INDIANA DEPARTMENT OF TRANSPORTATION
DIVISION OF MATERIALS AND TESTS
GEOTECHNICAL ENGINEERING DIVISION

FIELD TESTING OF SOIL, GRANULAR SOIL, COARSE AGGREGATE AND CHEMICALLY MODIFIED SOILS

The procedures for determining the maximum dry density, optimum moisture content, in-place density, in-place strength, and moisture content of soils, granular soil, and coarse aggregates in the field will be as follows:

TEST METHODS

Attachment I lists the test methods that will be used to test soils, granular soil, and aggregates. The test methods are as follows:

AASHTO T 99	--	Moisture-Density Relations of Soils Using a 2.5-kg (5.5-lb) Rammer and a 305-mm (12-in.) Drop
AASHTO T 191	--	Density of Soil In-Place by the Sand-Cone Method
AASHTO T 224	--	Correction for Coarse Particles in the Soil Compaction Test
AASHTO T 255	--	Total Evaporable Moisture Content of Aggregate by Drying
ITM 506	--	Field Determination of Moisture Content of Soils
ITM 508	--	Field Determination of Deflection Using Light Weight Deflectometer
ITM 509	--	Field Determination of Strength Using Dynamic Cone Penetrometer
ITM 510		Determining Sulfate Content in Soils By Colorimetric Test.
ITM 512	--	Field Determination of Maximum Dry Density and Optimum Moisture Content of Soils

Mix design for chemically modified soils performed by Contractors.

SOILS

Soils will be defined as cohesive material with more than 35 % passing the No. 200 sieve. Soils are further defined as follows:

Clay Soil – Soil with a maximum dry density of 1 1/4 lb/ft^3 or less
Silty Soil – Soil with a maximum dry density greater than 114 lb/ft^3 and less than or equal to 120 lb/ft^3
Sandy Soil – Soil with a maximum dry density greater than 120 lb/ft^3

Options 1 or 2 may be used for each of the following tests if there is more than one option.

Maximum Dry Density and Optimum Moisture Content

1. AASHTO T 99 (Method A)
2. ITM 512

In-Place Density

1. AASHTO T 191*

In-Place Strength

1. ITM 509

Moisture Content

1. ITM 506

* Correction for coarse particles will be made in accordance with AASHTO T 224.

GRANULAR SOIL

Granular soil will be defined as soil that is non-cohesive with 35 % or less passing the No. 200 sieve. Options 1 or 2 may be used for the following tests, if there is more than one option.

Maximum Dry Density and Optimum Moisture Content

1. AASHTO T 99 (Method A or C)

In-Place Density

1. AASHTO T 191*

In-Place Strength

1. ITM 508 (Granular soils with aggregate retained on the 3/4 in. sieve, structural backfill sizes 2 in. and 1 ½ in., and b borrow with a similar gradation)

2. ITM 509 (Granular soils with aggregate that is 100% passing the 3/4 in. sieve, structural backfill sizes 1 in., 1/2 in., No. 4 and No. 30 and b borrow with a similar gradation)

Moisture Content

1. ITM 506

* Corrections for coarse particles will be made in accordance with AASHTO T 224.

COARSE AGGREGATES

Coarse aggregates are defined as having a minimum of 20% retained on the No.4 sieve. Coarse aggregates may be tested by Option 1 or 2 if there is more than one option.

Maximum Dry Density and Optimum Moisture Content

1. AASHTO T 99 (Method C)

In-Place Density

1. AASHTO T 191*

In-Place Stiffness

1. ITM 508 (coarse aggregate sizes No. 43, 53, and 73)

Moisture Content

1. AASHTO T 255 (reported to the nearest whole number)

* Corrections for coarse particles will be made in accordance with AASHTO T 224.

