APPENDIX D

VTM - 10

Virginia Test Method
For
Determining Percent of Moisture and Density
of Soils and Asphalt
(Nuclear Method)

I. Scope

This method covers the procedure to be used in determining the percent of moisture and density of soil embankments, base, subbase, and select materials, and the percent density for asphalt concrete.

II. Apparatus

The apparatus required shall consist of the following:

A. Portable Nuclear Moisture-Density Gauge
B. Transport case (blue)
C. Charger
D. Reference Standard Block
E. Transport Documents (Bill of Lading)
F. Leveling Plate/Drill Rod Guide
G. Drill Rod w/extraction tool
H. Hammer (4 lbs.) used for Driving the Pin
I. Safety Glasses
J. Square-Point Shovel
K. No. 4 sieve
L. Set Balance Scales
M. Drying Apparatus
N. Miscellaneous Tools such as Mixing Pans and Spoons

III. Procedure

There are two different methods to determine percent density and percent moisture using the portable nuclear density gauge. The methods are direct transmission and backscatter.

The direct transmission method requires punching a hole into the surface of the material being tested and lowering the source rod to the desired depth of test. This method is used to test soil and aggregate materials. Please note that when testing soils, the backscatter position **shall not** be used as a means of acceptance for density.

In the backscatter method, the source rod is lowered to the first notch below the safe position placing the source and detectors in the same horizontal plane. No hole is required for the probe since it is flush with the bottom of the gauge. This method is used to test aggregate (subbase, and base course) and asphalt materials. This method of testing is performed in accordance with Section 304 of the Road and Bridge Specifications - Constructing Density Control Strips.

The Roller Pattern is performed first. The purpose is to determine the number of passes to be made by the roller in various combinations of static and/or vibratory rolls to achieve maximum density for that depth of material using that roller. The data collected from the gauge is entered on the TL-53A form. Properly plotted, this will provide a graphical comparison of the number of roller passes necessary to produce a properly compacted product. Once completed this information is used to establish a Control Strip(s).

The Control Strip determines the target values for density that will define the acceptance criteria for the material placed and compacted using the previous determined roller pattern. The values determined by the control strip will not change until a new roller pattern is required. This data collected is to be entered on the TL-54A form. The Control Strip provides an accurate method of evaluating materials, which are relatively uniform and exhibit smooth surfaces.

A. **Roller Pattern**

The Roller Pattern is constructed on the same material being placed and once established, will be used for the remainder of the project. The Roller Pattern is 75 feet in length plus some additional area to accommodate the lateral positioning of the roller. The width and depth of the material depends on the projects design.

Listed below are the steps used to construct a Roller Pattern:

Note: Refer to the Manual of Operations and Instructions if additional information is needed.

1. Establish an area at least 10 feet from any structure, and 33 feet from other radioactive sources (another gauge) to take standard counts. This area can be concrete, asphalt, or a well compacted soil with a minimum density of 100 lb/ft^3. Do not use truck beds, tailgates, tabletops, etc. When using Troxler's model 3440 gauge, turn it on and wait for it to perform its self-test. When completed the gauge will enter the "Ready" mode. At this time, standard counts can be taken and recorded.

   Note: A standard count will be taken each day of use. If count fails, refer to the gauges Manual of Operation and Instruction guide for further instructions or call your district materials section for assistance.

2. To prepare a Roller Pattern, place the material on a section of roadway approx. 75 feet in length for the typical application width (an area of at least 100 yd^2), and at the proper loose depth before any rolling is started. (The Contractor should be allowed to place 100 feet of material prior to the 75 foot section for plant mix stabilization, adjustment, and compaction purposes, with testing to be conducted at the completion of the roller pattern.) The compaction is to be completed uniformly and in the same manner for the remainder of the job. (It is also recommended that a 50 foot section be placed before and after the roller pattern section for positioning of the roller.)

   The moisture content of aggregates should be kept as near optimum as possible throughout the rolling operation. Water must be added when needed to maintain optimum moisture in accordance with Section 308 and 309 of the Road and Bridge Specifications during the compaction process.

   To speed up operations, select the 15-second mode on the read out panel and record the density and moisture readings. When testing the control strip and test section, select the 60 second mode for acceptance.

3. Make two (2) passes (1 pass is counted each time the roller crosses the test site) with the roller over the entire surface of the Roller Pattern. Make sure the previous passes have been completed over the entire surface before the next pass is started. When testing asphalt materials, take a nuclear test for density only, using the Backscatter Method. The above test on aggregates and asphalt materials should be made at three randomly selected

points within the area to be tested. Choose points with good surface conditions, and try to spread the 3 tests over most of the 75 foot section, making sure not to place the gauge closer than 18 inches to an unsupported edge. Be sure to mark the exact location where the gauge is placed. (If using spray paint to mark the locations, do not spray the gauge with paint.) The gauge, when in use, shall always be positioned parallel with the roadway, with the source end toward the direction of the paver. Record these results on the Roller Pattern Form TL-53A, and obtain the total and average for both moisture and density.

