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**Washington State
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TECHNICAL MANUAL

Materials Manual

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Environmental and Engineering Programs

Materials Laboratory

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WSDOT Standard Operating Procedure SOP 615

Determination of the % Compaction for Embankment & Untreated Surfacing Materials using the Nuclear Moisture-Density Gauge

1. Scope

This procedure covers the procedures for determining the in-place density, moisture content, gradation analysis, oversize correction, and determination of maximum density of compacted soils and untreated surfacing materials using a nuclear density device in the direct transmission mode.

2. References

- a. WSDOT FOP for AASHTO T 99 for Method of Test for Moisture-Density Relations of Soils
- b. WSDOT FOP for AASHTO T 180 for Method of Test for Moisture-Density Relations of Soils
- c. WSDOT FOP for AASHTO T 224 for Correction for Coarse Particles in Soil Compaction Test
- d. WSDOT FOP for AASHTO T 255 for Total Moisture Content of Aggregate by Drying
- e. WSDOT FOP for AASHTO T 272 for Family of Curves — One Point Method
- f. WSDOT FOP for AASHTO T 310 for In-Place Densities and Moisture Content of Soils and Soil-Aggregate by Nuclear Methods (Shallow Depth)
- g. WSDOT T 606 Method of Test for Compaction Control of Granular Materials

3. Test Location

When selecting a test location, the tester shall visually select a site where the least compactive effort has been applied. Select a test location where the gauge will be at least 6 in (150 mm) away from any vertical mass. If closer than 24 in (600 mm) to a vertical mass, such as in a trench, follow gauge manufacturer correction procedures.

Note 1: When retesting is required due to a failing test; retest within a 10 foot radius of the original station and offset.

4. Nuclear Density Test

Determine the dry density and moisture content of soils and untreated surfacing materials using the nuclear moisture-density gauge in accordance with WSDOT FOP for AASHTO T 310, and record on DOT Form 350-074 “Field Density Test”.

5. Oversize Determination

a. WSDOT FOP AASHTO T 99 and WSDOT T 606

A sample weighing a minimum of 9 lbs will be taken from beneath the gauge. Care shall be taken to select material that is truly representative of where the moisture density gauge determined the dry density and moisture content.

There are two methods for determining the percentage of material retained on the No. 4 sieve:

Method 1

1. Dry the sample to SSD conditions, (i.e. dried until no visible free moisture is present, material may still appear damp). Allow the sample to cool sufficiently and record mass to the nearest 0.1 percent of the total mass or better.
2. Shake sample by hand over a verified No. 4 (4.75 mm) sieve. Limit the quantity of material on the sieve so that all particles have the opportunity to reach the sieve openings a number of times during the sieving operation. The mass retained on the No. 4 (4.75 mm) sieve at the completion of the sieving operation shall not exceed 800 grams, 1.8 pounds, for the 12" sieve, or 340 grams, 0.75 pounds; for the 8" sieve.
3. Remove and weigh the material on the No. 4 (4.75 mm) sieve to the nearest 0.1% of the total mass or better and record.

Notes 2: This method is only recommended for crushed surfacing materials, materials with high clay content, or other granular materials that are at or near the optimum moisture content for compaction.

Method 2:

1. Determine the mass of the sample to the nearest 0.1% of the total mass or better and record.
2. Charge the material in a suitable container with water, agitate the material to suspend the fines, then slowly decant and screen the material over a verified No. 4 (4.75 mm) sieve. Repeat the process as necessary to remove as much No. 4 (4.75 mm) minus material as possible. DO NOT overload the sieve.
3. Place the washed sample retained on the No. 4 (4.75 mm) sieve into a tared container. Blot the material to a SSD condition (i.e. no visible free moisture present, material may still appear damp) during this step.
4. Weigh the mass of the material on the No. 4 (4.75 mm) sieve to the nearest 0.1% of the total mass or better and record.

b. WSDOT FOP AASHTO T 180

Follow either Method 1 or Method 2 in 5 a. with the following exception; sieve the material over a $\frac{3}{4}$ in (19.0 mm) sieve.

