STATE OF OHIO DEPARTMENT OF TRANSPORTATION

SUPPLEMENT 1015 COMPACTION TESTING OF UNBOUND MATERIALS

December 31, 2012

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1015.01 General. Compaction testing of unbound materials consists of determining the inplace density of a material (such as fine-grained soil, granular material, or shale) and calculating the percent compaction of the material based on a maximum dry density. Depending on the material, determine the maximum dry density using either the one-point Proctor method, the onepoint Proctor with aggregate correction method, or the test section method.

Perform compaction testing according to this supplement for Items 203, 204, 205, 206, 304, 411, 503, 611, 840 and other items when this supplement is specified.

The Department will perform the compaction tests unless specifically stated otherwise in the Contract Documents.

1015.02 Definitions.

Fine-grained soil. A soil with more than 35 percent of the material finer than the No. 200 sieve. Fine-grained soils include soils classified as A-4a, A-4b, A-5, A-6a, A-6b, A-7-5, and A-7-6 according to AASHTO M 145 (as modified by the Department's *Specifications for Geotechnical Explorations*).

Granular material. A soil, aggregate or stone with 35 percent or less of the material finer than the No. 200 sieve. Granular material includes coarse aggregate; granular material types A through F; sand; select granular backfill for MSE walls; Items 304, 410, 411, and 614; and material classified as A-1-a, A-1-b, A-2-4, A-2-5, A-2-6, A-2-7, A-3, and A-3a according to AASHTO M 145 (as modified by the Department's *Specifications for Geotechnical Explorations*).

Roller pass. When used in the context of compacting soil and unbound materials, one roller pass is when compaction equipment travels over a given point on a surface one time. The compaction equipment may consist of a roller or may also consist of other types of equipment, such as a vibratory plate compactor.

1015.03	Referenced Standards
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	AASHTO
Test Method	Designation
Moisture-Density Relations of Soils (Standard Proctor)	T 99
Correction for Coarse Particles in the Soil Compaction Test	T 224
Family of Curves – One Point Method	T 272
In-Place Density and Moisture Content of Soil and	Т 310
Soil-Aggregate by Nuclear Methods	1 510

1015.04 Apparatus. Use a nuclear density/moisture gage and other equipment required by AASHTO T 310. Use a mold, rammer, balance or scale, straightedge, sieves, and other equipment that conforms with AASHTO T 99, Method C.

1015.05 Forms. Use the following ODOT forms to record compaction test results.

CA-EW-5
CA-EW-6
CA-EW-5
CA-EW-4

1015.06 Procedure.

A. General. Depending on the material type, determine the in-place density and maximum dry density using the mode of operation and method as shown in the following table. The test section method may also be used for fine-grained soils instead of the one-point Proctor method if justified by the material or site conditions.

	Nuclear Gage Mode	Method of Determining
Material Type	of Operation	Maximum Dry Density
Fine-grained soil, p	ercent oversize particles	(retained on ³ / ₄ -inch sieve)
less than 10%	Direct transmission	One-point Proctor
10 to 25%	Direct transmission	One-point Proctor with aggregate correction
more than 25%	Backscatter	Test section
Granular material	Backscatter	Test section
Shale	(See 1015.07)	(See 1015.07)

TABLE 1015.06-1 COMPACTION TESTING PROCEDURE

B. In-place Density and Moisture. Determine the in-place density and moisture content using a nuclear gage according to AASHTO T 310 and as described below.

1. Standard count. Take a standard count at the beginning of each day the gage is in use. To take a standard count, place the reference block on a flat surface at least six feet (2 m) from any building or structure and at least 30 feet (10 m) from any other radiation source (like another nuclear gage). The flat surface must have a density greater than 100 lb/ft³ (1600 kg/m³), so asphalt, concrete, compacted aggregate, compacted soil and similar materials are acceptable, but truck beds, tailgates, tables, etc. are not. Place the gage on the reference block such that it rests between the raised edges of the block and the right side of the gage is firmly against the metal butt plate on the block. Ensure the source rod is in the "safe" position and start the standard count.