All further tests for the Roller Pattern must be made in the same 3 locations, with the gauges source rod pointing in the same direction as the first test. Plot the average dry density versus the number of roller passes on the graph.

4. Make additional passes with the roller over the entire surface of the Roller Pattern, and again obtain and record the 3 readings for density and moisture in the same location as the previous set of readings. Calculate the average from the readings and record them on the Form TL-53A. Continue the rolling and testing of the section until the Roller Pattern reaches its maximum density before decreasing or the curve levels off. To be certain this is a sufficient degree of compaction, make one additional roll over the entire surface and test again.

   Note: The number of passes that are indicated do not necessarily have to be set at two (2) each time. It may be found that in some instances one pass would be sufficient between readings and, in other instances, 3 or 4 passes would be required. An accurate count of the required passes should be maintained and may vary, depending on subgrade conditions, roller efficiency, type of materials and moisture content.

   Note: When testing aggregates, upon completion of the control strip, perform a direct transmission test to validate that compaction has been obtained comparing the result to AASHTO T-99. Refer to Table II for the minimum percent density required.

Notes on determination of Maximum Attainable Density with Roller Pattern/Control Strip Technique

The Control Strip shall be rolled until maximum dry density for granular materials or maximum density for asphalt materials is obtained. Materials compacted to maximum density provide a solid platform on which to construct pavement. Materials at maximum density increase pavement load carrying capacity and pavement life. Opportunities for future pavement distress will be greatly decreased. In the interest of good construction procedure and practice, the inspector should use these guidelines to the best of his/her ability. (These guidelines should not be considered as an addition to the Specifications.)

In brief, the change in density in a typical Roller Pattern, for example, on Aggregate Base Material, Type I, Size 21B, may look as shown below:

Number of Passes	Change in Density, lb/ft^3
4	+ 3.1
6	+ 2.1
8	+ 2.3
10	+ 0.9
11	+ 0.4

Table I

It can be seen from the above that continued rolling after 10 passes resulted in diminishing returns. This is typical for many Roller Patterns. Based on an analysis of this type, the following is recommended as a guideline for granular materials.

In the event that the increase in dry density for a Roller Pattern on granular material is less than 1 lb/ft^3 one additional pass shall be required.

For asphalt base, the same guidelines as for granular materials should be used, with the exception that after the increase becomes less than 0.5 lb/ft^3 per pass, one additional pass shall be required. If the density does not increase by 1 lb/ft^3 with the additional pass, rolling should be discontinued.

Occasionally, there will be instances where a decrease in density rather than a small increase will occur. This usually occurs for two reasons: a false break, where the density levels off well before maximum density is achieved, and over rolling. In this case, consideration should be given to the number of passes already made and the materials involved, making certain that the break occurring in the Roller Pattern curve is not greater than 1.5 lb/ft^3. When the break is greater than the above value, re-compact the material to the maximum dry density based on the peak of the roller pattern.

A new roller pattern should be established whenever there are multiple lifts of material or there is a change in the following:

Source of material
Compaction equipment
Visual change in subsurface conditions
Gradation or type of material
Nuclear Density Gauge - only another Control Strip is to be performed.
Test section readings are significantly above the target values by more than 8 lb/ft^3
- Review the items in the above list. Check with the roller operator to see if they are doing anything other than the number of passes established in the roller pattern. If these things do not produce the reason, perform another control strip.

B. **Control Strip**

1. To prepare a Control Strip, an additional 300 ft. of roadway is required extending from the Roller Pattern area (same spreaderbox width at the same designed depth). This area is to be rolled the same number of passes from the Roller Pattern.

2. In order to determine the maximum dry density of the Control Strip, 10 readings for density and moisture should be performed and recorded over the entire 300 ft. section. Calculate and enter the data on the TL-54A Form. The Target Values of 98% and 95% of the average dry density can now be determined. The dry density determined from the average of the Control Strip should compare within 3 lb/ft^3 of the roller pattern's maximum dry density. This applies to both aggregate and asphalt materials.

   Note 1: When testing Asphalt Concrete, the gauge should be programmed to the asphalt mode.

   Note 2: When testing aggregates a verification test will be performed at the completion of the control strip using the direct transmission method or other methods approved by the Engineer.