6. Calculation of Percent Retained and Percent Passing

- a. Calculate the percent retained as follows:

$$\% \text{ retained} = 100 \times \frac{\text{mass retained}}{\text{original mass}} \text{ (round to nearest percent)}$$

$$\% \text{ retained (Pc)} = 100 \times \frac{\text{mass retained on sieve}}{\text{original mass of sample}}$$

- b. Calculate percent passing as follows:

$$\% \text{ passing} = 100 - \% \text{ retained}$$

7. Calculating Percent Compaction

- a. Calculate the dry density as follows:

$$d = \frac{100}{100 + W} (m)$$

Where:

- d = dry field density of total sample, pcf
- m = total field wet density, pcf
- W = moisture content of total field sample

- b. Corrected Theoretical Maximum

$$Df = \frac{D_d \times P_f}{\left(100 - \left(\frac{D_d \times P_c}{k}\right)\right)}$$

Where:

- Df = corrected theoretical maximum density pcf
- D_d = dry density, pcf
- P_f = percent passing
- P_c = percent retained
- k = 62.4 × (specific gravity of coarse particles) (Note 1)

Note 3: If the specific gravity has been determined, this value may be used in the calculations. Determine the specific gravity according to AASHTO T 85 for WSDOT FOP for AASHTO T 99 and WSDOT FOP for AASHTO T 180 or WSDOT T 606 (Test 3). If the specific gravity of the coarse particles is unknown use 2.67.

The WSDOT materials testing program MATS has been developed to produce a Density Curves Table in each test report for soils density. The tester should use this table to determine the corrected field density.

To determine the corrected theoretical maximum density using the Density Curves Table enter the Table at the line corresponding to the % passing or % retained (T99 & T 180 requires percent retained, T 606 requires percent passing), read across to the column labeled Max this number is the Corrected Theoretical Maximum Density.

c. Calculate the percent of compaction using the following equation:

$$\% \text{ compaction} = \frac{\text{Dry Density (lbs/ft}^3\text{)} \times 100}{\text{corrected theoretical maximum density (lbs/ft}^3\text{)}}$$

8. Report

Report data on DOT Form 350-074, “Field Density Test” and on DOT Form 351-015 “Daily Compaction Test or in the MATS database.

Report the percent of compaction to the nearest whole number.

Performance Exam Checklist

WSDOT Standard Operating Procedure SOP 615 Determination of the % Compaction for Embankment & Untreated Surfacing Materials using the Nuclear Moisture-Density Gauge

Participant Name _____ Exam Date _____

- | Procedure Element | Yes | No |
|--|--------------------------|--------------------------|
| 1. The tester has a copy of the current procedure on hand? | <input type="checkbox"/> | <input type="checkbox"/> |
| 2. All equipment is functioning according to the test procedure, and if required, has the current calibration/verification tags present? | <input type="checkbox"/> | <input type="checkbox"/> |

Gradation Analysis

3(A) Method 1

- | | | |
|--|--------------------------|--------------------------|
| 1. Sample Dried to a SSD condition (dried until no visible free moisture present) and mass recorded? | <input type="checkbox"/> | <input type="checkbox"/> |
| 2. Sample allowed to cool sufficiently prior to sieving? | <input type="checkbox"/> | <input type="checkbox"/> |
| 3. Sample was shaken by hand through the appropriate sieve for a sufficient period of time? | <input type="checkbox"/> | <input type="checkbox"/> |
| 4. Recorded mass of material retained on the appropriate sieve? | <input type="checkbox"/> | <input type="checkbox"/> |
| 5. Calculated and recorded percent of material retained and passing the appropriate sieve? | <input type="checkbox"/> | <input type="checkbox"/> |

3(B) Method 2

- | | | |
|---|--------------------------|--------------------------|
| 1. Mass of sample determined prior to washing? | <input type="checkbox"/> | <input type="checkbox"/> |
| 2. Material charged with water in suitable container and agitated to suspend fines? | <input type="checkbox"/> | <input type="checkbox"/> |
| 3. Sample decanted over required sieve for a sufficient amount of time without overloading sieve? | <input type="checkbox"/> | <input type="checkbox"/> |
| 4. Retained material dried to SSD condition and mass determined? | <input type="checkbox"/> | <input type="checkbox"/> |
| 5. Recorded mass of material retained on appropriate sieve? | <input type="checkbox"/> | <input type="checkbox"/> |
| 6. Calculated and recorded percent of material retained and passing appropriate sieve? | <input type="checkbox"/> | <input type="checkbox"/> |

Correction for Coarse Particles

- | | | |
|--|--------------------------|--------------------------|
| 7. Appropriate computer-generated chart used to determine the corrected theoretical maximum density, based on the percent retained on the appropriate sieve? | <input type="checkbox"/> | <input type="checkbox"/> |
| 8. All calculations performed correctly? | <input type="checkbox"/> | <input type="checkbox"/> |

First attempt: Pass Fail Second attempt: Pass Fail

Signature of Examiner _____

Comments: