Field Soils Testing 2016

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Course Objectives

- Required Field Tests
  - Procedures
  - Frequencies
  - Specifications
- Required State Form Numbers (SFN)
- Inspection Duties

Certification

- Soils Field Tester
  - 5- year certification
    - Classroom – or test out
    - Written Exam
    - Hands-on performance exam

Field Tests

- Field Tests Required
  - T 99 and T 180 – Moisture Density Relations of Soils (Manual Hammer)
    - 1-Point Proctor
  - T 265 – Laboratory Determination of Moisture Content of Soils
  - D 2167 – Density of Soil In-Place by Rubber Balloon Method

Field Tests

- Field Tests Required
  - T 217 Determination of Moisture in Soil by Means of Calcium Carbide Gas Pressure Moisture Tester (Speedy)
  - T 191 Density In-Place by the Sand Cone Method
  - D 4643 – Microwave Method of Drying Soils

Field Test Procedures and Forms

- Online Manuals
  - Field Sampling and Testing Manual
  - *http://www.dot.nd.gov/divisions/materials/testingmanual.htm*
  - Portion of Section 200 is included in book
    - Official and current versions are available online
- Forms and Worksheets are Online
  - *http://www.dot.nd.gov/dotnet/forms/forms.aspx*

Other Training Resources

- YouTube Videos
  - http://www.youtube.com/user/ugptindsu
- Online Training Modules, UGPTI
  - Each test procedure has a separate learning module.
  - http://www.translearning.org/

The Overall Picture

- Why do we need to perform these tests?
- What goal are we trying to achieve?

Compaction!!
Compaction!!
Compaction!!

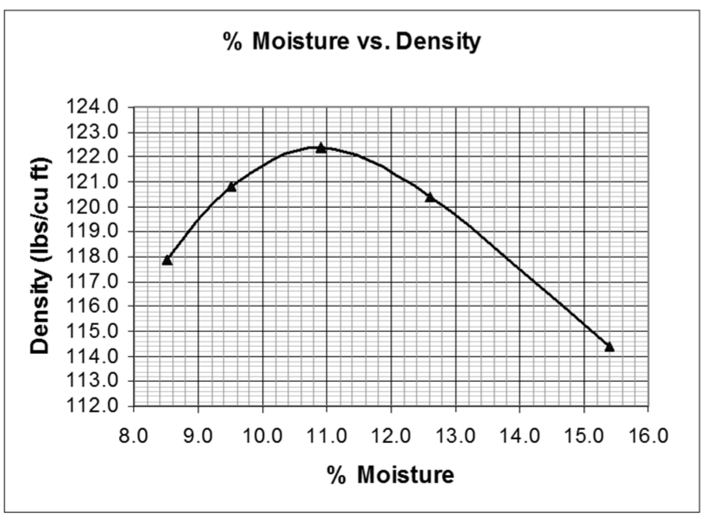
Overall Picture

- Benefits of Compaction
  - Minimize Future Settlement
  - Increase Shear Strength
  - Decrease Permeability
  - Increases Resistance to Frost Action
  - Increase Slope Stability

T 99 & T 180 - Moisture-Density Relations of Soils

- What influences compaction?
  - Moisture Content
  - Energy applied to soil

T 99 & T 180 - Moisture-Density Relations of Soils



T 99 & T 180 - Moisture-Density Relations of Soils

- By performing a moisture-density relationship (Proctor test) on a given soil we can gain a wealth of information about the soil before it is ever compacted in the field such as:
  - Maximum dry density
  - Optimum moisture content at it's maximum dry density
  - Type and physical characteristics of soil

T 99 & T 180 - Moisture-Density Relations of Soils

- Optimum Moisture Definition
  - *Moisture content at which a soil can be compacted to its Maximum Dry Density with a given compactive effort*
- Maximum Dry Density Definition
  - *The dry unit weight defined by the peak of a compaction curve*

T 99 & T 180 - Moisture-Density Relations of Soils

- NDDOT allows use of two methods: Method A & D
- Method D shall only be used in lieu of Method A when there is more than 5% by weight of material retained on the No. 4 sieve

T 99 & T 180 - Moisture-Density Relations of Soils

- Two different standards for moisture-density relations are presently used by the NDDOT
- The main difference is the compaction energy applied to the soil within the mold

T 99 & T 180 - Moisture-Density Relations of Soils – Method A

Feature	T 99	T 180
Weight of Hammer	5.5 lbs	10 lbs
Distance of Drop	12”	18”
Number of Soil Layers	3	5
Diameter of Mold	4”	4”
Soil Passing Sieve Size	No. 4	No. 4
Hammer Blows/layer	25	25

T 99 & T 180 - Moisture-Density Relations of Soils – Method D

Feature	T 99	T 180
Weight of Hammer	5.5 lbs	10 lbs
Distance of Drop	12”	18”
Number of Soil Layers	3	5
Diameter of Mold	6”	6”
Soil Passing Sieve Size	3/4”	3/4”
Hammer Blows/layer	56	56