CHEMICAL MODIFIED SOILS

Chemical modified soils will be tested with the Dynamic Cone Penetrometer (DCP) or Light Weight Deflectometer (LWD)

In-Place strength/ Stiffness

1. ITM 509
2. ITM 508

DRY DENSITY

The dry density of the material will be determined as follows:

$$W = \frac{W_1}{w + 100} \text{ x } 100$$

where:

W = dry density in lb/ft^3 of compacted soil
W_1 = wet density in lb/ft^3 of compacted soil
w = moisture content (percent) of sample

The dry density and wet density will be reported to the nearest 1 lb/ft^3 and the moisture content will be reported to the nearest 1 %.

DEFLECTION AND MODULUS WITH LIGHT WEIGHT DEFLECTOMETER (LWD)

The LWD test is a portable Falling Weight Deflectometer developed to enable fast testing of constructed layers of embankment under load conditions to approximate loads imposed by traffic.

The LWD criteria will be in accordance with 203.24. The critical steps in conducting this test procedure in accordance with ITM 508 are as follows:

1. Assure that the load plate is in full contact with the surface of the soil

2. The guide rod is required to be perpendicular to the load plate.

3. The falling weight is caught after the weight rebounds from striking the plate

4. A test is considered invalid if the operator does not catch the falling weight after the weight has rebounded from the plate or the load plate moves laterally

5. Drops 1 to 3 are used to seat the load plate and drops 4 to 6 are used to measure the stiffness of the material

6. Average of drops 4 to 6 is maximum deflection at a single test location (mm)

MOISTURE CONTENT

One moisture content test will be required for each day that density or strength measurements are taken. The sample for moisture content is required to be representative of the entire depth of the compaction lift being tested. Additional moisture content tests may be required during the day if there is a failing moisture test or a change in the material. Additional moisture test shall be performed when required by specification. Moisture content may be determined by drying the sample with a stove, hot plate, or microwave oven, or by means of a moisture probe. All tests are required to be in accordance with ITM 506.

CHEMICAL MODIFIED SOILS (SECTION 215)

Cement, lime, lime by-products, and fly ash are allowed in soil stabilization and modification. The selection of the chemical modifier is recommended by an INDOT Qualified Geotechnical Consultant. The DCP or LWD may be used.

When the DCP is used, disposable cones are required. Three random test locations will be determined in accordance with ITM 802 for each 1,400 cyd of chemically modified soil. The average of the blow counts obtained at the three locations will be the DCP blow count representing the 1,400 cyd section. The following requirements for compaction apply when using the DCP:

1. The average DCP blow count will not be less than 17 for the top 6 in. of a 14 in. lift. Blow counts of 15 and above will be used to determine the average.

2. The average DCP blow count will not be less than 16 for the bottom 8 in. of a 14 in. lift. Blow counts of 14 and above will be used to determine the average.

Locations with test results less than the specified minimum blow counts will be retested or shall be reworked if the minimum blow count is not obtained.

DCP criteria for chemical modified soils were developed at optimum moisture content. The higher moisture content will decrease DCP blow counts. Moisture content tests of the soil are required to be conducted during mixing and shall be at or above the optimum moisture content. Moisture contents shall be maintained at or above the optimum moisture content for the first 48 h after mixing with quicklime or hydrated lime. The moisture test is required to be conducted for each 4h of chemical and soil mixing. The Contractor is required to verify that the material is 100 % passing the 1 in. sieve and at least 60 % passing the No. 4 sieve.

Chemical modified soils may be tested for strength 24h after compaction. Construction traffic or equipment shall not be allowed on the chemical modified soil until the modified soils meet the compaction test requirements.

The DCP test for chemical modified soil is discontinued at 25 blow counts if the DCP does not penetrate to the required depth of the layer of the chemical modified soil. Verification of the depth of the treated soil may be determined by spraying phenolpthalene solution on the soil.

As an alternate to the DCP test, LWD may be used for acceptance testing of chemically modified soils in accordance with 203.24.

