

Press ENTER

when complete.

Note A-8: Models may include additional steps which are not shown here. Contact the District Laboratory Engineer for guidance.

4. Enter the maximum dry density by pressing each number and decimal point in sequence on the keypad. The display will show the maximum dry density similar to the following example. Each number and the decimal point will be displayed as it is pressed.

Record the maximum dry density as PR on the worksheet.

PR = 116.5

5. Store the maximum dry density (PR) in the device memory by pressing the **ENTER** key. This maximum dry density will be used to determine the percent density until a new theoretical dry weight density is stored in memory. Record on the worksheet as PR.
6. Using the scraper plate, scrape and lightly tamp an area in an approximately 1 m (3 ft) diameter circle around the intended probe location. Remove all loose stones or surface materials and fill small voids with native fines or sand.
7. Seat the device solidly on the prepared site with the probe at the location of the intended access hole to check surface preparation and levelness. Mark location and orientation of the device, then remove it.
8. Density and Moisture Testing
 - a. Identify and set the test depth to be used.

Note A-9: The test depth shall be the deepest setting possible that will not penetrate beneath the lift of material being tested.

- b. Using the scraper plate/drill rod guide, the drill rod and maul, place the scraper plate at the location prepared in Step IV.B and punch an access hole. Punch the access hole at least 50 mm (2 in.) deeper than the test depth to be used. Place one foot on the rod guide plate while driving the rod into the material.

- c. Remove the rod by pulling straight up in order to avoid disturbing the access hole. Use the extraction tool, if necessary.
- d. Place the nuclear device on the prepared surface in the exact location and orientation as in Step IV.B.7. Insert the source rod into the access hole to the predetermined test depth.
- e. Seat the nuclear device solidly by rotating it about the source rod using a back and forth rotational motion. Be sure that the entire bottom of the device is in complete contact with the prepared surface of the material to be tested. The source rod must also be in contact with the side of the hole adjacent to the detector tube.
- f. After the device is seated, if there are still voids between the bottom of the nuclear device and the prepared surface to be tested, fill these minor depressions with native fines or sand, and reseal the nuclear device. Do not build up the area where the nuclear device is to be in contact with the surface.
- g. Press **START/ENTER** on the keypad to begin the test counts. The display will be similar to the following example.

Depth: 6 in.
PR: 116.5 PCF
Time: 60 sec

- h. After the 60 sec count period, the device will display percent density (%PR), dry density of test (DD), wet density of test (WD), the moisture in kg/m^3 (lb/ft^3) (M), and the percent moisture (%M). (%M is an instantaneous moisture and is not to be used in any calculations or as moisture control.) The display will appear similar to the following example.

%PR = 99.8%
DD = 116.3 PCF
WD = 122.5 PCF
M = 6.2 %M = 5.3

- i. Record the percent density of test as %NPR on the worksheet.
- j. Record the dry density of test as NDD for test 1 on the worksheet.
- k. Record the wet density of test as WD for test 1 on the worksheet.
- l. Record moisture in kg/m^3 (lb/ft^3) as M for test 1 on the worksheet. The value for DD should be verified to ensure accuracy of the value obtained due to possible rounding errors encountered with this model.

Note A-10: *To obtain the density test count (DC) and moisture test count (MC), the **SHIFT** key and sift function keys must be used. **SHIFT** and shift function keys are color coded yellow. The **SHIFT** key must be pressed before pressing a function key. Pressing the **SHIFT** key causes the display's top line to change to (**SHIFT/FUNCTION**). After the **SHIFT** key is pressed, you have four seconds to press the proper function key. If a function key is not pressed within four seconds, the device will react as if no key had been pressed.*

- m. Obtain the density count and moisture count by depressing the SHIFT key and the counts key (yellow coded on the top of the "1" key). The display will appear similar to the following example.

Dens ct. = 3666
Moist ct. = 185
SHIFT/RECALL to see Readings

- n. Record the density count as DC for test 1 on the worksheet.
o. Record the moisture count as MC for test 1 on the worksheet.
p. Repeat Steps IV.B.7 and IV.B.8 d – n for test 2 and 3, as outlined on page 1, and record on the worksheet. If the dry density of any test is more than 50 kg/m^3 (3 lb/ft^3) below the highest dry density of the three test, reseal the nuclear device in the same orientation as the original test and rerun that test to verify the results. Use the higher of the two test results (original and retest) to calculate percent density. Record retest on additional forms.

Note A-11: When a test is taken within 5 ft of a vertical surface, pipe, structure, etc. take only one test.

- q. Average the values of NDD and %NPR (if applicable) and record as ADD and %PR, respectively, on the worksheet.

*Note A-12: To recall the last test taken, press **SHIFT**, then press the **RECALL** key. The display will show the results of the last test taken, similar to the following example.*

%PR = 99.8%
DD = 116.3 PCF
WD = 122.5 PCF
M = 6.2 %M = 5.3

V. Report

- A. Optimum Moisture Content (OM) from DOTD TR 418 or TR 415 to the nearest 0.1%.
B. Average Dry Density (ADD) to the nearest 1 kg/m^3 (0.1 lb/ft^3).
C. Maximum Dry Density (PR) to the nearest 1 kg/m^3 (0.1 lb/ft^3).
D. Percent Density (%PR) to the nearest 0.1%.
E. Nuclear Device Number and Inspector Nuclear Film Badge Number.
F. Family of Curves Number (if applicable).

VI. Normal Test Reporting Time

Normal test reporting time is 20 minutes

MATT MENU SELECTION - 07

Louisiana Department of Transportation and Development
DENSITY & MOISTURE CONTENT WORK SHEET

DOTD 03-22- 0750
 Metric/ English
 Rev. 12/98

Metric/English (M or E) (Entry Field Located on Menu)

Project No. 999-99-9999 Date Tested 11/16/14 Material Code 421
 Submitted By D.O.T. Purpose Code 11 Spec. Code 3
 Test Method N N = Nuclear S = Sand Cone Item Number 13011(1011)
 Station Tested 114 + 35 Section & Test No. 108-1011

