Washington State Department of Transportation

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. AASHTO T 99 for Method of Test for Moisture-Density Relations of Soils

   b. AASHTO T 180 for Method of Test for Moisture-Density Relations of Soils

   c. AASHTO T 224 for Correction for Coarse Particles in Soil Compaction Test

   d. T 255 – WSDOT FOP for AASHTO for Total Moisture Content of Aggregate by Drying

   e. T 272 – WSDOT FOP for AASHTO for Family of Curves — One Point Method

   f. T 310 – WSDOT FOP for AASHTO 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 in the Materials Testing System (MATS), WSDOT Form 350-074, Field Density Test, or other form approved in writing by the State Materials Engineer.

5. Oversize Determination

   a. 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 in sieve, or 340 grams, 0.75 pounds; for the 8 in sieve.

   (3) Remove and weigh the material on the No. 4 (4.75 mm) sieve to the nearest 0.1 percent of the total mass or better and record.

   Method 2 – Method 2 is 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.

   (1) Determine the mass of the sample to the nearest 0.1 percent 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 percent of the total mass or better and record.

   b. AASHTO T 180

   Follow either Method 1 or Method 2 in 5 a. with the following exception; sieve the material over a ¾ in (19.0 mm) sieve.

6. Calculations

   a. Calculate the percent retained as follows:

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

   b. Calculate percent passing as follows:

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

   c. 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

   d. Calculate the corrected theoretical maximum density as follows:

   $$D_d = \frac{100 \times (D_f) \times (k)}{[(D_f) \times (P_c) + (k) \times (P_f)]}$$

   Where:
   - D_d = corrected dry density of combined fine and oversized particles, expressed as lbs/ft3.
   - D_f = dry density of fine particles expressed as lbs/ft3, determined in lab.
   - P_c = percent of coarse particles, by weight.
   - P_f = percent of fine particles, by weight.
   - k = 62.4 x Bulk Specific Gravity.

   Calculate in-place dry density to the nearest 0.1 lbs/ft3.

   Note 2: If the specific gravity of the coarse particles has been determined, use this value in the calculation for the "k" value. If the specific gravity is unknown then use 2.67. Either AASHTO T 85 or WSDOT T 606 Test 3 may be used to determine the specific gravity of the coarse particles.

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

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

7. Density Curve Tables

   The Materials Testing System (MATS) Density Curve Tables is the WSDOT preferred method for determining the corrected theoretical maximum density.

   a. MATS calculates the corrected theoretical maximum density in accordance with AASHTO T224 Section 4.2 and reports the results in the Density Curve Table.

   b. 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.

8. Report

   a. Report the results using one or more of the following:

      - Materials Testing System (MATS)
      - WSDOT Form 350-074 and 351-015
      - Form approved in writing by the State Materials Engineer

   b. Report the percent of compaction to the nearest whole number.

Performance Exam Checklist

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Participant Name _____ Exam Date _____

Procedure Element	**Yes**	**No**
1. The tester has a copy of the current procedure on hand?	☐	☐
2. All equipment is functioning according to the test procedure, and if required, has the current calibration/verification tags present?	☐	☐
Gradation Analysis		
3(A) Method 1		
1. Sample Dried to a SSD condition (dried until no visible free moisture present) and mass recorded?	☐	☐
2. Sample allowed to cool sufficiently prior to sieving?	☐	☐
3. Sample was shaken by hand through the appropriate sieve for a sufficient period of time?	☐	☐
4. Recorded mass of material retained on the appropriate sieve?	☐	☐
5. Calculated and recorded percent of material retained and passing the appropriate sieve?	☐	☐
3(B) Method 2		
1. Mass of sample determined prior to washing?	☐	☐
2. Material charged with water in suitable container and agitated to suspend fines?	☐	☐
3. Sample decanted over required sieve for a sufficient amount of time without overloading sieve?	☐	☐
4. Retained material dried to SSD condition and mass determined?	☐	☐
5. Recorded mass of material retained on appropriate sieve?	☐	☐
6. Calculated and recorded percent of material retained and passing appropriate sieve?	☐	☐
Correction for Coarse Particles		
7. Appropriate MATS Density Curve Table used to determine the corrected theoretical maximum density, based on the percent passing or retained on the appropriate sieve?	☐	☐
8. All calculations performed correctly?	☐	☐

First Attempt: Pass ☐ Fail ☐ Second Attempt: Pass ☐ Fail ☐

Signature of Examiner _____

Comments: