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Tennessee Department of Transportation
Division of Materials and Tests

Nuclear Density Testing (SOP 7-1)

Purpose: The purpose of this document is to provide guidance for conducting nuclear density tests on hot mix asphalt, backfill, soil, aggregate base, embankments, and other materials requiring density tests in accordance with SOP 1-1.

Discussion: Many compacted materials on TDOT projects are accepted by means of testing with nuclear density gauges. This document intends to provide guidance and define best practices for operation of these gauges to unify testing operations statewide. Testing details of common concern include proper setup of gauge information, depth of test probes, time length of tests, and recording of data.

Basic Procedure: All test procedures shall be in accordance with AASHTO T310, "*In-Place Density and Moisture Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)"* and ASTM D2950, "*Standard Test Method for Density of Bituminous Concrete In-Place by Nuclear Methods"* except as revised herein.

Specific instructions on conducting standard counts, entering maximum specific gravity values, offsets, correction factors, and proctor information can be found in the users' manuals corresponding to the make and model of the gauge in use.

Instructions on conducting standard counts can be found in Part Three of this SOP. You can also find specific information in the users' manual for the gauge being used.

PART ONE – ACCEPTANCE TESTING

For All Asphalt Mixtures That Require Density Testing

Step 1: Conduct Standard Count in accordance with Part Three.

Step 2: Enter maximum specific gravity (Gmm) value from asphalt mix design.

Step 3: Enter gauge correction factor from test strip. See Part Two for determining correction factors. (Note: testing may be done prior to obtaining the correction factor, however all tests done during this time must be corrected as soon as possible and prior to finalizing the records for acceptance or assurance tests.)

Step 4: Set gauge setting to Backscatter.

Step 5: Place gauge in location to be tested.

Footnote 1: For guidance on testing frequencies, random numbers, and selecting test locations, see SOP 1-1.

Step 6: Activate a test. When collecting a density test, the following approach **shall** be used:

- *"Four Nineties" Test:* Four tests shall be conducted at a single location, rotating around the test location 90 degrees at a time, as shown in Figure 1. The four test results will then be averaged to obtain a single test value for that location. Test counts for this approach shall be 15 seconds or longer.

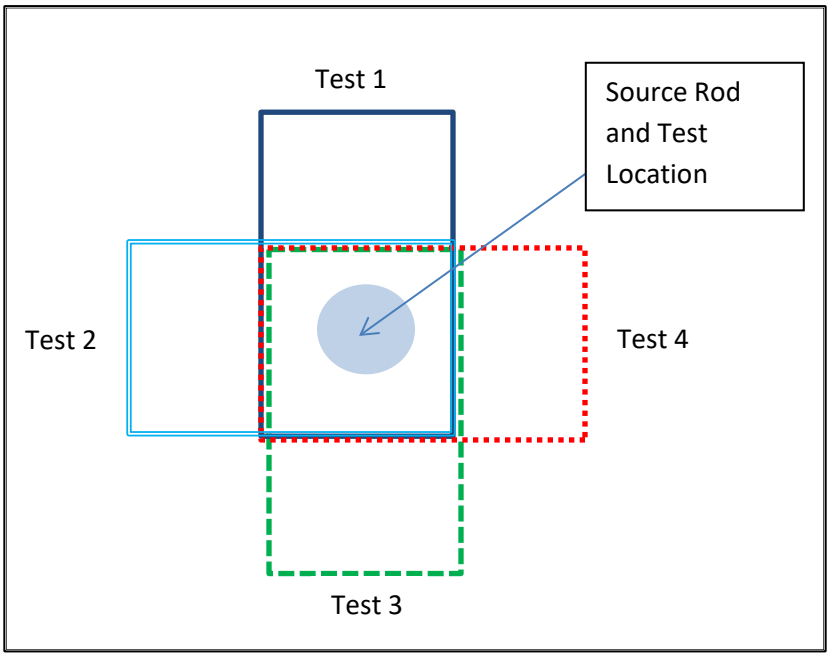

Figure 1. Testing at four 90˚ locations

Step 7: Record the test value into the appropriate paperwork.

- DT-0315, Daily Asphalt Density Report
- SiteManager D2950 – Density of Bituminous Concrete in Place

Soil and Aggregate Materials

Materials: Backfill (Earth retaining structures), Select granular backfill (Earth retaining structures), Embankments, Subgrade preparation, Lime-treated subgrade, Soil-Cement Base, Mineral Aggregate Base and Surface, Aggregate for Underdrains, Aggregate-Cement base course, Aggregate Lime fly ash base course, & Conditioned mineral aggregate base.

Step 1: Conduct Standard Count in accordance with Part Three.

Step 2: Enter maximum dry density and optimum moisture content from Proctor Density report.

Step 3: Select Test location. Create a test hole using the scraper plate, drill rod, and extraction tool provided with the gauge. Take caution to not expand the test hole when extracting the drill rod.

Footnote 2: For guidance on selecting test locations, see SOP 1-1.

Step 4: Set gauge setting to Direct Transmission at a depth reasonably close to one half the depth of the compacted lift.