Location: _____		Lift No: _____		Depth of Test: _____	
OM:	Optimum % Moisture Content of Total Material (TR 415 or TR 418)	OM			
%FM:	Field % Moisture Content at Compaction (TR 403) (See back for calculations)	%FM			
P ₁ :	% Pulverization 19mm (3/4" SIEVE) (TR 431) (See back for calculations)	P ₁			<u>95</u>
P ₂ :	% Pulverization 4.75mm (NO.4 SIEVE) (TR 431) (See back for calculations)	P ₂			<u>57</u>
(TR 415) Cross Reference Test No. _____		Sta. No.: _____		Max. Dry Density Method <input type="checkbox"/>	
				(1 = TR 415 A 2 = TR 415 B 3 = TR 418)	
a:	Total Wet Mass (Wt.) of Sample				
b:	Mass (Wt.) of +4.75 (+4) Material				
c:	% By Mass (Wt.) of 4.75 (+4) Retained (100 b/a)				
d:	Mass (Wt.) of Mold & Soil				
e:	Mass (Wt.) of Mold				
f:	Mass (Wt.) of Compacted Soil (d - e)				
g:	Wet Density (f / 0.944) or (f / 2.832) or (f / 2.124) (f x 30) or (f x 10) or (f / 0.073)				
h:	Mass (Wt.) of Wet Soil				
i:	Mass (Wt.) of Dry Soil				
j:	Mass (Wt.) of Water (h - i)				
k:	% Moisture Content (100 j/i) (TR 403)				
l:	Dry Density 100g / (100 + k)				
om (from Family of Curves): _____		pr (from Family of Curves): _____		FAMILY OF CURVES ZONE NUMBER <input type="checkbox"/>	
SAND METHOD (TR 401)		NUCLEAR METHOD (TR 401)			
SA: Mass (Wt.) of Sand in Mold		Nuclear Device Number _____	Test 1	Test 2	Test 3
SB: Vol. of Mold		Insp. (Nuclear Badge No.) _____			
SC: Unit Mass (Wt.) of Sand (SA/SB)		DS: Density Standard Count	<u>3540</u>	<u>3540</u>	<u>3540</u>
SD: Orig. Mass (Wt.) of Sand		DC: Density Test Count	<u>3666</u>	<u>3645</u>	<u>3690</u>
SE: Final Mass (Wt.) of Sand		DR: Density Count Ratio (DC / DS)	<u>1.036</u>	<u>1.030</u>	<u>1.042</u>
SF: Mass (Wt.) of Sand in Cone (SD-SE)		WD: Wet Density	<u>122.5</u>	<u>123.0</u>	<u>122.0</u>
SG: Orig. Mass (Wt.) of Sand		MS: Moisture Standard Count	<u>660</u>	<u>660</u>	<u>660</u>
SH: Final Mass (Wt.) of Sand		MC: Moisture Test Count	<u>185</u>	<u>189</u>	<u>187</u>
SI: Mass (Wt.) of Sand in Cone & Hole (SG-SH)		MR: Moisture Count Ratio (MC / MS)	<u>0.280</u>	<u>0.286</u>	<u>0.283</u>
SJ: Mass (Wt.) of Sand in Hole (SI-SF)		M: Moisture by Mass (Wt.)	<u>6.2</u>	<u>6.4</u>	<u>6.3</u>
SV: Vol. of Hole (SJ/SC)		MP: Moisture by Percent - TR 401 <input type="checkbox"/> / TR 403 <input type="checkbox"/>	<u>5.3</u>	<u>5.5</u>	<u>5.4</u>
SW: Dry Mass (Wt.) of Material		NDD: Dry Density (WD - M) or $\frac{100 \times WD}{100 + MP}$	<u>116.3</u>	<u>116.6</u>	<u>115.7</u>
SDD: Dry Density (SW / SV)	<u>116.1</u>	%NPR: % Density (NDD / PR) x 100	<u>99.8</u>	<u>100.1</u>	<u>99.3</u>
PR: Maximum Dry Dens. (TR 415 / TR 418)	<u>116.1</u>	ADD: Average Dry Density (NDD) or (NDD/3)	<u>111.61.12</u>		
%PR: % Density (Sand) (SDD / PR) x 100	<u>99.1</u>	PR: Maximum Dry Density (TR 415/TR 418)	<u>111.61.15</u>		
		%PR: % Dens.(Nuclear) (% NPR) or (% NPR/3)	<u>99.1.17</u>		

Remarks _____ (Signature)

Density & Moisture Content Worksheet – Front
 Figure A-1

Pulverization, P₁ and P₂ (TR 431)

* Test No.	* Utilize as many columns as necessary per test section.		1	2	3	4
Adjusted Wet Mass (Wt) Sample (A)			1984			
Mass (Wt) of + 19 mm (3/4 in) Material (B ₁)			95			
Mass (Wt) of + 4.75 mm (No. 4) Material (B ₂)			750			
% Pulverization 19 mm (3/4 in) (P ₁)	$100 \times \frac{(A - B_1)}{A}$		95%			
% Pulverization 4.75 mm (No. 4) (P ₂)	$100 \times \frac{A - (B_1 + B_2)}{A}$		57%			

Field Moisture Content at Compaction, % FM (TR 403)

* Test No.	* Utilize as many columns as necessary per test section.		1	2	3	4
Total Wet Mass (Wt) of Matl. at Compaction (A)						
Total Dry Mass (Wt) of Matl. at Compaction (B)						
Mass (Wt) of Water (C)	(A - B)					
% Field Moisture Content (% FM)	$100 \times \frac{C}{B}$					

**Optimum Moisture and Maximum Dry Density Adjustments
 for Material Containing 20% - 60 % Siliceous Aggregate
 (TR 415)**

		1	2	3
Optimum % Moist. of Tot. Material, (OM)	$OM = \left[\left(\frac{100 - c}{100} \right) \times om \right] + \frac{c}{100}$			
Maximum Dry Density, lb/ft ³ (PR) (English)	$PR = \frac{160 \times pr \times z}{\frac{c}{100} \times pr \times z + [160 \times (1 - \frac{c}{100})]}$			
Maximum Dry Density, kg/m ³ (PR) (Metric)	$PR = \frac{2564 \times pr \times z}{\frac{c}{100} \times pr \times z + [2564 \times (1 - \frac{c}{100})]}$			

**Density & Moisture Content Worksheet – Back
 Figure A-1**

METRIC/ENGLISH

DOTD Designation: TR 401-02
Method B – Troxler Model 3411

I. Scope

- A. This method of test is designed to determine the in-place density of soils, aggregates, or soil-aggregate mixtures, untreated, treated or stabilized, using the Troxler Model 3411 nuclear device.
- B. Reference Documents
 - 1. DOTD TR 403 – Determination of Moisture Content.
 - 2. DOTD TR 415 – Field Moisture – Density Relationships.
 - 3. DOTD TR 418 – Moisture – Density Relationships.

II. Apparatus

- A. **Approved Troxler Model 3411 nuclear device** – with locks and keys.
- B. **Operator’s manual** – for nuclear device.
- C. **Transport case** – for nuclear device, with locks and keys.
- D. **Reference standard block**
- E. **Scraper plate/drill rod guide**
- F. **19 mm (¾-inch) drill rod or 19 mm (¾-inch) auger.**
- G. **Extraction tool** (optional)
- H. **Standard Count Log**
- I. **Operator’s nuclear film badge and operator’s license**
- J. **Dry fine sand**
- K. **Hand tools** – 2 - 3 kg (4 – 6 lb) maul, shovel, straightedge
- L. **Worksheet** – Moisture and Density Content Worksheet, DOTD Form No. 03-22-0750 (Figure B-1)

I. Standardization

- A. Procedure
 - 1. Activate the device by turning the **POWER/TIME** switch with positions **OFF, NORM, SLOW, or FAST** to **SLOW**. The **PWR/TIME** switch turns the unit on and selects the time period for an accumulation. The **SLOW, NORM, or FAST** positions correspond to periods of 4, 1, or 0.25 min, respectively for accumulation purposes.
 - 2. Warm up the device for at least 10 min after turning it on before taking any count. Use the **SLOW** position for all standard counts; use **NORM** position for all test counts.
 - 3. With the probe retracted, clean the top of the reference standard block, being sure that there is no soil or other material which would prevent a good seat between the device and the block.
 - 4. With the probe retracted, clean the base of the device, being sure that there is no soil or other material which would prevent a good seat between the device and the block.
 - 5. Place the reference standard block on the compacted material with a minimum density of 1600 kg/m³ (100 lb/ft³) at least 2 m (6 ft) from any large object and at least 10 m (30

ft) from any other nuclear device. Any time a test is to be performed in an area with less than a 2 m (6 ft) clearance from an object (e.g., near a wall, pipe, vehicle or in a trench), the standard counts shall be taken on the same place as the test counts and for each test and shall not be entered in the standard count log.

6. Place the device on the reference standard block with the source rod in **SAFE** position, making sure there is a good seat between the device and the block.

***Note B-1:** The keyboard is color coded for ease of use. Five keys have dual functions. The large yellow **SHIFT** key determines the mode of the dual function keys. The functions labeled in yellow (**STANDARD**, **%MA**, **%PR**, and **TST**) are operational when the shift key is depressed. The functions labeled in white are operational when the shift key is not depressed.*

7. Take a set of standard counts as follows:
 - a. Turn the **POWER/TIME** switch to **SLOW**.
 - b. Depress and hold the key labeled **SHIFT**.
 - c. Depress the **STANDARD** key and release it.
 - d. Release the **SHIFT** key.
 - e. At the end of the **SLOW TIME PERIOD** (4 min), the standard count will be retained in memory until another set of counts is taken or the device is turned off.
 - f. To obtain the density standard count, depress the key labeled **DS**. The number which appears in the instrument display is the density standard count.
 - g. To obtain the moisture standard count, depress the key labeled **MS**. The number which appears in the instrument display is the moisture standard count.
8. Record the density standard count as **DS** on the worksheet. Record the moisture standard count as **MS** on the worksheet. Record both standard counts in the Standard Count Log.