T 99 & T 180 - Moisture-Density Relations of Soils

Sample Size Required

Test	Method A	Method D
One Point	7 lbs	25 lbs
Multi Point	35 lbs	125 lbs

T 99 & T 180 - Moisture-Density Relations of Soils

- Procedures
  - Method A or D
    - T-99 or T-180

T 99 & T 180 - Moisture-Density Relations of Soils

- If soil is damp, dry in air or drying apparatus not exceeding 140 degrees F
- Break up soil chunks so can be passed thru No. 4 sieve
- Discard any material retained on No. 4 sieve
- Continue to dry mass of soil down until near or completely dry

T 99 & T 180 - Moisture-Density Relations of Soils

Procedure

- Divide sample into 5 individual samples (7 lb)
- Add water to 1st sample to approx. 4 percentage points below optimum
- Mix remaining samples as sample one increasing water by 2.5% or approx. (60 ml) for each point

T 99 & T 180 - Moisture-Density Relations of Soils

- Allow samples to cure for at least 12 hours
- Weigh empty mold minus collar and base plate and record to nearest 0.01 lbs. Record on SFN 10063
- Assemble mold, collar, and base plate and place on rigid/stable foundation

T 99 & T 180 - Moisture-Density Relations of Soils

- Add sufficient material to the mold to produce a compacted layer of approx. 1¾" for T 99 or 1" for T 180.
- Lightly tamp the soil until it is no longer loose or fluffy
- Soil compacted with 25 evenly distributed blows

T 99 & T 180 - Moisture-Density Relations of Soils

- After each layer trim any soil along the mold walls and distribute on top of compacted layer
- Keep manual hammer perpendicular to base of mold and lift to it's maximum position
- Repeat procedure for each lift
  T-99 3 lifts
  T-180 5 lifts

T 99 & T 180 - Moisture-Density Relations of Soils

- Final layer should be just over the top of mold
- After the last layer carefully remove collar by rotating it first to break the bond between it and soil before lifting off
- Trim soil level with top of mold using a straightedge

T 99 & T 180 - Moisture-Density Relations of Soils

- After trimming clean off outside of mold. Remove from base plate
- Weigh mold and wet soil and record to nearest 0.01 lbs
- Subtract weight of mold by weight of the mold + wet soil and divide by volume of mold (1/30 Ft)
- Record as wet density in lbs/cubic ft

T 99 & T 180 - Moisture-Density Relations of Soils

- Wet wt. of soil = (wt. of mold + soil) – wt. of mold
- Wet density (pcf) = wet wt. of soil ÷ vol. of mold

T 99 & T 180 - Moisture-Density Relations of Soils

- Extrude from mold and collect a sample for water content determination
- Slice soil specimen vertically through center
- Moisture sample removed from one cut face over full length of inside of soil cylinder
- Approx. 100 grams of wet soil

T 99 & T 180 - Moisture-Density Relations of Soils

- Place moisture sample in container, cover, and weigh
- Record weight of wet soil to nearest 0.1 gram
- Dry to constant weight as per T 265
- Calculate moisture content to nearest 0.1%

T 99 & T 180 - Moisture-Density Relations of Soils

- Compute and record Dry Density to nearest 0.1 pcf
- Dry Density, (pcf) = (wet density x 100)/(100 + % moisture)

T 99 & T 180 - Moisture-Density Relations of Soils

- Repeat process for each point
- Process continued until wet density decreases or stabilizes
- Moisture content and dry density calculated for each sample

MOISTURE-DENSITY RELATIONSHIP TESTS
North Dakota Department of Transportation, Materials & Research Division
SFN 10063 (Rev. 01-2009)

Project Number Example	PCN 20134	Station	Depth Below Grade
Offset From Centerline		Type of Soil	
AASHTO Designation T180	Date	Test Number	

Density

Determination No.		1	2	3	4	5
A. Volume of Mold	cu. ft.	0.0333	0.0333	0.0333	0.0333	0.0333
B. Weight of Mold + compacted soil	lbs.	8.07	8.25	8.41	8.51	8.56
C. Weight of Mold	lbs.	4.17	4.17	4.17	4.17	4.17
D. Weight of Compacted Soil = B - C	lbs.	3.90	4.08	4.24	4.34	4.39
E. Wet density = D/A	lbs./cu. ft.	117.1	122.5	127.3	130.3	131.8
F. Dry density = $\frac{E \times 100}{100 + L}$	lbs./cu. ft.	109.6	112.9	115.4	116.0	115.0