SOILS DRYING WITH CHEMICAL MODIFIERS (SECTION 217)

For drying soils having moisture over 2% above optimum moisture content, fly ash or lime is allowed to be used. Soils containing greater than 6% by dry weight calcium, magnesium carbonate or organic material, or having a maximum dry density of less than 95 pcf, or with soluble sulfate content greater than 1,000 ppm shall not be used.

The moisture content of the mixture shall be at the optimum moisture content or above the optimum moisture content as determined by the mix design in accordance with 215.03. The Contractor is required to perform moisture tests during the day to verify the spread rate application of the flyash or lime.

Acceptance of chemically modified soils will be performed on the finished grade with the DCP, gradation tests and moisture tests and will meet the following requirements:

1. A minimum DCP blow count of 20 for 12 in. and a minimum DCP blow count of 8 for the top 6 in.

2. A minimum of two passing DCP test for each 1,000 lft for each 2-lane pavement section

3. A minimum of one gradation test for every 2,500 lft for each 2-lane pavement section

4. A minimum of one moisture test for every 4h of lime soils mixing

Construction traffic is allowed after the minimum DCP blow count is obtained and shall be routed in one direction so that the chemically modified soil does not pump or rut.

ONE POINT PROCTOR – CLAY, SILTY, OR SANDY SOILS (SOILS >35% PASSING NO. 200 SIEVE)

All soils are required to be compacted to not less than the specified strength based on the DCP or the minimum percent of maximum dry density. The moisture content is required to be in the specified range of the optimum moisture content. To determine the compliance with these requirements, samples representing each soil type on the contract are required to be tested in a laboratory for maximum dry density and optimum moisture content in accordance with AASHTO T 99. The soil classification and DCP count are determined from these tests. As soils may have a wide variation in properties on a given contract, determination of the correct DCP criteria or the maximum dry density and optimum moisture content in a laboratory for every possible soil combination is difficult. However, testing a sample representing each main soil type on the contract will be beneficial in determining the correct DCP blow count.

A procedure has been developed for field determination of the maximum dry density and optimum moisture content of the soils encountered at each location on the contract. The procedure consists of compacting the soil in accordance with ITM 512 and using the charts in Appendix II to determine the adjusted maximum wet density, adjusted maximum dry density, and adjusted optimum moisture content. Knowing the optimum moisture content, the DCP blow count may then be adjusted, if necessary, using the table in Appendix IV. This procedure is referred to as a One Point Proctor Test.

Using the One Point Proctor charts in Appendix II, the following steps are used to obtain the correct target values:

1. Conduct a One Point Proctor Test in accordance with ITM 512 on a sample obtained from the grade. The moisture content is required to be maintained within -3 % and +1 % of the optimum moisture content during the compaction of the sample.

2. Plot the point on the Maximum Wet Density vs. Moisture Content chart (Figure 1) determined from the wet density and moisture content obtained. If the point is between two curves on the chart, project the point, using the same curvature as the nearest line, to the maximum wet density/moisture content solid line. The intersecting point on the solid line is the adjusted maximum wet density of the soil.

3. Draw a horizontal line from the point on the maximum wet density/moisture content solid line to intersect the Maximum Wet Density vs. Maximum Dry Density line (Figure 2).

4. Draw a vertical line from the intersection point on the line in Figure 2 to the Optimum Moisture Content vs. Maximum Dry Density line (Figure 3). The intersecting point on the horizontal axis of the Maximum Wet Density vs. Maximum Dry Density chart (Figure 2) is the adjusted maximum dry density of the soil.

5. Draw a horizontal line from the intersection point on the line in Figure 3 to the vertical axis of the Optimum Moisture Content vs. Maximum Dry Density chart (Figure 3). The intersecting value on the vertical axis of the Optimum Moisture Content vs. Maximum Dry Density chart (Figure 3) is the adjusted optimum moisture content of the soil.

