Florida Method of Test
for
DENSITY OF SOILS AND BITUMINOUS CONCRETE MIXTURES IN PLACE BY THE NUCLEAR METHOD

Designation: FM 1-T 238

1. SCOPE

1.1 This method covers procedures for a rapid nondestructive measurement of the density of soil and soil-aggregate in-place using Direct Transmission (Method A) and measurement of the in-place density of compacted bituminous concrete mixtures using Backscatter (Method B). See notes 1 and 2.

Note 1: Department of Transportation personnel, or its agents, operating equipment containing radioactive materials (nuclear gauges) should be experienced with the materials with which they are working. Additionally, Department personnel shall be certified by the FDOT Radiation Administrative Officer or designee. An agent's personnel should have documented evidence they have received the training designated for them by the agent's radioactive materials license.

Note 2: Persons operating equipment containing radioactive materials (nuclear gauges) shall be familiar with and comply with requirements of the Instructions or Operating Manual for the piece of equipment being operated. Said manual shall be readily available to the operator during equipment operation.

2. APPARATUS

2.1 Nuclear Gauge (with lock) - Any brand, make or model of gauge meeting FDOT specifications at time of purchase or obtainment and having a proven history of reliable results as outlined in the Nuclear Manual may be used. The current specifications may be obtained from the FDOT Radiation Administrative Officer at the State Materials Office for the various types of gauges currently being purchased.

2.2 Reference Standard - A reference standard of uniform, unchanging density and moisture value shall be provided with each gauge for the purpose of verifying equipment operation and background count, and to establish conditions for determining count rate reproducibility. The reference standard cannot be used with a gauge other than the one for which it was

issued. Current gauge purchasing specifications require the standard be able to be utilized without the aid of the manufacturer's transporting container or any other accessory.

2.3 Scraper Plate (with drill rod guide) - A rectangular, flat, straight-edged plate with a drill rod guide, constructed of steel or aluminum and used to plane the test site to the required smoothness and for drilling the access hole for direct transmission measurements.

2.4 Drill Rod - A drill rod used with the drill rod guide of the scraper plate to drill the access hole into the material to be tested.

2.5 Drill Rod Extraction Tool - When available, this is used to remove the drill rod from the hole.

2.6 Hammer - A four or six pound hammer for driving the drill rod. Caution: Eye protection should be worn when using any device for hammering against metal or stone where possible material chipping may occur.

2.7 Charger Cord - Charger cable or cables, if required by the gauge, capable of charging at 110 volts AC or 12 volts DC the gauge's power pack for field operation per operator or instruction manual.

2.8 Transporting and Storage Container (with lock) - The manufacturer of the gauge furnishes a container approved by the U.S.D.O.T. for transporting and storing the gauge. The F.D.O.T. also has an approved container, which is secured in the bed of a truck, thereby making it unnecessary to transport the gauge in the manufacturer's container. Gauges owned by F.D.O.T. that once required the manufacturer's shipping container to achieve a standard count per instruction or operator's manual have been furnished with new reference standards which do not require the container to obtain this count.

2.9 Moisture Tester - A calcium carbide gas pressure moisture tester conforming to FM 5-507 which can be transported and stored in the compartment provided in the container mentioned in FM 1-T 238 Section 2.8.

2.10 Manufacturer's Instructions - The instruction or operating manual supplied by the manufacturer will be utilized for operation of the gauge and for achieving most test results unless noted otherwise. The manufacturer's instructions may be found in the "nuclear gauge" chart book furnished by the State Materials Office.

2.11 Level - A Locke level or stringline as needed to determine the vertical location of the test.

2.12 Measuring Tape or Ruler - As needed to determine the lateral location of the test.

2.13 Square Shovel - For preparing the test site (earthwork).

3. CALIBRATION

3.1 Gauges are required to be calibrated yearly or at any time the operator determines there is a need for recalibration if confirmed by DRSO or his designee. Exception of this may be made per Note 8, which follows the example of 8.8.