Step 5: Place gauge in location to be tested and insert test probe into test hole at a depth reasonably close to one half the depth of the compacted lift. Pull gauge back to ensure probe makes contact with material being tested.

Step 6: Activate a test. When collecting a density test, the following approach shall be used:

Single Count Test: A single test shall be conducted at any test location, given that the test count is equal to 60 seconds.

Step 7: Record the test value into the appropriate paperwork.

- DT-0298, Daily Report on Soil and Aggregate Stabilization
- DT-0304, Daily Report on Embankment
- DT-0307, Daily Report on Mineral Aggregate Base
- DT-0314, Density Worksheet – Nuclear Method (Aggregate, Soil)
- SiteManager T310 – Nuclear Density/ Moisture of Soil and Aggregate

PART TWO – DETERMINATION OF ASPHALT CALIBRATION FACTORS

- Conduct test strips in accordance with most current version of TDOT Standard specifications, subsection 407.15. Nuclear Gauge readings are not valid on Asphalt until the gauge is correlated to the mix and project location. A new test strip shall be required for each project and each mix design used on the project (for mix types that require density testing as noted above). Uncorrelated gauges shall not be used for acceptance or assurance testing.
- Test strips are required for all asphalt mixtures that require density testing.
- The minimum size of a single test strip is 400 yd^2, but a larger area is recommended. The following roadway lengths provide an area of 400 yd^2 :
    - 9’ wide= 400’ long
    - 10’ wide= 360’ long
    - 11’ wide= 330’ long
    - 12’ wide= 300’ long
- Compaction of the test strip shall commence immediately after placement of the bituminous mixture.
- TDOT form DT-0316, Density and Roller Pattern Test Strip

Step 1: Compact test strip area

Step 2: Layout ten test strip test locations such that the full length and width of the test strip is covered. Mark test location and test number on pavement with spray paint. DO NOT spray base of gauge with marking paint.

Step 3: Conduct and record ten sets of uncorrected density (4 90s test method) tests on the compacted test strip area and record test information

Step 4: Cores shall be cut at same locations as nuclear density tests and tested by TDOT Plant Technician for laboratory density in accordance with AASHTO T166. (NOTE: The contractor’s technician shall not conduct this testing)

Footnote 3: Only Method A of T166 shall apply when testing test strip cores for density. Cores shall be COMPLETELY DRY before testing. Accelerated drying in accordance with ASTM D 7227 (core drying device) is permitted.

Step 5: The nuclear gauge correction factor shall be the difference between the average of ten nuclear gauge readings and the average of ten core density values.

Additional notes on test strips and correction factors:

- Nuclear gauges are specific to an individual gauge, mix, and project. DO NOT develop a correction factor with a different gauge unit than the one to be used during mainline acceptance testing.
- Developing correction factors based on cores that were not allowed to dry completely will influence results in a manner that can mislead test results into appearing as if they are higher than they actually are. In other words, wet cores appear heavier or denser than they actually are.
- In accordance with TDOT Specifications, a new test strip is required when:
    - There is a change in job mix formulas
    - A change in the source of materials occurs
    - A change in the material from the same source is observed
    - There is reason to believe that the test strip density is not representative of the mixture being placed. For example, test results are consistently above 100% density or test results have been consistent for a steady number of days and had suddenly changed significantly.
    - A change in paving or compaction equipment occurs.

PART THREE – TAKING THE STANDARD COUNT

- Keep a log of your standard counts.
- Standard counts provide a quick reference check to ensure that the gauge is operating correctly.
- A standard count must be taken daily on the reference standard block.
- Max Density and Moisture Variation: **1%** for density and **2%** for moisture.

Preparatory steps before taking the standard count:

1. Turn the gauge on and let it **warm up for a minimum of 10 minutes** (Troxler & InstroTek only).
2. The base of the gauge and the top of the standard block must be clean and debris free.
3. Place the reference block on the material you will be performing the density test.
4. Troxler & IntsroTek gauges, ensure the source rod is placed at the opposite end of the butt plate.
5. Humboldt gauges, ensure the source rod is placed toward the standard block handle.
6. Make sure to slide the gauge towards and up against the butt plate (Troxler & InstroTek) or handle (Humboldt) on the standard count block.

7. Make sure the source rod is in the safe locked position before taking the standard test.
8. Make sure there are no other gauges within 30 feet.
9. Make sure to take the test in an area away from any large vertical objects including walls, vehicles and people.
10. **DO NOT** warm up the gauge or take a standard count on the tailgate of the truck.

If any one of these apply: (Does not apply to Humboldt gauges. Refer to chapter 3.2 in users manual)

- **A standard count log has NOT been kept**
- **The standard count fails**
- **The gauge hasn't been used in the last 30 days**

Do the following: (Does not apply to Humboldt gauges. Refer to chapter 3.2 in users manual)

Step 1: Take five new counts

Step 2: Average the first four

Step 3: Compare with the 5th reading using the equation below:

$$\%\ \text{DIFFERENCE} = \frac{\text{AVERAGE} - \text{5TH READING}}{\text{AVERAGE}} \times 100$$

Step 4: Check if the reading is within the required limits.

Max Density and Moisture Variation: 1% for density and 2% for moisture. If the standard count still fails, call your Regional RSO.