B. Frequency

1. Take standard counts at least once each day; when the gauge has been idle for 4 hr or more or when test results are suspected of being in error.
2. If tests are to be taken where the nuclear device must be placed less than 2 m (6 ft) from an object (e.g., near a wall or in a trench), the density and moisture counts shall be taken at each test location. These counts shall not be entered in the Standard Count Log.
3. If the day-to-day shift in the standard count is greater than 2% for moisture or 1% for density as compared to the average of the previous four sets, there is a possibility of a device malfunction or operator error in placing the device on the standard block. Since the radiation source may cause this degree of shift, a second attempt to acquire usable standard counts is permissible. If instability is suspected, four or five sets of standard counts may be performed. If the highest and lowest counts are different by more than 25 for density or 12 for moisture, the device is to be returned to the DOTD Materials and Testing Section for a complete stability check. If over a time period of several months, the cumulative shift in standard counts exceeds 4% for moisture or 2% for density, the calibration of the device is to be checked.

II. Procedure

A. Site Location

1. Select a test location greater than 2 m (6 ft) from an object. If the test location must be within 2 m (6 ft) of an object, standard moisture and density counts shall be taken at each test location before density testing and shall not be entered in the standard count log.
2. When it is not necessary to match the exact location at which the maximum dry density was determined, select the test site randomly in accordance with the Materials Sampling Manual.

Note B-2: When in-place density is to be compared with moisture-density relationships determined in accordance with DOTD TR 415 for percent compaction, the test site for in-place density shall be the same location as the original site that material was obtained for the moisture-density relationships.

B. Testing

Note B-3: The Model 3411 nuclear density gauge can display density results in either pounds per cubic foot or kilograms per cubic meter. The "PCF-SI" Switch is located on the underside of the scaler board, and can be accessed by removing the four knurled screws at each corner of scaler. Placing the switch in the PCF position will cause the gauge to display densities in lb/ft³, and the SI position will display densities in kg/m³. The DEPTH switch on the Model 3411 gauge is incremented in inches and cannot be set to display metric units. The following represent metric equivalents to the settings on the DEPTH switch.

2 in.	=	50 mm
4 in.	=	100 mm
6 in.	=	150 mm
8 in.	=	200 mm
10 in.	=	250 mm
12 in.	=	300 mm

1. Warm up the equipment at least ten minutes.
2. Set the control functions as follows.
 - a. Set the **POWER/TIME** switch to **NORM**.
 - b. Set the **DEPTH** switch to the specified depth for the test.

Note B-4: The test depth shall be the deepest setting possible that will not penetrate beneath the lift of material being tested.

- c. Set the moisture correction switches to +, **0**, and **0**, respectively.
3. Test Site Preparation

- a. Using the scraper plate, scrape and lightly tamp an area in an approximately 1 m (3 ft) diameter circle around the intended probe location. Remove all loose stones or surface materials and fill small voids with native fines or sand.
 - b. Using the scraper plate/drill rod guide, the drill rod and maul, place the scraper plate at the location prepared in Step IV.B.3.a and punch an access hole. Punch the access hole at least 50 mm (2 in.) deeper than the test depth to be used. Place one foot on the rod guide plate while driving the rod into the material.
 - c. Remove the rod by pulling straight up in order to avoid disturbing the access hole, using the extraction tool, if necessary.
 - d. Place the nuclear device on the prepared surface in the exact location and orientation as in Step 3.b., with the source rod inserted in the access hole to the predetermined test depth.
 - e. Seat the nuclear device solidly by rotating it about the source rod using a back and forth rotational motion. Be sure that the entire bottom of the device is in complete contact with the prepared surface of the material to be tested. The source rod must also be in contact with the side of the hole adjacent to the detector tube.
 - f. After the device is seated, if there are still voids between the bottom of the device and the prepared surface to be tested, fill these minor depressions with native fines or sand, and reseal the device. Do not build up the area where the device is to be in contact with the surface.
4. Density and Moisture Testing
- a. Push the **MEASURE** button to begin the test counts.
 - b. When the device stops counting, the timing period has expired. Depress the button labeled DC to obtain the density test count. Record the density test count as DC for test 1 on the worksheet.
 - c. Depress the button labeled MC for the moisture test count and record the moisture test count as MC for test 1 on the worksheet.
 - d. Depress WD for wet density in kilograms per cubic meter (pounds per cubic foot). Record wet density as WD for test 1 on the worksheet.
 - e. Depress **WD** for moisture content in kilograms per cubic meter (pounds per cubic feet) and record as M for test 1 on the worksheet.
 - f. Depress **DD** for dry density and record as NDD for test 1 on the worksheet.
 - g. Repeat Steps 3.b and 3.e – 4.f for tests 2 and 3, as outlined in the introduction, and record.

Note B-5: When test is taken within 2 m (6 ft) of a wall, pipe, or other structure, take only one test.

- h. Calculate %NPR for each test and record.
- i. Average the values of NDD and %NPR (if applicable) and record as ADD and %PR, respectively, on the worksheet. If the dry density of any test is more than 50 kg/m³ (3 lb/ft³) below the highest dry density of the three tests, reseal the device in the same orientation as the original test and rerun that test to verify the results. Use the higher of the two test results (original and retest) to calculate percent density. Record restarts on additional form.

V. Calculations

Calculate the percent density (%NPR) using the following formula.

$$\%NPR = \frac{NDD}{PR} \times 100$$

Where:

PR = theoretical dry density, kg/m³ (lb/ft³)

ND = dry density of test, kg/m³ (lb/ft³)

III. Report

- A. Optimum moisture content (OM) DOTD TR 418 or TR 415 to the nearest 0.1%.
- B. Average dry density (ADD) to the nearest 1 kg/m³ (0.1 lb/ft³).
- C. Maximum dry density (PR) to the nearest 1 kg/m³ (0.1 lb/ft³).
- D. Percent density (%PR) to the nearest 0.1%.
- E. Nuclear device number and Inspector Nuclear Film Badge number.
- F. Family of curves number (if applicable).

VI. Normal Test Reporting Time

Normal test reporting time is 20 minutes.

MATT MENU SELECTION - 07

Louisiana Department of Transportation and Development
DENSITY & MOISTURE CONTENT WORK SHEET

DOTD 03-22-0750
 Metric/ English
 Rev. 12/98

Metric/English (M or E) (Entry Field Located on Menu)
 Project No. 9999999999 Date Tested 11/16/19 Material Code 421
 Submitted By 010711 Purpose Code Spec. Code 3
 Test Method N N = Nuclear S = Sand Cone Item Number 3011(011)
 Station Tested 114 + 35 Section & Test No. 108-1001

Location: _____		Lift No: _____		Depth of Test: _____	
OM:	Optimum % Moisture Content of Total Material (TR 415 or TR 418)	OM			<u>11</u>
%FM:	Field % Moisture Content at Compaction (TR 403) (See back for calculations)	%FM			<u>11</u>
P ₁ :	% Pulverization 19mm (3/4" SIEVE) (TR 431) (See back for calculations)	P ₁			<u>95</u>
P ₂ :	% Pulverization 4.75mm (NO.4 SIEVE) (TR 431) (See back for calculations)	P ₂			<u>57</u>
(TR 415) Cross Reference Test No. _____		Sta. No.: _____		Max. Dry Density Method <input type="checkbox"/>	
				(1 = TR 415 A 2 = TR 415 B 3 = TR 418)	
a:	Total Wet Mass (Wt.) of Sample				
b:	Mass (Wt.) of +4.75 (+4) Material				
c:	% By Mass (Wt.) of 4.75 (+4) Retained (100 b/a)				
d:	Mass (Wt.) of Mold & Soil				
e:	Mass (Wt.) of Mold				
f:	Mass (Wt.) of Compacted Soil (d - e)				
g:	Wet Density (f / 0.944) or (f / 2.832) or (f / 2.124) (f x 30) or (f x 10) or (f / 0.075)				
h:	Mass (Wt.) of Wet Soil				
i:	Mass (Wt.) of Dry Soil				
j:	Mass (Wt.) of Water (h - i)				
k:	% Moisture Content (100 j/i) (TR 403)				
l:	Dry Density 100g / (100 + k)				

om (from Family of Curves): _____ pr (from Family of Curves): _____ FAMILY OF CURVES ZONE NUMBER