6. Once the adjusted optimum moisture content is determined, proceed to the chart in Appendix IV and draw a vertical line from the Optimum Moisture horizontal axis to the line on the chart representing the Maximum Dry Density vs. Optimum Moisture. Draw a horizontal line from the intersection point on the line to the vertical axis representing the DCP criteria. The intersecting value is the required number of DCP blows for a penetration of 6 in. for clay soils and a penetration of 12 in. for silty and sandy soils.

Attachment III has three examples of the procedure indicated above to determine the adjusted maximum wet density, adjusted maximum dry density, and the adjusted optimum moisture content.

The charts in Attachments II, III, and IV are used for clay, silty, or sandy soils. These charts are not applicable for granular soils, b borrow, structure backfill, coarse or fine aggregates, or chemical modified soils.

ATTACHMENT I

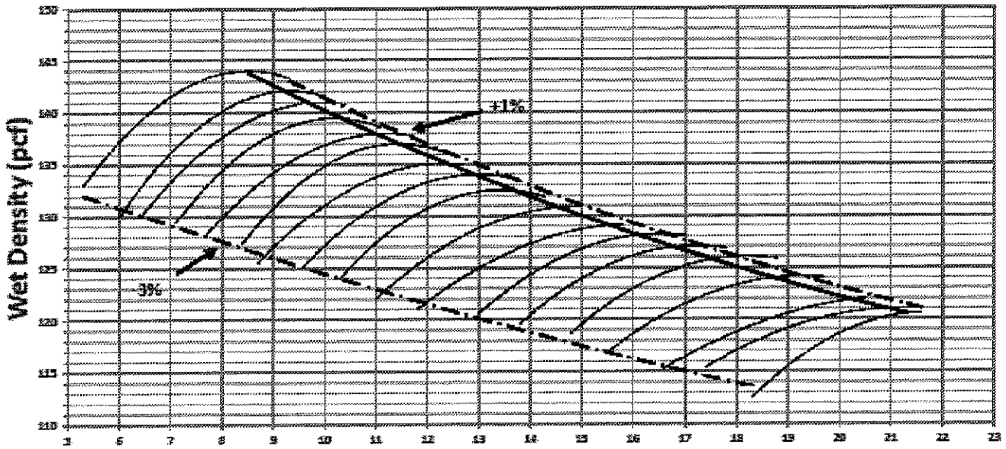
Material Types	Lab Testing	Field Testing					
		Maximum Density (ITM 512)	DCP (ITM 509)	Sand Cone (AASHTO T 191)	Moisture Test		LWD (ITM 508)
					ITM 506	AASHTO T 255	
Soil	**AASHTO T 99 (Method A)**	**X**	**X**	**X**	**X**	**N/A**	**N/A**
Granular Soils (Soils with aggregate retained on the 3/4 in., structural backfill sizes 2 in. and 1 1/2 in., and b borrow with a similar gradation)	**AASHTO T 99 (Method A or C)**	**N/A**	**NA**	**X**	**X**	**N/A**	**X**
Granular Soils (Soils with 100% passing ¾ in., structural backfill Sizes 1 in., 1/2 in. No. 4, and No.30, and b borrow with a similar gradation)	**AASHTO T 99 (Method A or C)**	**N/A**	**X**	**X**	**X**	**N/A**	**N/A**
Coarse Aggregates (No. 5, 43, 53, and 73)	**AASHTO T 99 (Method A or C)**	**N/A**	**N/A**	**X**	**N/A**	**X**	**X**
Coarse Aggregates (No. 8, 9, 11, or 12)	**Field testing is not required. Compaction shall be in accordance with the applicable specification.**						
Chemical Modified Soils	**Mixed Design Performed by Contractor**	**N/A**	**X**	**N/A**	**X**	**N/A**	**X**