C. **Test Sections**

1. To complete a test section, 5 readings are required. Each test section for asphalt concrete will be one quarter mile in length for the full width of the roadway or one half mile in length or half the width of the roadway. Each test section for aggregate base, subbase, and select materials will be one half mile in length per application width. The length of test sections for shoulders will be the same as the mainline. If possible test alternating sides. Five (5) readings will be made on each test section for both density and moisture using the same method of test used on the Roller Pattern and Control Strip. Rolling is continued until none of the 5 readings is less than 95% of the Control Strip density, and the average of the 5 readings is equal to or greater than 98% of the Control Strip density. This does not apply to aggregate shoulder material, which requires an average density of 95 ± 2 percentage points of the control density, with individual densities within 95 ± 5 percentage points of the control density. No other test will be required, unless specified by the Engineer. When test section readings are significantly above or below the target values by more than 8 lb/ft^3 another Control Strip will be established.

2. When testing turn lanes, acceleration lanes, deceleration lanes, and crossovers, take 2 or 3 readings on each, whichever is needed, to complete the full test section.

   Note: For sections of roadway less than 900 feet, the direct transmission method or other approved testing methods for density determinations may be used. If obvious signs of distress are observed while rolling, cease rolling and evaluate the area of distress. Such signs include cracking, shoving, etc. Structural failures will cause the gauge to give an erroneous reading indicating more compaction is needed, when actually over-compaction is causing the failure. If this situation occurs, it should be brought to the attention of the District Materials Section for an evaluation.

   Note: When taking tests for Asphalt Concrete only record the wet density from the gauge.

D. **Direct Transmission Method**

1. Establish an area at least 10 feet from any structure and 33 feet from other radioactive sources (another gauge) to take standard counts. This area can be concrete, asphalt, or a well compacted soil with a minimum density of 100 lb/ft^3. Do not use truck beds, tailgates, tabletops, etc. When using VDOT's model 3440, turn it on and wait for it to perform its self-test. When it is completed the gauge will enter the "Ready" mode. At this time, standard counts can be taken and recorded.

2. When testing soil, level off an area on which to place the device with the leveling plate furnished with the gauge. The surface of this area should be as smooth as possible to obtain an accurate test. Care should be taken not to additionally compact the surface during its preparation.

3. All density tests on embankments and subgrade will be tested using the Direct Transmission Method.

   a. Place the guide plate on the surface. Make a hole in the material with the driving pin provided, using the guide plate to be sure the hole is straight and vertical.

   b. Extend the source rod just enough to place it in the hole. Then extend the rod to the desired depth of test making sure the device is sitting flush on the surface and the rod is pulled back tight against the back side of the hole. Take a one-minute count in this position.

4. The test is complete and the results recorded on Form TL-124A.

   If the material tested is represented by a predetermined proctor test the dry unit weight should be entered into the gauge prior to testing. This allows the gauge to calculate the percentage of compaction.

   When it is apparent that the material being placed is different from the material that is described, such as color, texture, rock size, etc., another proctor may need to be made to compare. Refer to the Manual of Instructions, Section 314 for additional information.

5. In the event the material contains appreciable amounts of material retained on the No. 4 sieve a correction shall be performed to determine the correct Proctor Density.

   If the material being placed is determined to be "rock fill" an entry must be recorded on the TL-124A Form, showing location and elevation of rock.

Aggregate material shall be compared to the theoretical maximum density as determined in accordance with the requirements of VTM-1. The density shall conform to the following:

% Retained on No. 4 Sieve	Minimum % Density
0-50	95
51–60	90
61-70	85

Table II

Note: Percentages of material will be reported to the nearest whole number. The requirements for percent density referenced above apply only to the direct transmission method for aggregate.

E. **Background Calculations for Trench and Sidewall Moisture Testing**

When a 3440 Nuclear Moisture-Density Gauge is operated within 24 inches of a vertical structure, the density and moisture counts will be influenced by the structure.

Due to the hydrogen-bearing materials in trench walls, on occasion, a higher moisture reading will be observed when testing backfill materials around pipe, culverts, abutments, etc. It is necessary, therefore, to determine the "background" effect and apply this correction to the observed moisture count readings. The background correction count should be determined each day of testing and when trench wall conditions (distance from wall, moisture content, material composition, etc.) vary.

Moisture in certain soil properties containing high amounts of hydrogen rich compounds such as ash, mica, organics, cement, boron and cadmium, will give inaccurate readings and as a result a moisture offset should be performed. The moisture offset should be a minus for ash, mica, organics and cement and a plus for boron and cadmium. See Page 5-4 in the Operation and Instruction Manual to perform the moisture offset. Other alternative methods to determine moisture content are the speedy moisture tester and hotplate method.

The procedure to determine the background effect and apply the necessary correction is as follows:

1. Take a standard count with the gauge on the standard block outside the trench and record these values.

2. Place the gauge on the standard block inside the trench in the testing area and select trench offset. The density and moisture trench offset constants will be calculated and stored. When the gauge is not being used for trench measurements disable the offset.