SAND METHOD (TR 401)		NUCLEAR METHOD (TR 401)			
SA: Mass (Wt.) of Sand in Mold		Nuclear Device Number <input type="checkbox"/>			
SB: Vol. of Mold		Insp. (Nuclear Badge No.) <input type="checkbox"/>			
SC: Unit Mass (Wt.) of Sand (SA/SB)		DS: Density Standard Count	<u>3540</u>	<u>3540</u>	<u>3540</u>
SD: Orig. Mass (Wt.) of Sand		DC: Density Test Count	<u>3666</u>	<u>3645</u>	<u>3690</u>
SE: Final Mass (Wt.) of Sand		DR: Density Count Ratio (DC / DS)	<u>1.036</u>	<u>1.030</u>	<u>1.042</u>
SF: Mass (Wt.) of Sand in Cone (SD-SE)		WD: Wet Density	<u>122.5</u>	<u>123.0</u>	<u>122.0</u>
SG: Orig. Mass (Wt.) of Sand		MS: Moisture Standard Count	<u>660</u>	<u>660</u>	<u>660</u>
SH: Final Mass (Wt.) of Sand		MC: Moisture Test Count	<u>185</u>	<u>189</u>	<u>187</u>
SI: Mass (Wt.) of Sand in Cone & Hole (SG-SH)		MR: Moisture Count Ratio (MC / MS)	<u>0.280</u>	<u>0.286</u>	<u>0.283</u>
SJ: Mass (Wt.) of Sand in Hole (SI-SF)		M: Moisture by Mass (Wt.)	<u>6.2</u>	<u>6.4</u>	<u>6.3</u>
SV: Vol. of Hole (SJ/SC)		MP: Moisture by Percent - TR 401 <input type="checkbox"/> / TR 403 <input type="checkbox"/>	<u>5.3</u>	<u>5.5</u>	<u>5.4</u>
SW: Dry Mass (Wt.) of Material		NDD: Dry Density (WO - M) or $\frac{100 \times WD}{100 + MP}$	<u>116.3</u>	<u>116.6</u>	<u>115.7</u>
SDD: Dry Density (SW / SV)	<input type="checkbox"/>	%NPR: % Density (NDD / PR) x 100	<u>99.8</u>	<u>100.1</u>	<u>99.3</u>
PR: Maximum Dry Dens. (TR 415 / TR 418)	<input type="checkbox"/>	ADD: Average Dry Density (NDD) or (NDD/3)	<u>1116.12</u>		
%PR: % Density (Sand) (SDD / PR) x 100	<input type="checkbox"/>	PR: Maximum Dry Density (TR 415/TR 418)	<u>1116.15</u>		
		%PR: % Dens.(Nuclear) (% NPR) or (% NPR/3)	<u>99.17</u>		

Remarks _____
 _____ (Signature)

Density & Moisture Content Worksheet – Front
 Figure B-1

Pulverization, P ₁ and P ₂ (TR 431)						
Test No.	Utilize as many columns as necessary per test section.		1	2	3	4
Adjusted Wet Mass (Wt) Sample (A)			1984			
Mass (Wt) of + 19 mm (3/4 in) Material (B ₁)			95			
Mass (Wt) of + 4.75 mm (No. 4) Material (B ₂)			750			
% Pulverization 19 mm (3/4 in) (P ₁)	$100 \times \frac{(A - B_1)}{A}$		95%			
% Pulverization 4.75 mm (No. 4) (P ₂)	$100 \times \frac{A - (B_1 + B_2)}{A}$		57%			

Field Moisture Content at Compaction, % FM (TR 403)						
Test No.	Utilize as many columns as necessary per test section.		1	2	3	4
Total Wet Mass (Wt) of Matl. at Compaction (A)						
Total Dry Mass (Wt) of Matl. at Compaction (B)						
Mass (Wt) of Water (C)	(A - B)					
% Field Moisture Content (% FM)	$100 \times \frac{C}{B}$					

Optimum Moisture and Maximum Dry Density Adjustments for Material Containing 20% - 60 % Siliceous Aggregate (TR 415)				
		1	2	3
Optimum % Moist. of Tot. Material, (OM)	$OM = \left[\left(\frac{100 - c}{100} \right) \times om \right] + \frac{c}{100}$			
Maximum Dry Density, lb/ft ³ (PR) (English)	$PR = \frac{160 \times pr \times z}{\frac{c}{100} \times pr \times z + [160 \times (1 - \frac{c}{100})]}$			
Maximum Dry Density, kg/m ³ (PR) (Metric)	$PR = \frac{2564 \times pr \times z}{\frac{c}{100} \times pr \times z + [2564 \times (1 - \frac{c}{100})]}$			

Density & Moisture Content Worksheet - Back
 Figure B-1

DOTD Designation: TR 401
Method C – HUMBOLDT MODEL HS-5001 EZ

I. Scope

- A. This method of test is designed to determine the in-place density of soils, aggregates, or soil-aggregate mixtures, untreated, treated or stabilized, using the Humboldt Model HS-5001 EZ nuclear device
- B. Reference Documents
 - 1. DOTD TR 403 – Determination of Moisture Content.
 - 2. DOTD TR 415 – Field Moisture – Density Relationships.
 - 3. DOTD TR 418 – Moisture – Density Relationships.

II. Apparatus

- A. **Approved Humboldt Model HS-5001 EZ nuclear device** – with locks and keys.
- B. **Operator’s manual** – for nuclear device.
- C. **Transport case** – for nuclear device, with locks and keys.
- D. **Reference standard block**
- E. **Scraper plate/drill rod guide**
- F. **19 mm (¾-inch) drill rod or 19 mm (¾-inch) auger.**
- G. **Extraction tool** (optional)
- H. **Standard Count Log**
- I. **Operator’s nuclear film badge and operator’s license**
- J. **Dry fine sand**
- K. **Hand tools** – 2 - 3 kg (4 – 6 lb) maul, shovel, straightedge
- L. **Calibration charts** – for density and moisture
- M. **Worksheet** – Moisture and Density Content Worksheet, DOTD Form No. 03-22-0750 (Figure C-1 front and back)

III. Standardization

- A. Procedure
 - 1. Turn the device on by pressing the **PWR** key. Allow the device to warm up for fifteen (15) minutes. The device will automatically go through a five second self-test routine.

Note C-1: Do not turn the device off while the self-test display is on. Turning the device off while the self-test display is on may result in the loss of device memory.

- 2. Clean the top of the reference standard block, being sure that there is no soil or other material which would prevent a good seat between the device and the block.
- 3. With the probe retracted, clean the base of the device, being sure that there is no soil or other material which would prevent a good seat between the device and the block.
- 4. Place the reference standard on the compacted material with a minimum density of 1600 kg/m³ (100 lb/ft³), at least 2 m (6 ft) from any large object and at least 10 m (30 ft) from any other nuclear device. When a test is to be performed in an area with less than a 2 m (6 ft) clearance from an object (e.g., near a wall, pipe, vehicle, or in a trench), the

trench offset factor, as determined in Step III.C should be utilized at the exact location as the test counts and shall not be entered in the Standard Count Log.

5. Place the device on the reference standard block with the source rod in **SAFE** position making sure there is a good seat between the device and the block. The label on the end of the gauge should be on the same end as the label on the standard block. The front of the gauge should be in contact with the label plate on the standard block.
6. Press the STD STAT key to begin the standard counts. The display will show the standard counts and offer two alternatives, similar to the following example.

DS = 3560 09/14/01
MS = 640 08:31
*** TAKE NEW STD**
*** USE CURRENT STD**

7. Press the **F3** key to take a new count and obtain the second display. The display will be similar to the following example.