If the standard count passes, accept the new standard. If the standard count does not pass, do not accept it. Check to see if all the requirements above were met. If so, take another standard count. If the second standard count also fails, erase all the stored standard counts and take four new sets of standard counts. Record the standard counts (both density and moisture) on the compaction testing form.

2. Preparation of surface. Remove all loose and disturbed material from an area large enough to accommodate the gage (for rough surfaces compacted with a footed roller, this may mean removing around 6 inches of material). Smooth the area with the scraper plate. Fill any voids in the smoothed surface with fine sand or fine-grained soil from nearby the test location.

If using the direct transmission mode to determine in-place density, place the scraper plate on the surface and press down firmly. Place the extraction tool over one of the guides on the scraper plate and then place the drill rod through the guide. Hammer the drill rod two inches (50 mm) deeper than the measurement depth. (Note that many drill rods have markings which include the additional two inches). Mark at least two edges of the scraper plate to make it easier to correctly place the gage. Remove the drill rod by pulling straight up and twisting the extraction tool. Pick up and remove the scraper plate.

3. Taking a measurement. While taking a measurement, ensure there are no other radiation sources (such as other nuclear gages) within 30 feet (10 m) of the gage.

If using the backscatter mode, place the gage on the prepared surface, extend the source rod to the backscatter position, and take a measurement.

If using the direct transmission mode, slightly tilt the gage and extend the source rod two inches (50 mm). Place the source rod into the hole formed by the drill rod, and lower the gage to the surface. Then extend the source rod to the required measurement depth. When testing subgrade compaction (Item 204 or 206) use a measurement depth of 12 inches (300 mm). When testing compaction of embankment or backfill materials, use a measurement depth of 8 inches (200 mm) (other measurement depths may also be used depending on lift thickness and site conditions.) Pull the gage to the right so that the side of the source rod that faces the center of the gage is in firm contact with the side of the hole. Take a measurement.

For both modes of operation, use a count time of at least one minute. A four minute count time may also be used for more accuracy.

Record the in-place readings for wet density, dry density, and percent moisture on the compaction testing form.

Return the source rod to the "safe" position and remove the gage.

4. Trench correction. When performing compaction testing in a trench, follow the gage manufacturer's recommended procedure to perform a trench correction (also called a trench offset).

The nuclear gage determines moisture content by measuring reflected slow neutrons, and it determines density in the backscatter mode by measuring reflected gamma photons. When operating the gage in a trench, the gage will measure additional reflected gamma photons and neutrons that "bounce" off the sides of the trench, thus increasing the density and moisture content readings. The trench correction procedure typically consists of taking two standard counts on the reference block, one outside of the trench and one inside of the trench, before determining the in-place density and moisture content of the trench backfill.

5. Moisture correction. The moisture content reading from the gage may be greater than the actual moisture content when testing soil that contains significant amounts of organic material, coal, gypsum, cement, lime, lime kiln dust, fly ash, or reclaimed asphalt concrete pavement (RACP). When directed by the Engineer, correct the moisture content according to the gage manufacturer's recommended procedure.

The nuclear gage determines moisture content by measuring the amount of hydrogen present in the material. If the material being tested contains significant amounts of hydrogen in a form other than free water (such as soil containing organic material, coal, gypsum, cement, lime, lime kiln dust, fly ash, or RACP), then the gage will report a moisture content reading that is greater than the actual moisture content. As a result, the gage will also report a dry density reading that is less than the actual dry density. The correction procedure typically consists of comparing the gage moisture content reading to the actual moisture content (determined using other applicable test methods) and determining the offset correction.

Do not perform a moisture correction on chemically stabilized soil (Items 205 and 206) unless directed by the Engineer. The specifications for Items 205 and 206 account for the fact that the cement, lime, or lime kiln dust mixed into the soil reduces the actual moisture content by binding with free water while not reducing the moisture content reading from the nuclear gage.**C**.

Maximum Dry Density. Determine the maximum dry density using the method specified in Table 1015.06-1 for the material type being tested. The methods are described below.

1. One-point Proctor. Determine the maximum dry density and optimum moisture content for the material according to AASHTO T 272, Method C, except as modified below. For the family of curves, use the "Typical Moisture Density Curves – Set C – May 1949" included with this document.