N/A – Not Applicable

ATTACHMENT II

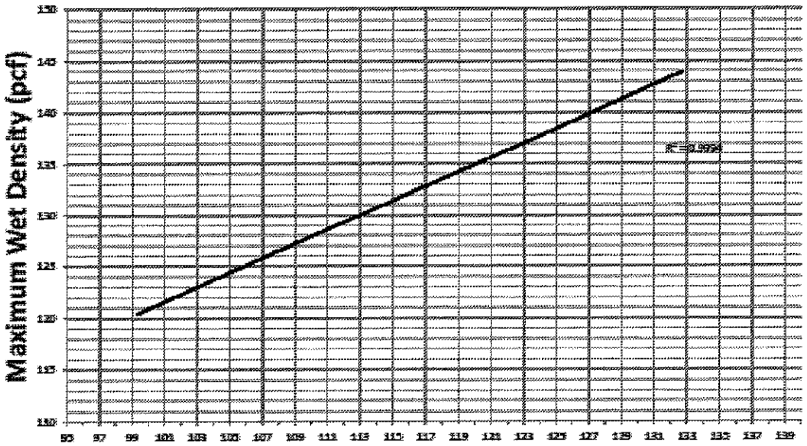
INDOT Family of Curves for One Point Proctor, ITM 512

Maximum Wet Density vs Moisture Content



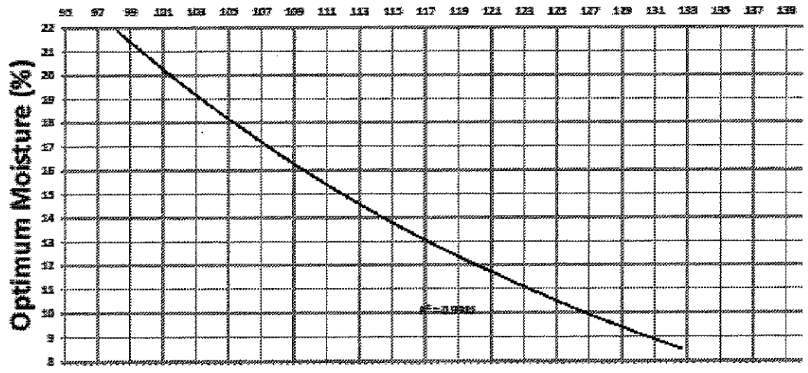
[Figure 1]

Maximum Wet Density vs Maximum Dry Density



[Figure 2]

Opt. Moisture Content vs Maximum Dry Density



[Figure 3]

- Charts to be used for Clay, Silty, or Sandy soils only.

-Moisture is required to be between -3% and +1% for a valid Maximum Wet Density.

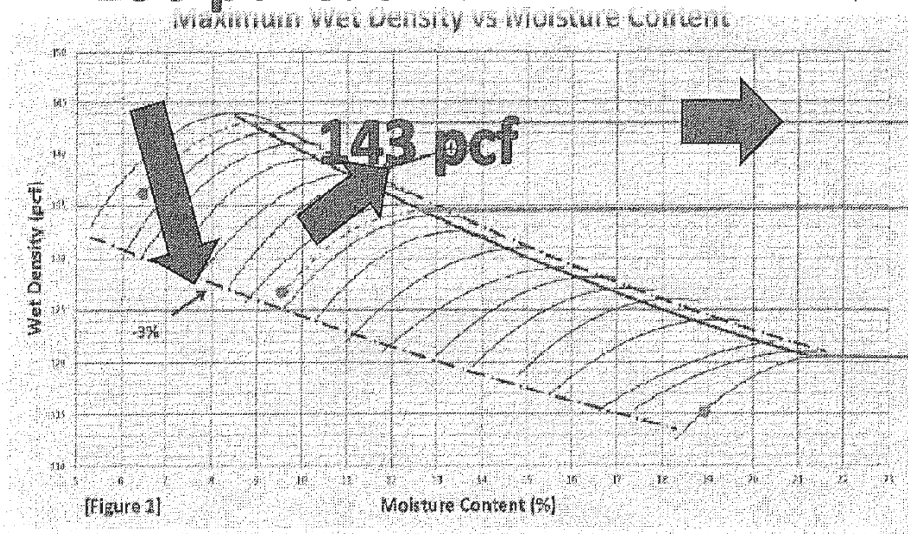
-These charts are an alternative to the INDOT Family of Curves and may be used in accordance with ITM 512.

ATTACHMENT III

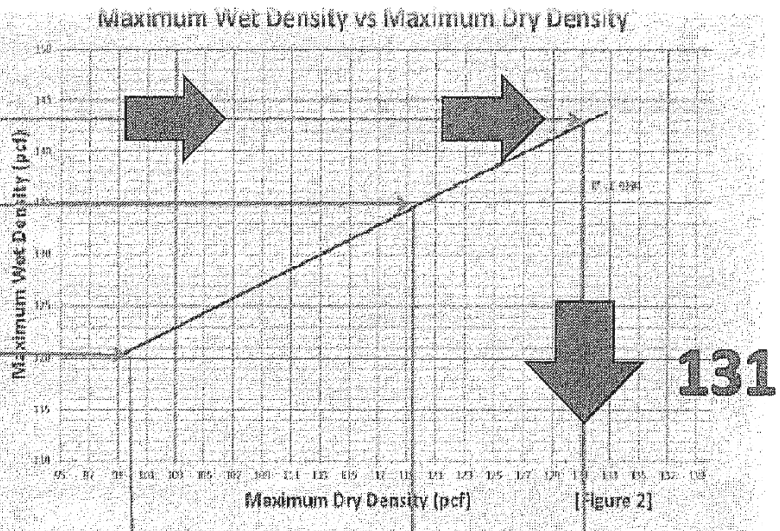
One Point Proctor
ITM - 512

EXAMPLE

136 pcf & 6.5%

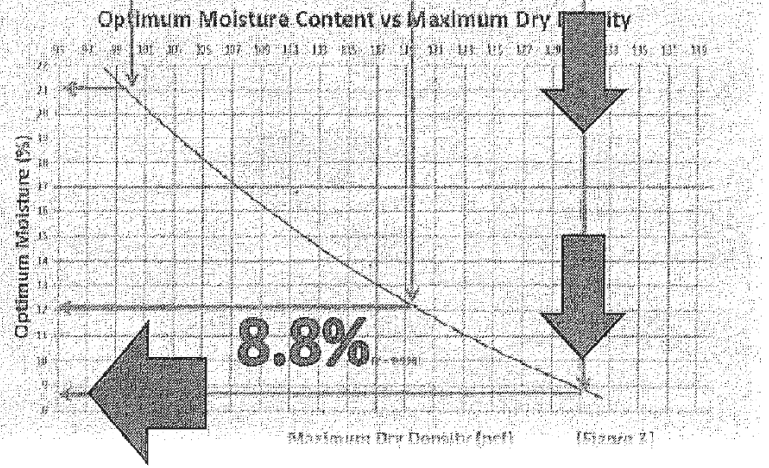


[Figure 1]



131.0 pcf

[Figure 2]



[Figure 3]

- Data not to be used with Granular Soils.

- Plot based on data acquired from July 1965 to January 1969 by Soils Department.

- Moisture must be between -3% and +1% for a valid Maximum Wet Density

- These charts are an alternative to the Family of Curves and may be used in accordance with ITM-512

- Revised 4/4/14

ATTACHMENT IV

Textural Classification	Maximum Dry Density (pcf)	Optimum Moisture Content Range (%)	Acceptable Minimum DCP value for 6 in.	Acceptable Minimum DCP value for 12 in.
Clay Soils				
Clay	<105	19 to 24	6	
Clay	105 - 110	16-18	7	
Clay	111 - 114	14-15	8	
Silty Soils				
Silty	115 - 116	13 to 14		9
Silty	117 - 120			11
Sandy Soils				
Sandy	121-125	8 to 12		12
Sandy	>125			15
Granular Soils - Structure Backfill and A-1, A-2, and A-3 Soils				
No. 30				6
No. 4				7
1/2 in.				11
1 in.				16