4. DAILY STANDARD COUNT

4.1 The gauge calibration data has been ratioed to standard density counts made at the factory or State Materials Office on the reference standard supplied with the gauge. New reference counts must be made in the field to compensate for component aging and drift within the instrument. A set of standard counts shall be taken and recorded in the gauges utilization log (diary) every day the gauge is used. If on a given day the gauge is not used, "idle" should be entered for that day in the diary. Diary entries are not necessary on weekends and holidays if gauge is not in use. It is recommended that this data be taken twice a day when the gauge is first received (new gauge) in order to detect any shift during daily use, per manufacturer's instructions.

4.2 If the day-to-day shift in the density standard count is greater than 1 percent or the moisture standard count is greater than 2 percent when compared to the average of the previous four sets of counts, there is a possibility of a gauge malfunction or operator error in placing the gauge on the standard, or in the count taking procedure. Additional attempts to obtain a usable standard count are recommended. This standard count comparison procedure is one of the reasons a utilization log (diary) shall be maintained with the standard density and moisture counts recorded, along with other gauge related information. The initial standard counts will normally be less than the factory or State Materials Office standard counts due to the higher background radiation levels in the factory and at State Materials Office.

5. GENERAL PROCEDURE FOR DAILY STANDARD COUNT (DENSITY AND MOISTURE WHEN APPLICABLE)

5.1 Obtain a set of standard counts at the start of each days use.

5.2 Place the reference standard on compacted soil (100 PCF or more), asphalt or concrete paving, at least ten (10) feet from any large object and at least thirty (30) feet from another gauge.

5.3 Prepare the gauge to achieve a set of standard counts as described in the gauge's instruction or operator's manual. See note 3.

Note 3: Some gauges have normally been equipped by the manufacturer with a reference standard which must be put on top of the shipping container and the combination used to achieve a standard count. This practice is stated in the gauge's instruction manual. During the process, the combination must be located at least ten (10) feet from any large object and at least thirty (30) feet from another gauge as stated in Section 5.2. In some cases, for these same gauges, the manufacturer has instead substituted a reference standard, which is not used with the shipping container, but is used as in Section 5.2 although the instruction manual may not account for this change. If this substitution has been made, disregard the instruction manual and proceed as in Section 5.2, 5.4, etc.

5.4 Insure that the gauge is properly positioned on the reference standard and that the source rod is in the proper position.

5.5 Turn power on and allow the gauge to stabilize for the period of time recommended by the manufacturer in the instruction or operator's manual.

5.6 Obtain a density standard count and moisture standard count, and record them in the gauges utilization log (diary). Moisture Count is not required for gauges, which are not approved for moisture content determination. If the gauge has a memory, retain standard counts in the gauge memory per manufacturer's instructions.

5.7 Return the reference standard to the compartment provided in the F.D.O.T. Transporting and Storage Container, or to the proper storage position in the vehicle being utilized to transport and store the gauge.

METHOD A - DENSITY OF SOIL AND SOIL-AGGREGATE IN PLACE USING DIRECT TRANSMISSION

6. PROCEDURE

6.1 Select a smooth test site free of surface irregularities where the gauge in test position will be at least (6) six inches away from any vertical projection.

6.2 Remove all loose and disturbed material as necessary to expose the top of the material to be tested.

6.3 Smooth the test surface sufficiently in size to accommodate the gauge. The maximum void beneath the gauge shall not exceed approximately 1/8 inch. Use native fines or fine sand to fill these voids. Using the scraper plate, lightly tamp an area equal to the bottom of the gauge. When the test site is below ground elevation, if at all possible, the plane of the surface to be tested shall extend approximately six (6) inches beyond the edges of the gauge on all sides.

6.4 Place the scraper plate with the drill rod guide on the test site.

6.5 Place the drill rod into the drill rod guide and drive a hole at least two (2) inches deeper than the desired test depth. The hole must be perpendicular to the prepared surface of the test site.

6.6 Remove the drill rod by rotating and pulling straight up. The drill rod extraction tool may be used to facilitate the procedure. DO NOT loosen the drill rod by tapping with a hammer.

6.7 Extend and place the source rod in the hole to the desired depth of measurement.

6.8 Seat the gauge firmly by rotating it about the source rod while pulling gently on the gauge in the direction that will bring the side of the source rod in firm contact with the side of the hole nearest the scaler.

6.9 Follow the manufacturer's instructions to obtain the WET DENSITY.

6.10 Record all required information applicable to the gauge used on the Density Log Sheet. The WET DENSITY should be recorded as applicable to the gauge used.

6.11 A nuclear moisture content determination may be used for Limerock, cemented coquina and shell-rock base material using the following gauges:

Troxler: 3401B, 3411B, 3430, 3440A

CPN: MCI (boron), MCI (helium), MC2 (boron), and MC3
Humboldt: 500IP and 5001C
InstroTek: **3500**

Follow the manufacturer's instructions to obtain the PERCENT MOISTURE and DRY DENSITY. Record PERCENT MOISTURE to the nearest 0.1 percent and DRY DENSITY to the nearest 0.1 PCF whether obtained from the gauge by direct reading or obtained by manual calculation.

6.12 Return the source rod to the SAFE OR STORAGE (top notch) position. Position the POWER switch to STAND BY if applicable for the gauge used.

6.13 Return the gauge to the transporting and storage container or to the proper storage area in the vehicle being utilized to transport and store it.

Note 4: The following steps (Sections 6.15 thru 6.17) are not necessary if PERCENT MOISTURE and DRY DENSITY have already been determined per Section 6.11.

6.14 Take a representative sample of the material from the test site and place in a suitable moisture-proof container.

6.15 The material shall be thoroughly mixed and a moisture determination made in accordance with FM 5-507.

6.16 Record the MOISTURE CONTENT to the nearest 0.1 percent.

6.17 Determine the DRY DENSITY to the nearest 0.1 PCF by dividing the WET DENSITY by the PERCENT MOISTURE plus 100 and multiplying the results by 100.

6.18 Determine the percent MAXIMUM DENSITY to the nearest whole percent by dividing the DRY DENSITY by the REQUIRED MAXIMUM DENSITY and multiplying the result by 100.

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METHOD B - DENSITY OF COMPACTED BITUMINOUS CONCRETE MIXTURES USING BACKSCATTER

7. PROCEDURE

7.1 Select a smooth test site that will allow the gauge to sit solidly on the site without rocking. The test site should not be within one foot of the edge of pavement being tested.

7.2 Place the gauge on the test site.

7.3 Extend the source rod to the backscatter position as described in the gauge's instruction or operator's manual. See Note 7.

7.4 Select the proper time duration and gauge function following the instructions in the manual and begin the test.

7.5 After the recommended period of time per Section 7.4 has elapsed, record the DENSITY MEASUREMENT COUNT, or the DIRECT DENSITY in PCF if available from the gauge being used.

7.6 Return the source rod to the SAFE OR STORAGE (top notch) position. DO NOT let the gauge rest on hot bituminous concrete. Remove the gauge immediately after returning the source rod to the SAFE OR STORAGE position.

7.7 Determine the DENSITY COUNT RATIO by dividing the BACKSCATTER DENSITY MEASUREMENT COUNT by the DENSITY STANDARD COUNT unless this step is unnecessary because of the gauge being used. See Note 6.

7.8 Refer to the BACKSCATTER DENSITY CALIBRATION TABLE using the CALCULATED DENSITY COUNT RATIO and record the density to the nearest 0.1 PCF unless this step is unnecessary because of the gauge being used.

7.9 Return gauge to transporting and storage container or proper storage area in the vehicle being utilized to transport and store the gauge. See Note 5.

Note 5: Inspect bottom surface of gauge. If necessary, use the mineral solvent described on the Periodic Maintenance Page found in the gauge chart book to clean the bottom surface of the gauge to prevent a buildup of asphalt.

Note 6: The Backscatter Density Calibration Table is interpolated in 0.1 PCF increments between 110 and 145 PCF.

Note 7: When nuclear density measurements are to be obtained on base courses by direct transmission, Method A paragraphs 6.1 thru 6.10 may be used. Since the test site is bituminous concrete, paragraphs 6.2 and 6.3 should be unnecessary, and the density obtained in 6.10 is the density of the bituminous concrete.

8. CORRECTION FACTOR

8.1 In order to determine the density of compacted bituminous concrete mixtures for the purpose of acceptance, a control strip must first be constructed. When the construction of the control strip has been completed, ten nuclear density determinations will then be made at random locations within the control strip. The average of these ten density determinations will then become the Control Strip Target Density. A correction factor must be applied to the Control Strip Target Density to verify that the Control Strip Density meets the minimum specified percentage of the Design Laboratory Density. Determining the correction factor involves cutting cores in the control strip, obtaining the bulk density of the cores in the laboratory, and arriving at a correction factor based upon the correlation between the core densities and nuclear densities. This correction factor is used only when computing the percentage of Design Laboratory Density obtained in the control strip. The correction factor will be determined in the following manner:

8.2 Take four nuclear density tests in accordance with Section 7 above. (The four tests should be part of the original ten taken throughout the control strip to obtain an average for Control Strip Target Density.) At each of these four test locations, two readings shall be taken. The second reading must be within 1.0 percent of the first reading. If the variation is greater than 1.0 percent, the gauge should be moved to another location. If the variation is less than 1.0 percent, then only the first reading is recorded. (The second reading is only a check.)

8.3 Record the nuclear density results to the nearest 0.1 PCF.

8.4 Before removing the gauge, mark on the pavement around the outside edge of the gauge at each location where a core is to be taken.

8.5 Cut a core from each of the four marked test locations. One additional core will also need to be cut from a random location within the control strip for Independent Assurance testing.

8.6 Determine the bulk density of each roadway core in accordance with Section FM 1-T 166, Method A or B.

Note 8: When it is necessary to expedite FM 1-T 166, Method A will normally be used. In this situation, the bulk density of the fifth core, must be determined by Method B in order that comparative testing can later be performed on the core for Independent Assurance purposes. The fifth core is to be used only for Independent Assurance testing and is not to be used in determining the correction factor.

8.7 Compare the nuclear density results with the bulk density of the cores in PCF.

8.8 The average difference between the nuclear and core densities will be the correction factor.

8.9 Add the correction factor algebraically to the Control Strip Target Density, which is the average of the ten determinations referenced in Section 8.1.

EXAMPLE:

Location Number	Nuclear Density (PCF)	Core Density (PCF)	Difference (PCF)
1	127.3	128.1	+ 0.8
2	118.4	120.5	+ 2.1
3	128.3	131.7	+ 3.4
4	126.8	129.5	+ 2.7
			9.0

$$\text{Correction Factor (Average Difference)} = \frac{9.0}{4} = +2.25 \text{ (PCF)}$$

Note 9: Four comparisons are made so that if one is an obvious outlier it can be disregarded, and there will still be three valid results to compute the correction factor. The following test can be used if there is any question as to whether an outlier exists:

$$\text{Allowable Range} = \pm \frac{R}{2}$$

Where: = Average of differences
R = Range between lowest and highest difference

Example:

The following differences are determined:

+ 0.8
+ 2.1
+ 3.4
+ 2.7

9.0

$= \frac{9.0}{4} = +2.25$

R = 3.4 - 0.8 = 2.6

$\frac{R}{2} = \frac{2.6}{2} = 1.3$

Allowable Range = $+ \frac{R}{2} = (+2.25) + 1.3 = +3.55$

$- \frac{R}{2} = (+2.25) - 1.3 = +0.95$

Allowable Range +0.95 to +3.55 THROW OUT 0.8

If two values are determined to be outliers using the above test, only the value that is out the farthest is discarded.

The same gauge used to determine control strip density must be used to determine acceptance densities for all paving governed by that particular control strip. If it becomes necessary to change gauges, a new control strip will be required and steps Section 8.1 thru 8.9 repeated before continuing acceptance densities. A gauge, which is operating properly and is within the criteria stated in Section 4.2 may be used as long as its related control strip governs the paving even though the gauge's yearly calibration period has expired. The practice of using a gauge with an expired calibration period should not become a frequent occurrence.

Note:10 The fifth core from each control strip shall be tested in accordance with FM 1-T 166, Method B. This core shall be identified with the project number, type of mix, mix design number, and control strip number, and stored on a flat surface in a cool, dry place until it is picked up by District Personnel for comparison testing.