Perform a one-point Proctor test for each and every compaction test. Obtain a soil sample from the area that was directly under the gage during the in-place density and moisture measurement. Prepare the sample by sieving it through a ³/₄-inch (19 mm) sieve. If a significant amount of oversize particles are retained on the ³/₄-inch (19 mm) sieve, calculate the percentage

of oversize particles as compared to the total sample weight and check to see if an aggregate correction is required.

Do not dry the sample. Use the sample at the in-place moisture content.

Place the Proctor mold on a concrete block or concrete surface when compacting the sample.

Use the wet density of the Proctor sample and the percent moisture from the in-place moisture reading to mark a point on the family of curves. If the point falls on one of the curves, use the maximum dry density and optimum moisture content for that curve. If the point falls in the space between two curves, use the higher curve to determine the maximum dry density and optimum moisture content. Record the curve letter, the maximum dry density and the optimum moisture content on the compaction testing form.

2. One-point Proctor with Aggregate Correction. Determine the maximum dry density and optimum moisture content for the material as described above for the one-point Proctor method. If the amount of oversize particles that are retained on the ³/₄-inch (19 mm) sieve is greater than or equal to 10 percent of the total sample and less than or equal to 25 percent, adjust the maximum dry density and optimum moisture content to account for the fact that the oversize particles were removed from the in-place soil sample. Calculate the corrected maximum dry density according to AASHTO T 224, using either the following equation or the Aggregate Correction Chart included with this document.

$$MDD_{c} = \frac{62.4 \ G_{s} \ MDD}{MDD \ \% \ C + 62.4 \ G_{s} \ (1 - \% \ C)}$$

Where:

 MDD_c = corrected maximum dry density

MDD = maximum dry density from one-point Proctor method

- G_s = bulk specific gravity (oven-dry basis) of oversize particles retained on ³/₄-inch (19 mm) sieve
- %C = percent of oversize particles (expressed as a decimal, e.g. 12% = 0.12)

After calculating the corrected maximum dry density, determine the corrected optimum moisture content by using the Typical Moisture Density Curves. Find the lowest curve that has a maximum dry density equal to or greater than the maximum dry density. Use the optimum moisture content for that curve as the corrected optimum moisture content.

3. Test Section. Determine the maximum dry density of the material by constructing a test section. Use Test Section Method A when the moisture-density curve (AASHTO T 99) of the material indicates one distinct optimum moisture content. Use Test Section Method B when the moisture-density curve does not indicate one distinct optimum moisture content for the material. Use Test Section Method C when the material has significant void space between particles (open graded) or is highly variable.

Construct test sections of the approximate size shown in the table below for the appropriate material. Notify the Engineer at least 24 hours before performing a test section.

TABLE 1015.06-2 APPROXIMATE SIZE OF TEST SECTION

Material	Test Section Size					
Embankment, subgrade or aggregate base	400 yd ²	(350 m^2)				
Trench backfill	10 yd²	(8 m²)				
Select granular backfill for MSE walls	40 yd ²	(35 m²)				

Test Section Method A

- 1. Place the material in the test section at a moisture content within one percent of the optimum moisture content.
- 2. Compact the material in the test section with two roller passes.
- 3. Measure the in-place density and moisture content according to 1015.06.B.
- 4. Mark the test location within the test section to ensure all in-place density tests are taken in the same location.
- 5. Compact the material in the test section with one more roller pass.
- 6. Measure the in-place density and moisture content again.
- 7. Repeat Steps 5 and 6 until the in-place dry density of the material decreases or stops increasing.
- 8. After the maximum dry density is achieved, compact the material with two more roller passes, and measure the in-place density and moisture content a final time to verify the maximum dry density was achieved.
- 9. Record the maximum dry density and the number of passes required to achieve the maximum dry density.

When the Contractor uses vibration to assist compaction, adjust the vibration as necessary to prevent instability or cracking. Reduce the moisture content if the material becomes unstable. Construct a new test section to determine a new maximum dry density when the material being compacted or the supporting foundation material changes significantly.

Test Section Method B

- 1. Place the material in the test section at a moisture content from 0 to 3 percent.
- 2. Determine the trial maximum dry density at this moisture content by following Steps 2 through 8 of Test Section Method A.
- 3. Record the trial maximum dry density, the moisture content, and the number of roller passes required to achieve the trial maximum dry density at this moisture content.
- 4. Repeat Steps 1 through 3 above, increasing the moisture content approximately 2 percent each time, until the additional water makes the material unstable or until the trial maximum dry density decreases or stops increasing with the added water.
- 5. Record the greatest trial maximum dry density from the steps above as the maximum dry density for the material. Also record the moisture content and the number of roller passes required to achieve this maximum dry density.

When the Contractor uses vibration to assist compaction, adjust the vibration as necessary to prevent instability or cracking. Construct a new test section to determine a new maximum dry density when the material being compacted or the supporting foundation material changes significantly.

Test Section Method C

- 1. Place the material in the test section at a moisture content at least 1.5 percent above a saturated surface dry condition.
- 2. Compact the material in the test section with two roller passes.
- 3. Measure the in-place density and moisture content according to 1015.06.B in three different locations. Calculate the average dry density.
- 4. Mark each test location within the test section to ensure each subsequent inplace density test is taken in the same location.
- 5. Compact the material in the test section with one more roller pass.
- 6. Measure the in-place density and moisture content again at the same three locations. Calculate the average dry density.
- 7. Repeat Steps 5 and 6 until the average dry density decreases or stops increasing, or the compaction begins to crush and break the aggregate pieces.
- 8. Once compaction of the test section is complete, measure the in-place density at ten different locations within the test section. Calculate the maximum dry density as the average dry density of the ten in-place density measurements.
- 9. Record the maximum dry density and the number of roller passes required to achieve the maximum dry density.

Apply water to the surface during compaction to maintain a moisture content at least 1.5 percent above a saturated surface dry condition. The Contractor may use water from the roller to achieve this. Construct a new test section to determine a new maximum dry density when the material being compacted or the supporting foundation material changes significantly.

D. Calculations. Calculate the percent compaction by dividing the in-place dry density measurement by the maximum dry density for the material. Use the corrected maximum dry density if an aggregate correction was required.

1015.07 Shale. The compaction testing method for shale depends on the durability of the shale. Test shale for durability according to 703.16.D to determine if the shale is durable or nondurable shale. Use the results from the durability testing to determine the appropriate compaction testing method for shale according to the following table. Perform the compaction testing according to 1015.06.

Test Results	Nuclear Gage Mode	Method of Determining
from 703.16.D	of Operation	Maximum Dry Density
Percent retained on	³ / ₄ -inch sieve after sittin	g in water for 48 hours
less than 10%	Direct transmission	One-point Proctor
10 to 25%	Direct transmission	One-point Proctor with aggregate correction
25% to 75%	Backscatter	Test section
more than 75%	Field test for durability	using a roller (see below).
Percent of shale that	t breaks down with six p	basses of a roller.
more than 40%	Backscatter	Test section
less than 40%	No compaction testing	. Compact with specified number of roller passes.

TABLE 1015.07-1 SHALE COMPACTION TESTING PROCEDURE

1015.08 Compaction Acceptance. The minimum compaction requirement as a percentage of the maximum dry density is given in the corresponding specification for the material. All compaction percentages are calculated based on the dry density of the material.

1015.09 Number of Tests. Divide the work into lots as shown in the following table. Perform the minimum number of compaction tests as shown in the table. When a lot is measured in square yards (square meters) and the material is placed in multiple lifts, perform at least the minimum number of compaction tests on each lift.

Item	Maximum Lot Size *	Minimum Number of Compaction Tests
203 and 205	2000 yd ³ (1530 m ³)	One per Lot
204 and 206	3000 yd² (2500 m²)	One per Lot
304 and 411	5000 yd² (4200 m²)	One per Lot
611 backfill	50 feet (17 m) of pipe	One per Lot or one every 5 th lift,
		whichever results in more compaction tests.
503 backfill	One structure	One every 5 th lift
840 select	300 ft	One for every lift
granular backfill	(100 m) of wall	in the Lot

TABLE 1015.09-1 MINUMUM NUMBER OF COMPACTION TESTS

* - The lot size may be modified by the Engineer to maintain a workable system. For example, two or more areas containing small quantities of embankment material could be combined into one lot.

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