TAKING STANDARD
TIME REMAINING 4:00
DS = 0000
MS = 000 Depth = SAF

8. When the standard count is completed, the device will beep and display the results of a four-minute standard count. If there are no errors, the results will be similar to the following example:

STD TEST RESULT
DS = 3540
MS = 660

Note C-2: If there is an error, the display will read similar to the following:

DS = 3500 %ERR = 1.0
MS = 640 %ERR = 3.0
***REJECT & TAKE NEW STANDARD**
***RETAIN THE NEW STANDARD**

The %ERR to the right of the density and moisture standard counts indicate that the new counts exceed the 1% density and 2% moisture limits from the average standard counts stored in the memory. If the display shows a %ERR for either or both standard counts, check the following causes and correct:

- *Other nuclear devices nearby*
- *Device not seated solidly on the reference block*

- *Device base or top of reference block not clean*
 - *Reference block not the correct one for the nuclear device.*
9. If the above conditions are normal, press **F4** (*RETAIN THE NEW STANDARD) and obtain a new standard count in accordance with Step III.A.7. Obtain new standard counts until the %ERR are within the limits shown in Step III.B.3 or until the fourth attempt is made. If, after four trials, the error still appears in the display, contact the District Laboratory Engineer or return the device to the Materials and Testing Section for evaluation.
 10. When the display indicates that the density and moisture standard counts (DS & MS) are within passing limits as shown in Step 8, continue to take new standard counts until the gauge produces four consecutive passing standards. Record the value displayed after the last attempt as DS and MS on the worksheet. These counts shall also be recorded on the Standard Count Log available with each device.

A. Frequency

1. Take standard counts at least once each day when the nuclear device has been idle for 4hr or more or when test results are suspected of being in error.
2. If tests are to be taken where the nuclear device must be placed less than 2 m (6 ft) from an object (e.g., near a wall or in a trench), determine the density and moisture standard counts at each test location, using the trench offset factor procedure, outlined in Step III.C. These counts are not to be entered in the Standard Count Log.
3. If the day-to-day shift in standard counts is greater than 2% for moisture or 1% for density, as compared to the average of the previous four sets, there is a possibility of a device malfunction or operator error in placing the device on the standard block. Since the radiation source may cause this degree of shift, a second attempt to acquire usable standard count is permissible. If instability is suspected, four or five sets of standard counts may be performed. If the highest and lowest counts are different by more than 25 for density or 12 for moisture, the device is to be returned to the Materials and Testing Section for a complete stability check. If, over a period of several months, the cumulative shift in standard counts exceeds 4% for moisture or 2% for density, the calibration of the device is to be checked.

C. Trench Offset Factor

Note C-3: *Prior to determining the trench offset factor, the standard count should be determined in accordance with Steps III.A. 1 – 10.*

1. Select a random test location at the area where the actual test will be taken.
2. Arrange the reference standard block and device in accordance with Steps III.A.1 – 5, except that the reference standard block will be set at the exact location as selected from the test.
3. Press the **Main Menu** key to obtain the first display as follows:

*** DATA 09/14/01**
*** SETUP 10:22**
*** ENGINEERING**
DEPTH = SAF

4. Press **F2** (*SETUP) to obtain the following display:

*** SETUP 2**
*** SET MEASURE MODES**
*** SET TRNCH COR.**
*** SET TARGETS**

5. Press **F3** (SET TRNCH COR.).

*** Place Rod in SAFE**
*** Place Ref in Trench**
*** Place gauge on Ref**
*** Press F4 to Begin**

6. Press the **F4** key to begin the four-minute count. The resulting display will be similar to the following:

Trench Connection
Time Remaining: 4:00
DC = 3650
MC = 720
Depth = SAF

7. When the four-minute count is complete, the display will be similar to the following:

Trench Connection
Trench CF = -341.
Ready for Measure

***Note C-4:** The trench offset factor must be changed for each new test location where the factor is required by repeating the preceding procedure.*

***Note C-5:** Once enabled, the trench offset factor is retained in memory and will affect all future test results until the gauge is turned off or the function is disabled from the setup menu. Therefore, a new standard count must be taken prior to performing tests outside the trench by following Steps III.A.3 – 10.*

IV. Procedure

A. Site Location

1. Select a test location greater than 2 m (6 ft) from an object. If the test location must be within 2 m (6 ft) of an object, standard moisture and density counts utilizing the trench offset procedure, outlined in Step II.C, shall be taken at each location before density testing and shall not be entered in the Standard Count Log.
2. When it is not necessary to match the exact location at which the maximum dry density was determined, select the test site randomly in accordance with the Materials Sampling Manual.

Note C-6: *When in-place density is to be compared with moisture-density relationships determined in accordance with DOTD TR 415 for percent compaction, the test site for in-place density shall be the same location as the original site that material was obtained for the moisture-density relationships.*

B. Testing

Note C-7: *The nuclear device shall be set to operate in the required units of measure, whether metric or English units, and to obtain a one-minute test count. The device will display densities in either kg/m^3 or lb/ft^3 . Refer to the Humboldt model HS-5001 EZ User Guide for the methods of resetting the units of measure and the time of the test count if these changes are needed.*

1. Enter the maximum dry density, obtained from DOTD TR 418 or DOTD TR 415, into the nuclear device by pressing the **MAX "D"** key. The display will show the last maximum dry density entered. If not correct, press **F3** to increase the value or **F4** to decrease the value.
2. Using the scraper plate, scrape and lightly tamp an area approximately 1 m (3 ft) diameter circle around the intended probe location. Remove all loose stones or surface materials and fill small voids with native fines or sand.
3. Seat the device solidly on the prepared site with the probe at the location of the intended access hole to check surface preparation and levelness.
4. Density Testing
 - a. Identify and set the test depth to be used.

Note C-8: *The test depth shall be the deepest setting possible that will not penetrate beneath the lift of material being tested.*

- b. Using the scraper plate/drill rod guide, the drill rod and maul, place the scraper plate at the location prepared in Steps IV.B.2 & 3 and punch an access hole. Punch the access hole at least 50 mm (2 in.) deeper than the test depth to be used. Place one foot on the rod guide plate while driving the rod into the material.
- c. Remove the rod by pulling straight up in order to avoid disturbing the access hole. Use the extraction tool, if necessary.
- d. Place the nuclear device on the prepared surface in the exact location and orientation as in Step IV.B.3. Insert the source rod into the access hole to the predetermined test depth.

- e. Seat the nuclear device solidly by rotating it about the source rod using a back and forth rotational motion. Be sure that the entire bottom of the device is in complete contact with the prepared surface of the material to be tested. The source rod must also be in contact with the side of the hole adjacent to the detector tube.
- f. After the device is seated, if there are still voids between the bottom of the device and the prepared surface to be tested, fill these minor depressions with native fines or sand, and reseal the device. Do not build up the area where the device is to be in contact with the surface.
- g. Push the MEAS on the keypad to begin the test counts. The display will be similar to the following example.

TAKING MEASUREMENT
TIME REMAINING 1:00
DC = 3540
MC = 660 DEPTH = 8

- h. After the 60 sec count period, the device will display percent density (%PR), dry density of test (DD), wet density of test (WD), the moisture in kg/m³ (lb/ft³) (M), and the percent moisture (%M). (%M is an instantaneous moisture and is not to be used in any calculations or as moisture control.) The display will appear similar to the following example.

DD=116.3 %M=5.3
WD=122.5 M=62
%PR=99.8 Max D=116.5
***NEXT MDEPTH = 8**

- i. Record the percent density of test as %NPR on the worksheet.
- j. Record the dry density of test as NDD for test 1 on the worksheet.
- k. Record the wet density of test as WD for test 1 on the worksheet.
- l. Record moisture in kg/m³ (lb/ft³) as M for test 1 on the worksheet. The value for DD should be verified to ensure accuracy of the value obtained due to possible rounding errors encountered with this model.
- m. Obtain the density count and moisture count by depressing **F4 (*NEXT)**. The display will appear similar to the following example.

DC = 3666 DS = 3540
MC = 185 MS = 660
VR = 0.35 %AV = 31.6
***LAST MDEPTH = 8**

- n. Record the density count as DC for test 1 on the worksheet.
- o. Record the moisture count as MC for test 1 on the worksheet.
- p. Repeat Steps IV.B.7 and IV.B.8 d –n for tests 2 and 3, as outlined on page 1, and record on the worksheet. If the dry density of any test is more than 50 kg/m³ (3

lb/ft³) below the highest dry density of the three tests, reseal the nuclear device in the same orientation as the original test and rerun that test to verify the results. Use the higher of the two test results (original and retest) to calculate percent density. Record retest on additional forms.

Note C-9: When a test is taken within 2 m (6 ft) of a vertical surface, pipe, structure, etc. take only one test.

- q. Average the values of NDD and % NPR (if applicable) and record as ADD and %PR, respectively, on the worksheet.

Note C-10: To recall the density and moisture results from Step h, press F4.

V. Report

- A. Optimum moisture content (OM) DOTD TR 418 or TR 415 to the nearest 0.1%.
- B. Average dry density (ADD) to the nearest 1 kg/m³ (0.1 lb/ft³).
- C. Maximum dry density (PR) to the nearest 1 kg/m³ (0.1 lb/ft³).
- D. Percent density (% PR) to the nearest 0.1%.
- E. Nuclear device number and Inspector Nuclear Film Badge number.
- F. Family of curves number (if applicable).

VI. Normal Test Reporting Time

Normal test reporting time is 20 minutes.

MATT MENU SELECTION - 07

Louisiana Department of Transportation and Development
 DENSITY & MOISTURE CONTENT WORK SHEET

DOTD 03-22-0750
 Metric/English
 Rev. 12/98

Metric/English (M or E) (Entry Field Located on Menu)

Project No. 999-99-99999, Date Tested 11/16/94, Material Code 4211
 Submitted By 00711, Purpose Code , Spec. Code 3
 Test Method N N = Nuclear S = Sand Cone Item Number 3011(011)
 Station Tested 114 + 35 Section & Test No. 108-1001

Location: _____		Lift No: _____		Depth of Test: _____	
OM: Optimum % Moisture Content of Total Material (TR 415 or TR 418)	OM	.			
%FM: Field % Moisture Content at Compaction (TR 403) (See back for calculations)	%FM	.			
P ₁ : % Pulverization 19mm (3/4" SIEVE) (TR 431) (See back for calculations)	P ₁	9 5			
P ₂ : % Pulverization 4.75mm (NO.4 SIEVE) (TR 431) (See back for calculations)	P ₂	5 7			
(TR 415) Cross Reference Test No. _____	Sta. No.: _____	Max. Dry Density Method <input type="checkbox"/> (1 = TR 415 A 2 = TR 415 B 3 = TR 418)			
a: Total Wet Mass (Wt.) of Sample					
b: Mass (Wt.) of +4.75 (+4) Material					
c: % By Mass (Wt.) of 4.75 (+4) Retained (100 b/a)					
d: Mass (Wt.) of Mold & Soil					
e: Mass (Wt.) of Mold					
f: Mass (Wt.) of Compacted Soil (d - e)					
g: Wet Density (f / 0.944) or (f / 2.832) or (f / 2.124) (f x 30) or (f x 10) or (f / 0.075)					
h: Mass (Wt.) of Wet Soil					
i: Mass (Wt.) of Dry Soil					
j: Mass (Wt.) of Water (h - i)					
k: % Moisture Content (100 j/i) (TR 403)					
l: Dry Density 100g / (100 + k)					
om (from Family of Curves): _____		pr (from Family of Curves): _____		FAMILY OF CURVES ZONE NUMBER <input type="checkbox"/>	
SAND METHOD (TR 401)			NUCLEAR METHOD (TR 401)		
SA: Mass (Wt.) of Sand in Mold		Nuclear Device Number <input type="checkbox"/>	Test 1	Test 2	Test 3
SB: Vol. of Mold		Insp. (Nuclear Badge No.) <input type="checkbox"/>			
SC: Unit Mass (Wt.) of Sand (SA/SB)		DS: Density Standard Count	3540	3540	3540
SD: Orig. Mass (Wt.) of Sand		DC: Density Test Count	3666	3645	3690
SE: Final Mass (Wt.) of Sand		DR: Density Count Ratio (DC / DS)	1.056	1.030	1.042
SF: Mass (Wt.) of Sand in Cone (SD-SE)		WD: Wet Density	122.5	123.0	122.0
SG: Orig. Mass (Wt.) of Sand		MS: Moisture Standard Count	660	660	660
SH: Final Mass (Wt.) of Sand		MC: Moisture Test Count	185	189	187
SI: Mass (Wt.) of Sand in Cone & Hole (SG-SH)		MR: Moisture Count Ratio (MC / MS)	0.280	0.286	0.283
SJ: Mass (Wt.) of Sand in Hole (SI-SF)		M: Moisture by Mass (Wt.)	6.2	6.4	6.3
SV: Vol. of Hole (SJ/SC)		MP: Moisture by Percent - TR 401 <input type="checkbox"/> / TR 403 <input type="checkbox"/>	5.3	5.5	5.4
SW: Dry Mass (Wt.) of Material		NDD: Dry Density (WD - M) or $\frac{100 \times WD}{100 + MP}$	116.3	116.6	115.7
SDD: Dry Density (SW / SV)		%NPR: % Density (NDD / PR) x 100	99.8	100.1	99.3
PR: Maximum Dry Dens. (TR 415 / TR 418)		ADD: Average Dry Density (NDD) or (NDD/3)	1 1 6 . 2		
%PR: % Density (Sand) (SDD / PR) x 100		PR: Maximum Dry Density (TR 415/TR 418)	1 1 6 . 5		
		%PR: % Dens.(Nuclear) (% NPR) or (% NPR/3)	9 9 1 . 7		

Remarks _____

(Signature) _____

Density & Moisture Content Worksheet - Front
 Figure C-1

Pulverization, P ₁ and P ₂ (TR 431)						
* Test No.	* Utilize as many columns as necessary per test section.		1	2	3	4
	Adjusted Wet Mass (Wt) Sample (A)		1984			
	Mass (Wt) of + 19 mm (3/4 in) Material (B ₁)		95			
	Mass (Wt) of + 4.75 mm (No. 4) Material (B ₂)		750			
	% Pulverization 19 mm (3/4 in) (P ₁)	$100 \times \frac{(A - B_1)}{A}$	95%			
	% Pulverization 4.75 mm (No. 4) (P ₂)	$100 \times \frac{A - (B_1 + B_2)}{A}$	57%			

Field Moisture Content at Compaction, % FM (TR 403)						
* Test No.	* Utilize as many columns as necessary per test section.		1	2	3	4
	Total Wet Mass (Wt) of Matl. at Compaction (A)					
	Total Dry Mass (Wt) of Matl. at Compaction (B)					
	Mass (Wt) of Water (C)	(A - B)				
	% Field Moisture Content (% FM)	$100 \times \frac{C}{B}$				

Optimum Moisture and Maximum Dry Density Adjustments for Material Containing 20% - 60 % Siliceous Aggregate (TR 415)				
		1	2	3
Optimum % Moist. of Tot. Material, (OM)	$OM = \left[\left(\frac{100 - c}{100} \right) \times om \right] + \frac{c}{100}$			
Maximum Dry Density, lb/ft ³ (PR) (English)	$PR = \frac{160 \times pr \times z}{\frac{c}{100} \times pr \times z + [160 \times (1 - \frac{c}{100})]}$			
Maximum Dry Density, kg/m ³ (PR) (Metric)	$PR = \frac{2564 \times pr \times z}{\frac{c}{100} \times pr \times z + [2564 \times (1 - \frac{c}{100})]}$			

Density & Moisture Content Worksheet - Back
Figure C-1

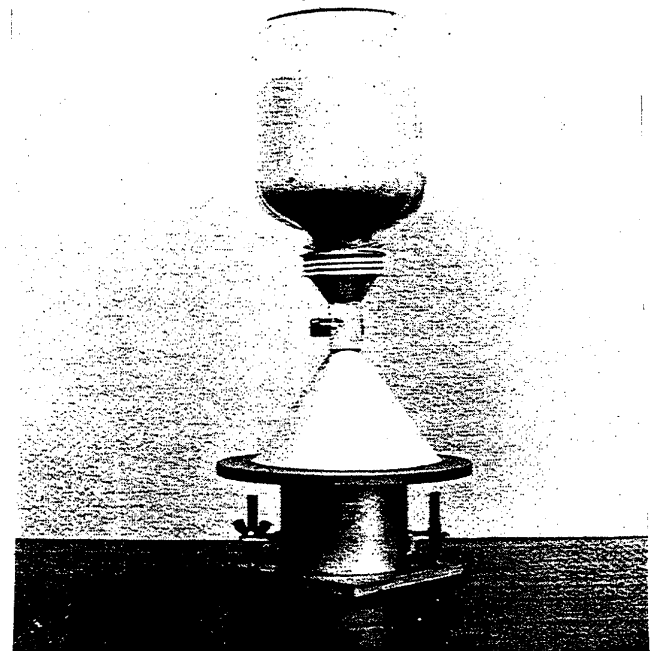
DOTD Designation: TR 401-02
Method D – Sand Cone

I. Scope

- A. This method of test is designed to determine the in-place density of soil or soil-aggregate mixtures using the sand cone.
- B. Reference Documents
 - 1. DOTD TR 403 – Determination of Moisture Content
 - 2. DOTD TR 415 – Field Moisture-Density Relationships
 - 3. DOTD TR 418 – Moisture-Density Relationships

II. Apparatus

- A. **Sand cone** – an approved metal cone with suitable valve, attached to a glass or plastic jar to hold sand (Figure D-1).
- B. **Sampling tools** – an auger or other cutting tool suitable for cutting a hole to the desired depth. Hand tools such as an ice pick, chisel, screwdriver, trowel, spoon, small brush, or other similar tools.
- C. **Balance or scale** – a balance having a minimum capacity of 10 kg or more sensitive to 1 g or a scale having a minimum capacity of 20 lb or more and sensitive to 0.01 lb.
- D. **Measure** – a 0.000944 m³ (1/30 ft³) mold with welded plate. The top surface of the plate shall be flush with the top surface of the mold. The metal plate provides support for the sand cone during calibration as shown in Figure D-1.
- E. **Containers** – suitable to contain sample and protect it from loss of material.
- F. **Sand** – standard (Ottawa) sand, (ASTM C 190), or any clean, dry, free-flowing, uncemented sand passing the 2 mm (No. 10) sieve and retained on the 300 μm (No. 50) sieve.
- G. **Worksheet** – Density and Moisture Content Worksheet, DOTD Form No. 03-22-0750 (Figure D-2 front and back).



**Sand Cone
Figure D-1**

III. Sand Calibration

- A. Before any tests are attempted, calibrate the sand before testing, and additionally when necessary, such as when there is significant change in humidity. Do not use sand which has not been properly screened. Reject dirty sand. Used sand is not to be

- used interchangeably with new sand. Check the sand cone valve for smooth functioning prior to use.
- B. Determine the unit mass of sand by the following method, using a sand cone and measure with welded plate.
1. Determine and record the mass of sand cone and jar filled approximately $\frac{3}{4}$ full of sand.
 2. With valve closed, invert sand cone and place on a smooth, level surface.
 3. Open valve and let sand flow into the cone to a stop. Close valve. In no case is the cone or surrounding area to be disturbed or vibrated during this operation.
 4. Remove and determine the mass of the container with remaining sand to determine the mass of sand to determine the mass of sand in the cone. Record mass on the back of the worksheet.
 5. Repeat Steps 1 – 4 until three separate determinations are within 0.005 kg (0.01 lb).
 6. Average and record the three mass determinations on the back of the worksheet.
 7. Refill sand cone and jar. Determine the mass and record on the back of the worksheet.
 8. With valve closed, invert sand cone and place on the center of the mold with welded plate.
 9. Open valve, let sand flow into the mold, and come to a stop. Close valve. In no case is the mold, cone or surrounding area to be disturbed or vibrated during this operation.
 10. Remove the container with remaining sand and determine the mass of sand in the mold and cone. Record on the back of the worksheet.
 11. Repeat Steps 8 – 10 until three weights within 0.02 lb are obtained.
 12. Average and record the three mass determinations on the back of the worksheet.
 13. Subtract the average obtained in Step 6 from the average obtained in Step 12, and record on the worksheet as mass of sand in mold (SA).
 14. Calculate unit mass of sand (SC) by dividing the mass of sand in mold (SA) by the mold volume of 0.000944 m^3 ($1/20 \text{ ft}^3$) (SB).

IV. Procedure

A. Site Location

1. When in-place density is to be compared with field Proctor density tests for percent compaction determinations, the test site for in-place density shall be selected in the same location as that randomly selected for field Proctor density tests.
2. When it is not necessary to match the location of a proctor, select the test sites randomly.

B. Testing

1. Check the sand cone for proper working condition of valve.
2. Fill the sand cone jar approximately $\frac{3}{4}$ full with clean dry sand. Determine and record the mass to the nearest 0.005 kg (0.01 lb) as original mass of sand (SD).

Note D-1: It is permissible to use multiple preweighed containers of sand, in lieu of a single jar and cone. If more than one sand cone is used, the volume of the cones must be within $\pm 0.0003 \text{ m}^3$ ($\pm 0.01 \text{ ft}^3$) of each other.

3. Level and carefully clean an area approximately 0.5 m by 0.5 m (18 in. by 18 in.). Avoid leaving any loose material on the surface.
4. With the valve closed, invert the sand cone on the prepared surface and mark the exact location on the ground so that it can be replaced in the same position later. If the sand cone seems to be unstable or not level, remove and repeat Step 3.
5. After setting the sand cone firmly against the prepared surface, open valve and let sand flow to a stop. Close the valve. Do not allow any vibration during this operation.
6. Remove sand cone, determine the mass to the nearest 0.005 kg (0.01 lb) and record as final mass of sand (SE).
7. Subtract final mass of sand (SE) from original mass (SD) to determine the mass of sand in cone (SF).
8. Remove all sand from cleaned surface without disturbing the prepared area and without leaving any loose sand. Do not reuse this sand until it has been screened.
9. Start excavating a hole in the center of the original position of the sand cone. Do not lose any material and do not disturb the sides of the hole. The smoother and more vertical the sides of the hole, the more accurate the test will be. Place the material removed from the hole in a container. Cover the material to prevent spillage or loss of material.
10. Make sure the hole is deep enough to represent the height of the lift, but not deep enough to penetrate the underlying lift. If the next lift is penetrated, start over with another hole. For lifts 150-mm (6-in.) thick or greater, the hole must have a minimum volume of 0.000990 m^3 (0.0350 ft^3). For lifts less than 150 mm (6 in.), the volume may be reduced to a minimum of 0.000710 m^3 (0.0250 ft^3). When finished excavating, gather up all the loose material in the hole so the bottom is smooth and level. Brush any material remaining on the tools into the sample container and cover.
11. Refill the sand cone jar approximately $\frac{3}{4}$ full with clean dry sand. Determine the mass to the nearest 0.005 kg (0.01 lb) and record as original mass of sand (SG).
12. After removing all loose material from the hole, invert the sand cone (with the valve closed) over the hole in the exact position marked in Step 9.
13. Open the valve and let the sand flow to a stop. Close valve. Do not allow any vibration during this operation.
14. Remove sand cone, determine the mass to the nearest 0.005 kg (0.01 lb) and record as final mass of sand (SH).
15. Subtract final mass of sand (SH) from original mass (SG) to determine the mass of sand in cone and hole (SI).
16. Remove sand from density hole and place in a separate can for screening prior to reuse.

17. Subtract mass of sand in cone (SF) from mass of sand in cone and hole (SI) to determine the mass of sand in hole (SJ).
18. The mass of sand in hole (SJ), divided by the unit mass of sand (SC), represent the volume of the hole in m^3 (ft^3) (V).
19. Dry total sample excavated from the hole and determine the dry mass of the material in accordance with DOTD TR 403 and record as SW.