AASHTO T99 or T180 Tested by RT

Moisture Content

Container No.		1	2	3	4	5
G. Wet Weight + Container	gms.	178.8	171.4	201.5	187.5	214.6
H. Dry Weight + Container	gms.	168.3	159.1	184.2	168.8	189.2
I. Moisture Loss = G - H	gms.	10.5	12.3	17.3	18.7	25.4
J. Weight of Container	gms.	15.1	15.1	17.1	17.1	16.0
K. Dry Weight of Soil = H - J	gms.	153.2	144.0	167.1	151.7	173.2
L. % Moisture (I/K) x 100		6.9	8.5	10.4	12.3	14.7

ASTM D4643 AASHTO T217, or T-265 Tested by RT

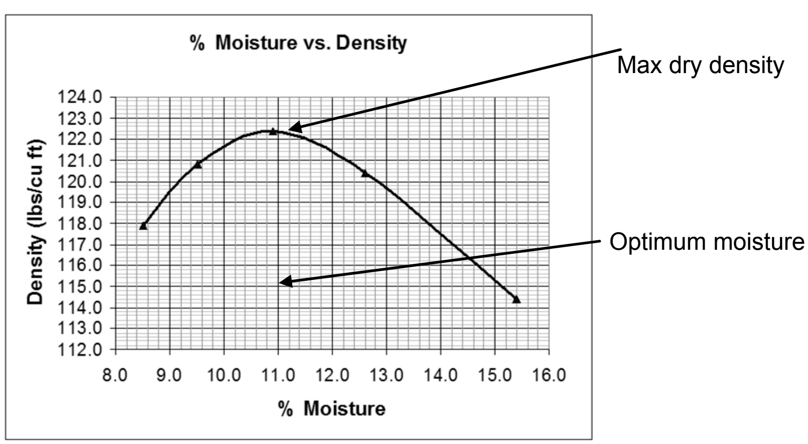
T 99 & T 180 - Moisture-Density Relations of Soils

- Graph data on cross-ruled area on form SFN 10063
- Dry density plotted on vertical (y) axis
- Moisture content plotted on horizontal (x) axis

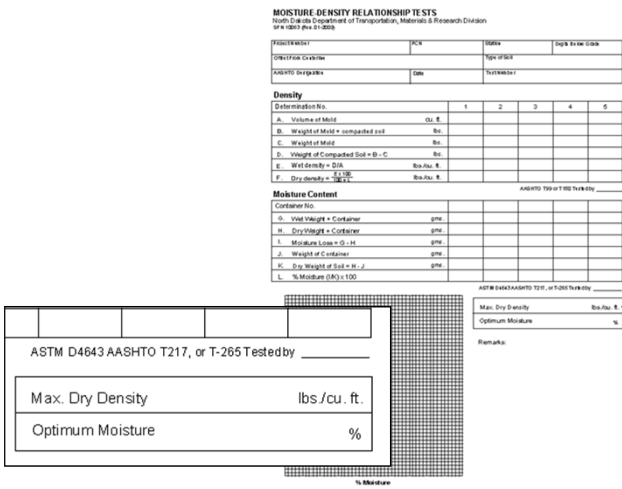
T 99 & T 180 - Moisture-Density Relations of Soils

- After points are plotted draw a smooth flowing curve through the plotted points
- From peak of curve select Maximum Dry Density to record to nearest 1 lbs/cu. ft.
- From peak of curve move vertically down and select Optimum Moisture and record to nearest 0.1%

T 99 & T 180 - Moisture-Density Relations of Soils



T 99 & T 180 - Moisture-Density Relations of Soils



SFN 10063

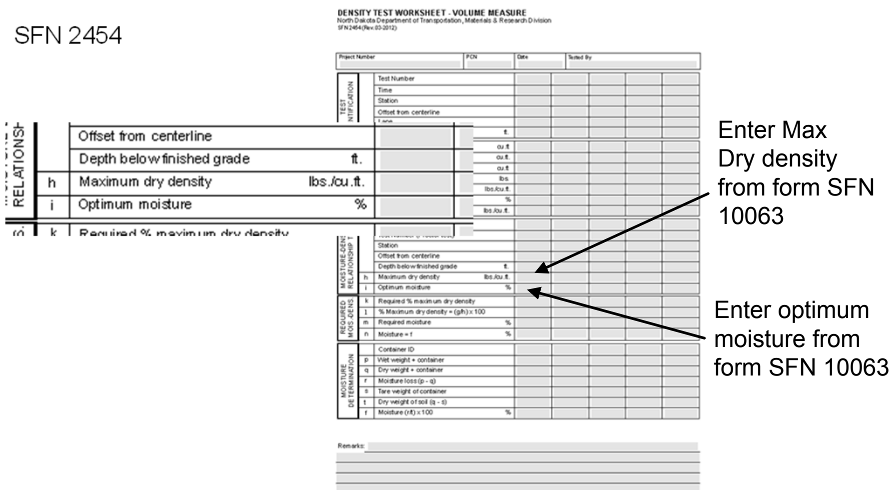
After you have determined, from graph, what the maximum dry density and optimum moisture are, record in the following lines

T 99 & T 180 - Moisture-Density Relations of Soils

- The maximum dry density and optimum moisture are again recorded on SFN 2454 for future use

T 99 & T 180 - Moisture-Density Relations of Soils

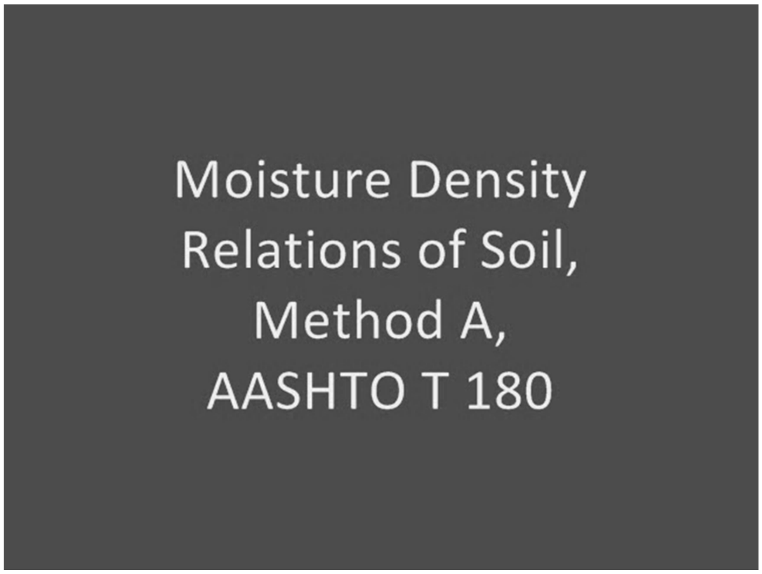
SFN 2454



Frequencies

- At each change in soil condition

Soil Compaction – Automatic Hammer video



Soil Compaction – Manual Hammer video

One Point Proctor

- The NDDOT has analyzed many moisture-density relationship curves and has found the curves follow certain patterns
- From this analysis, typical moisture-density relationship curves have been established and printed

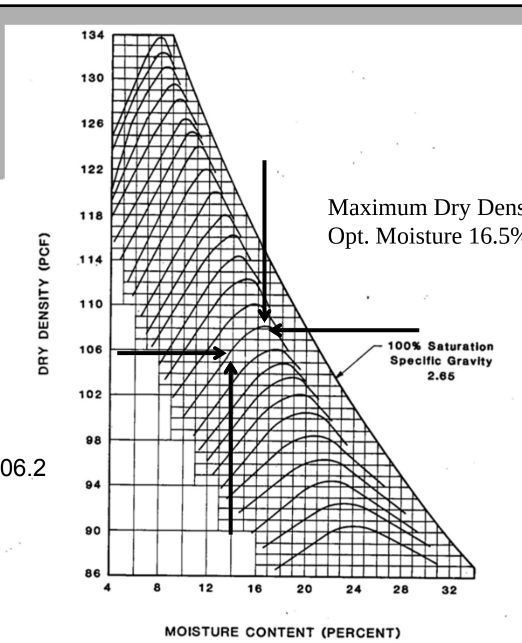
One Point Proctor

- Compacting one specimen as was done for first specimen of 5-point proctor test
- Determining the specimen's dry density and moisture content
- Follow curve (that point lies on) to highest point of curve, which indicates maximum dry density and optimum moisture content.

One Point Proctor

- If point lies between two curves, follow imaginary curve between two curves to find peak
- The next two slides depict typical moisture-density relationship curves for T 180

One Point Moisture Density

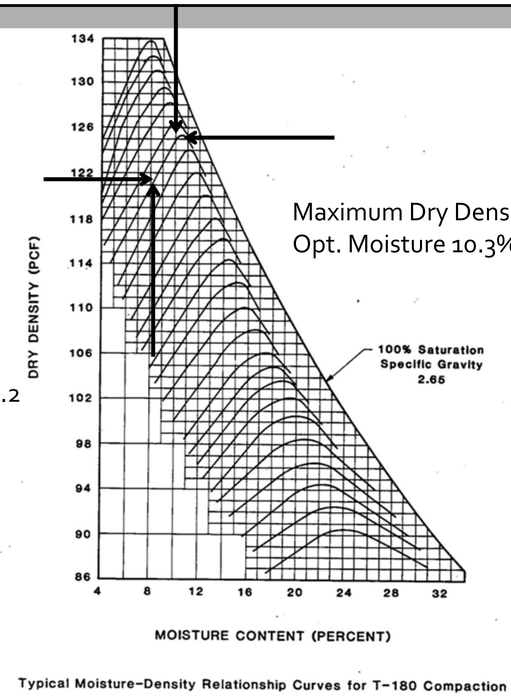


Maximum Dry Density 108 lbs/cu.ft.
Opt. Moisture 16.5%

Dry Density – 106.2
Moisture – 14.1

Typical Moisture–Density Relationship Curves for T–180 Compaction

One Point Moisture Density



Maximum Dry Density 126 lbs/cu.ft
Opt. Moisture 10.3%

Dry Density -121.2
Moisture – 8.2

Why Use One Point Method

- The proctors already done do not match the soil just tested.
- You question the results of test.
- Faster turnaround for result.

Obtain Sample for One Point Proctor

One Point Problems

- Moisture level must be slightly drier than optimum and must fall to left of curve data
- One points are not recommended for granular material

Report These Results

- Use SFN 10063 and only one column but note on top "One Point Test"
- It will be assigned a test number also

Specifications

- Embankment Construction
  - Section 203.04 E.2

  2. Compaction Control, Type A.

  Construct all fills, excluding rock fills, with moisture and density controls. Place embankment in lifts not to exceed 12 inches of loose material.

  Manipulate substandard areas by working the soil until the specified density and uniform moisture content are achieved.

Specifications

- *Embankment Construction, continued*

  Compact material as specified in Section 203.04 E.2.a, “ND T 180” unless the contract specifies otherwise.

Specifications

- a. **ND T 180.**

Compact material to at least 90 percent of the maximum dry density with a moisture content no less than the optimum moisture and no more than 5.0 percentage points above the optimum moisture. The Engineer will determine the maximum dry density and optimum moisture content as specifi ed in ND T 180.

Specifications

- b. **ND T 99.**
Compact material to at least 95 percent of the maximum dry density with moisture content no less than 4.0 percentage points below the optimum moisture, and no more than 5.0 percentage points above the optimum moisture. The Engineer will determine the maximum dry density and optimum moisture content as specified in ND T 99.

Specifications

- 714.04 A.7 **Compaction Control for Aggregate.**

Compact aggregate according to Section 203.04 E.2, "Compaction Control, Type A" The moisture content of the aggregate at the time of compaction shall be not less than 2.0 percentage points below, nor more than 3.0 percentage points above the optimum moisture content.

Specifications

- 714.04 A.8 Compaction for Control Non-Aggregate Material

If Common Excavation Type A is specified, follow the compaction requirements in Section 203.04 E.2, "Compaction Control, Type A." If Common Excavation Type B is specified, follow the compaction requirements in Section 203.04 E.3, "Compaction Control, Type B."

- Use a maximum lift thickness of 6 inches.

T 265 - Laboratory Determination of Moisture Content of Soils

- Determines total moisture content of soil, by removing all moisture from sample.
- Drying Oven is heat source used for T 265

T 265 - Laboratory Determination of Moisture Content of Soils

- Weigh empty container including cover and record tare weight
- Determine sample size needed from table in T 265

T 265 - Laboratory Determination of Moisture Content of Soils

- Cover to avoid moisture loss and weigh to the nearest 0.1 gram (wet weight)
- Remove cover and place in oven at 230 +/- 9°F (110 +/- 5°C)

T 265 - Laboratory Determination of Moisture Content of Soils

- Dry to constant weight or overnight (15 or 16 hours)
- Allow sample to cool before placing on balance
- Weigh the sample with cover and record as dry weight.
- Calculate moisture to nearest 0.1%

T 265 - Laboratory Determination of Moisture Content of Soils

- Calculate % moisture as follows:
- A=[(B-C)/(C-D)] x 100
  A = % moisture
  B = Mass of original sample and container
  C = Mass of dry sample and container
  D = Mass of container

T 265 - Laboratory Determination of Moisture Content of Soils

Typical containers used in oven drying.

T 265 - Laboratory Determination of Moisture Content of Soils

- What if sample is not allowed to dry overnight?
  - Place sample in oven for specified period.
  - Remove from oven, cover, and allow to cool.
  - Weigh and record.
  - Repeat process until two successive readings show a constant weight.

T 265 - Laboratory Determination of Moisture Content of Soils

- Constant Weight - When further drying will cause less than 0.1% additional loss in mass when weighed at specified interval
- Intervals
  - T 265 - Oven Drying – One Hour

D 2167 - Density of Soil In-Place by Rubber Balloon Method *(principle)*

- The rubber balloon test utilizes a graduated glass cylinder filled with water
- An assembly for applying air pressure
- A balloon attached to the cylinder.

D 2167 - Density of Soil In-Place by Rubber Balloon Method *(principle)*

- Air pressure is forced into the cylinder and forces the water filled balloon out of the cylinder and into the test hole.

D 2167 - Density of Soil In-Place by Rubber Balloon Method *(principle)*

- Pressure continues to be applied until water filled balloon completely fills test hole
- The water (volume) displaced from cylinder as test hole is being filled is read directly from graduated cylinder.

D 2167 – Density of Soil In-Place by Rubber Balloon Method *(procedure)*

- All information is recorded on SFN 2454
- Record the balloon volume readings to 0.00000 cu. Ft.

D 2167 – Density of Soil In-Place by Rubber Balloon Method *(procedure)*

- Choose your spot, remove loose material, and level the test area
- Secure the base plate and fasten down
- Place volume measure on base plate for initial reading

D 2167 – Density of Soil In-Place by Rubber Balloon Method *(procedure)*

- Using hand pump, while holding down on measure, force water into the balloon until resistance is felt
- Apply calibrated pressure and note reading on glass cylinder. Record reading on State Form 10063

D 2167 – Density of Soil In-Place by Rubber Balloon Method *(procedure)*

- Apply calibrated pressure and note reading on glass cylinder
- This is your initial reading! Record on SFN 2454
- Remove the vessel from the base plate while taking note where vessel is aligned with the plate


32
VOLUMEASURE
0130


bar
100×kPa
psi

D 2167 - Density of Soil In-Place by Rubber Balloon Method *(procedure)*

- Dig a hole with the auger, trowel, or other tools
- Test hole must be approx. 4" wide and 5" deep
- Carefully remove the soil and do not lose any material from the hole (also remove soil from tools and base plate)

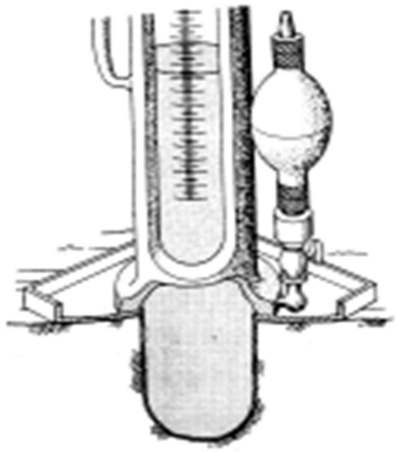
D 2167 - Density of Soil In-Place by Rubber Balloon Method *(procedure)*

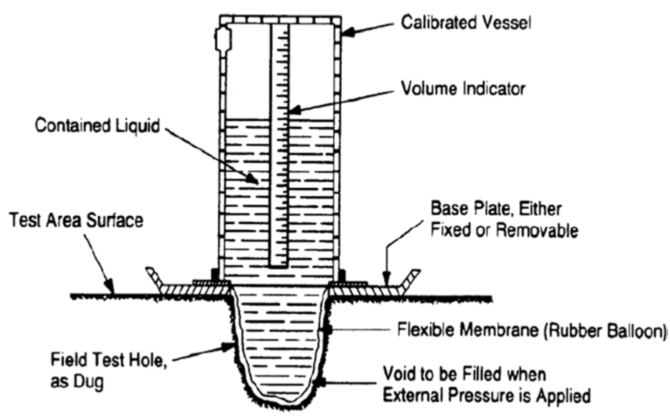
- Collect soil in a tarred container with a cover
- Put vessel back on base plate at the previous mark

D 2167 - Density of Soil In-Place by Rubber Balloon Method *(procedure)*

- Pump balloon down into test hole and apply calibrated pressure
- Read and record final reading
- Volume of test hole is determined by as follows:

Volume of Hole = Final Reading – Initial Reading




Calibrated Vessel
Volume Indicator
Contained Liquid
Test Area Surface
Base Plate, Either Fixed or Removable
Flexible Membrane (Rubber Balloon)
Field Test Hole, as Dug
Void to be Filled when External Pressure is Applied

D 2167 - Density of Soil In-Place by Rubber Balloon Method *(procedure)*

- The soil removed is weighed
- Calculate wet density of the soil as follows:

Wet Density = Wet weight of Soils/Volume of hole

D 2167 – Density of Soil In-Place by Rubber Balloon Method *(procedure)*

- A moisture test is ran using reserved material and dry density is computed as follows:

Dry Density = (Wet Den. x 100)/(100 + % moisture)

- Record the results on SFN 2454

D 2167 - Density of Soil In-Place by Rubber Balloon Method *(procedure)*

- The ratio between tested density and proctor density indicates the percent of compaction
- Record results on SFN 2454
- Report Dry Density to the nearest 0.1 lbs/cu. ft

IN-PLACE TEST VOLUME MEASURE	a	Final volume reading	cu.ft.	0.03350	0.04600	0.03525
	b	Initial volume reading	cu.ft.	0.00525	0.01850	0.00725
	c	Volume of hole = a - b	cu.ft.	0.02825	0.02750	0.02800
	d	Wet weight of soil	lbs.	3.6	3.6	3.7
	e	Wet density = d/c	lbs./cu.ft.	123.6	131.2	133.2
	f	Moisture	%	11.9	17.5	15.1
	g	Dry Density = (e X 100) /(100+f)	lbs./cu.ft.	110.5	111.7	115.7

Frequencies

- Excavation Embankment
  - 1 test per lift per 1500 ft. of roadway

- Reshape Roadway – Subgrade Prep – Stabilized Subgrade
  - 1 test per lift per 1500 ft. of roadway

Density of Soil In-Place - Video

T 217 - Determination of Moisture in Soil by Means of Calcium, Carbide Gas Pressure Moisture Tester (Speedy)

- The "Speedy Moisture Test" is used to determine moisture content of fine grained soils in the field
- **Advantage**: Moisture content can be determined in remote area where there may be no electrical power and results can be obtained quickly

T 217 - Determination of Moisture in Soil by Means of Calcium, Carbide Gas Pressure Moisture Tester (Speedy)

- Use care when performing this test and working with the calcium chloride reagent
- The reagent has an expiration date and should be verified before using

T 217 - Determination of Moisture in Soil by Means of Calcium, Carbide Gas Pressure Moisture Tester (Speedy)

- Depending on manufacturer, some models use 20 grams of soil and others use 26 grams for sample size
- Instructions may tell you to put reactant in body, others in the cap or cover
- Either method is fine as long as soil and reagent are not mixed before securing cover to body

T 217 - Determination of Moisture in Soil by Means of Calcium, Carbide Gas Pressure Moisture Tester (Speedy)

- Make sure body of tester is free of residue from previous test
- Place steel balls in the body of tester
- Take 3 – 5 full measures of reagent and place in body of tester

T 217 - Determination of Moisture in Soil by Means of Calcium, Carbide Gas Pressure Moisture Tester (Speedy)

- Weigh out soil sample
- Place soil sample in cap of tester"
- Hold "Speedy" in horizontal position and carefully place cap on end of tester
- Bring the stirrup into position

T 217 - Determination of Moisture in Soil by Means of Calcium, Carbide Gas Pressure Moisture Tester (Speedy)

- Hold tester vertically so material in cap falls into "Speedy" body
- Hold the unit horizontally and rotate 10 seconds rest 20 seconds
- Repeat cycle for a minimum of 3 minutes or until the gauge stops moving

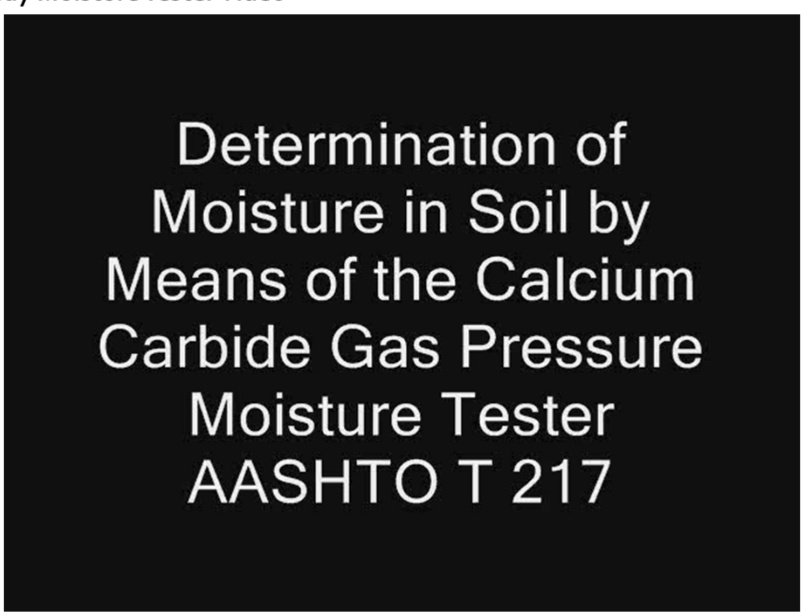
T 217 - Determination of Moisture in Soil by Means of Calcium, Carbide Gas Pressure Moisture Tester (Speedy)

- When needle stops moving, hold tester in a horizontal position at eye level and read dial
- Read to the nearest 0.1%
- The dial reading is in % moisture by wet mass and needs to be converted to dry mass

T 217 - Determination of Moisture in Soil by Means of Calcium, Carbide Gas Pressure Moisture Tester (Speedy)

- Use the "Conversion Chart for Speedy Tester" DOT 13942 to get corrected moisture.
- Record on SFN 2454 line "n" as moisture.

Speedy Moisture Tester Video



Conversion Chart for Speedy Tester

DOT Form 13942

Wet Weight %	Dry Weight %
13.0	14.9
13.1	15.1
13.2	15.2
13.3	15.3
13.4	15.5
13.5	15.6
13.6	15.7

T 217 - Determination of Moisture in Soil by Means of Calcium, Carbide Gas Pressure Moisture Tester (Speedy)

- When test is finished point tester away from everyone and slowly release the gas pressure.
- Empty contents
- Clean Tester

Calibration

- When -At a minimum once a year
  - Best Management Practices calibrate every couple weeks
- How – Compare Speedy results with oven dry results for the same soil at different moisture contents.