Note D-2: *When a representative portion of the total wet mass of material from the density hole is used to determine moisture content, record (on the back of the worksheet), the mass of wet material as (A) and the mass of dry material as (B) to the nearest 5 grams (0.01 lb).*

V. Calculations

- A. Record and calculate values to the same degree of accuracy shown in the example on the worksheet.
- B. The dry density of test (SDD) is calculated by dividing the dry mass of material (SW) by the volume of the density hole (SV).
- C. Calculate the percent density (%PR) by dividing the dry density of test (SDD) by the maximum dry density (PR), as determined by DOTD TR 415 or TR 418, and multiplying by 100.

VI. Report

- A. Maximum dry density (PR) to the nearest $1 \text{ kg}/m^3$ ($0.1 \text{ lb}/ft^3$).
- B. Dry density of test (SDD) to the nearest $1 \text{ kg}/m^3$ ($0.1 \text{ lb}/ft^3$).
- C. Percent density (%PR) to the nearest 0.1%.
- D. Optimum moisture (OM) from DOTD TR 481 or TR 415 to the nearest 0.1%.

VIII. Normal Test Reporting Time

Normal test reporting time including calibration is 4 hours.

MATT MENU SELECTION - 07

Louisiana Department of Transportation and Development
DENSITY & MOISTURE CONTENT WORK SHEET

DOTD 03-22-0750
 Metric/ English
 Rev. 12/98

Metric/English (M or E) (Entry Field Located on Menu)

Project No. 999-99-9999 Date Tested 11-16-19-4 Material Code 421
 Submitted By 00711 Purpose Code 11 Spec. Code 3
 Test Method N N = Nuclear S = Sand Cone Item Number 3011(011)
 Station Tested 114 + 35 Section & Test No. 108-1001

Location: _____	Lift No: _____	Depth of Test: _____
OM: Optimum % Moisture Content of Total Material (TR 415 or TR 418)	OM	<u>11.1</u>
%FM: Field % Moisture Content at Compaction (TR 403) (See back for calculations)	%FM	<u>11.1</u>
P ₁ : % Pulverization 19mm (3/4" SIEVE) (TR 431) (See back for calculations)	P ₁	<u>915</u>
P ₂ : % Pulverization 4.75mm (NO.4 SIEVE) (TR 431) (See back for calculations)	P ₂	<u>571</u>
(TR 415) Cross Reference Test No. _____	Sta. No.: _____	Max. Dry Density Method <input type="checkbox"/> (1 = TR 415 A 2 = TR 415 B 3 = TR 418)
a: Total Wet Mass (Wt.) of Sample		
b: Mass (Wt.) of +4.75 (+4) Material		
c: % By Mass (Wt.) of 4.75 (+4) Retained (100 b/a)		
d: Mass (Wt.) of Mold & Soil		
e: Mass (Wt.) of Mold		
f: Mass (Wt.) of Compacted Soil (d - e)		
g: Wet Density (f / 0.944) or (f / 2.832) or (f / 2.124) (f x 30) or (f x 10) or (f / 0.075)		
h: Mass (Wt.) of Wet Soil		
i: Mass (Wt.) of Dry Soil		
j: Mass (Wt.) of Water (h - i)		
k: % Moisture Content (100 j/i) (TR 403)		
l: Dry Density 100g / (100 + k)		

om (from Family of Curves): _____ pr (from Family of Curves): _____ FAMILY OF CURVES ZONE NUMBER 11

SAND METHOD (TR 401)		NUCLEAR METHOD (TR 401)			
		Nuclear Device Number _____ Insp. (Nuclear Badge No.) _____	Test 1	Test 2	Test 3
SA: Mass (Wt.) of Sand in Mold		DS: Density Standard Count	<u>3540</u>	<u>3540</u>	<u>3540</u>
SB: Vol. of Mold		DC: Density Test Count	<u>3666</u>	<u>3645</u>	<u>3690</u>
SC: Unit Mass (Wt.) of Sand (SA/SB)		DR: Density Count Ratio (DC / DS)	<u>1.036</u>	<u>1.030</u>	<u>1.042</u>
SD: Orig. Mass (Wt.) of Sand		WD: Wet Density	<u>122.5</u>	<u>123.0</u>	<u>122.0</u>
SE: Final Mass (Wt.) of Sand		MS: Moisture Standard Count	<u>660</u>	<u>660</u>	<u>660</u>
SF: Mass (Wt.) of Sand in Cone (SD-SE)		MC: Moisture Test Count	<u>185</u>	<u>189</u>	<u>187</u>
SG: Orig. Mass (Wt.) of Sand		MR: Moisture Count Ratio (MC / MS)	<u>0.280</u>	<u>0.286</u>	<u>0.283</u>
SH: Final Mass (Wt.) of Sand		M: Moisture by Mass (Wt.)	<u>6.2</u>	<u>6.4</u>	<u>6.3</u>
SI: Mass (Wt.) of Sand in Cone & Hole (SG-SH)		MP: Moisture by Percent - TR 401 <input type="checkbox"/> / TR 403 <input type="checkbox"/>	<u>5.3</u>	<u>5.5</u>	<u>5.4</u>
SJ: Mass (Wt.) of Sand in Hole (SI-SF)		NDD: Dry Density (WD - M) or $\frac{100 \times WD}{100 + MP}$	<u>116.3</u>	<u>116.6</u>	<u>115.7</u>
SV: Vol. of Hole (SJ/SC)		%NPR: % Density (NDD / PR) x 100	<u>99.8</u>	<u>100.1</u>	<u>99.3</u>
SW: Dry Mass (Wt.) of Material		ADD: Average Dry Density (NDD) or (NDD/3)	<u>111.61.2</u>		
SDD: Dry Density (SW / SV)	<u>111.6</u>	PR: Maximum Dry Density (TR 415/TR 418)	<u>111.61.5</u>		
PR: Maximum Dry Dens. (TR 415 / TR 418)	<u>111.6</u>	%PR: % Dens.(Nuclear) (% NPR) or (% NPR/3)	<u>99.17</u>		
%PR: % Density (Sand) (SDD / PR) x 100	<u>111.6</u>				

Remarks _____
 _____ (Signature)

Density & Moisture Content Worksheet - Front
 Figure D-1

Pulverization, P ₁ and P ₂ (TR 431)						
* Test No.	* Utilize as many columns as necessary per test section.		1	2	3	4
Adjusted Wet Mass (Wt) Sample (A)			1984			
Mass (Wt) of + 19 mm (3/4 in) Material (B ₁)			95			
Mass (Wt) of + 4.75 mm (No. 4) Material (B ₂)			750			
% Pulverization 19 mm (3/4 in) (P ₁)	$100 \times \frac{(A - B_1)}{A}$		95%			
% Pulverization 4.75 mm (No. 4) (P ₂)	$100 \times \frac{A - (B_1 + B_2)}{A}$		57%			

Field Moisture Content at Compaction, % FM (TR 403)						
* Test No.	* Utilize as many columns as necessary per test section.		1	2	3	4
Total Wet Mass (Wt) of Matl. at Compaction (A)						
Total Dry Mass (Wt) of Matl. at Compaction (B)						
Mass (Wt) of Water (C)	(A - B)					
% Field Moisture Content (% FM)	$100 \times \frac{C}{B}$					

Optimum Moisture and Maximum Dry Density Adjustments for Material Containing 20% - 60 % Siliceous Aggregate (TR 415)					
		1	2	3	
Optimum % Moist. of Tot. Material, (OM)	$OM = \left[\left(\frac{100 - c}{100} \right) \times om \right] + \frac{c}{100}$				
Maximum Dry Density, lb/ft ³ (PR) <i>(English)</i>	$PR = \frac{160 \times pr \times z}{\frac{c}{100} \times pr \times z + [160 \times (1 - \frac{c}{100})]}$				
Maximum Dry Density, kg/m ³ (PR) <i>(Metric)</i>	$PR = \frac{2564 \times pr \times z}{\frac{c}{100} \times pr \times z + [2564 \times (1 - \frac{c}{100})]}$				

Density & Moisture Content Worksheet – Back

Figure D-1