What Can go Wrong

- Moisture exceeds 20% gauge limit – Use ½ sample of material then double the gauge reading
- Moisture is too low to read – Two or more 26g samples can be added then divide the gauge reading by the number of samples put in

Frequencies

- Excavation and Embankment
  - 1 test per lift per 1500 feet of roadway
- Reshape Roadway – Subgrade Prep. – Stabilized Subgrade
  - 1 test per lift of 1500 feet of roadway

Safety

- This procedure involves a potentially dangerous chemical reaction. When Calcium Carbide reacts with water, acetylene gas is produced. Breathing acetylene gas, and/or running the test where potential for sparks or other ignition may cause a fire and must be avoided
- If gauge goes up past 20%, open the top to vent the gas.

T 191 – Density In-place by the Sand Cone Method

- Scope
  - This method covers determination of in-place density of compacted soil or soil-aggregate mixtures.
  - The in-place dry density is expressed as a percentage of soils maximum dry density and can be compared to specification requirements

T 191 – Density In-place by the Sand Cone Method

- Items to be discussed
  - Equipment Preparation
    - Filling the apparatus
    - Determining the mass of sand required to fill the funnel and base plate (Cone Correction)
    - Determining the bulk density of sand (D_s)
  - Procedures
  - Calculations
  - Calibration

T 191 – Density In-place by the Sand Cone Method- *equipment preparation*

- **Filling the apparatus**
  - Place upright on level surface, close valve and fill funnel with sand
  - Open valve! Keep funnel at least half full with sand
  - When sand stops flowing, close valve sharply and empty excess sand
  - Determine and record mass of apparatus filled with sand (m1)

T 191 – Density In-place by the Sand Cone Method- *equipment preparation*

- Cone Correction [Cc]
  - Place base plate on level surface. Invert sand cone and seat funnel on base plate
  - Open valve! Allow sand to flow until sand stops flowing
  - Close valve! Remove apparatus and determine mass of apparatus and remaining sand (m2)

T 191 – Density In-place by the Sand Cone Method- *equipment preparation*

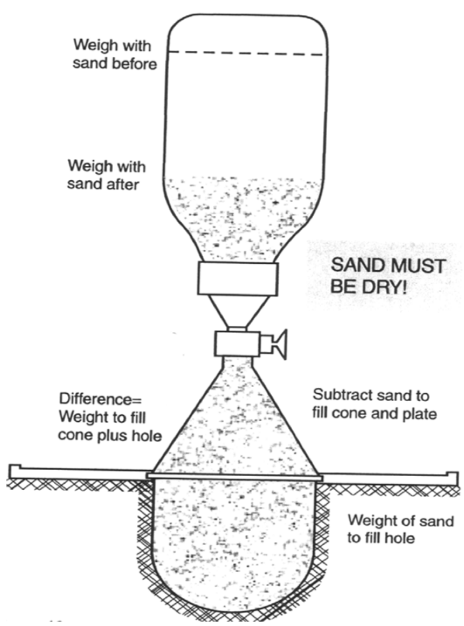
- Cone Correction Continued;
  - Mass of sand required to fill cone and base plate [Cc] is calculated by $Cc = m1 - m2$
  - Where: Cc = Cone Correction
    - m1 = Mass of apparatus filled with sand
    - m2 = Mass of apparatus filled with remaining sand
  - Complete all calculations on SFN 59724

T 191 – Density In-place by the Sand Cone Method- *equipment preparation*

- Determination of bulk density of sand (D_B)
  - Materials and Research has determined that (D_B) equals 95 lbs/cubic foot for a given source of sand
  - If the sand source should change it would require that a new bulk density be determined.

T 191 – Density In-place by the Sand Cone Method- *procedures*

- Fill apparatus with sand and record total mass
- Select spot and level
- Place base plate over level area and fasten down
- Dig a test hole
- Place excavated material into moisture tight container



T 191 – Density In-place by the Sand Cone Method- *procedures*

Max Particle Size	Min Test Hole Volume	Min Size For Moisture
No. 4	0.025 cubic feet	100 g
½″	0.050 cubic feet	250 g
1′	0.075 cubic feet	500 g
2″	0.100 cubic feet	1000 g

T 191 – Density In-place by the Sand Cone Method-*procedures*

- Place apparatus on base plate and open valve
- After sand has stopped flowing close valve
- Remove apparatus
- Record the final mass

T 191 – Density In-place by the Sand Cone Method- *procedures*

- Weigh the wet material removed to the nearest 0.01 lb. and record
- Use a representative portion of soil for moisture determination

T 191 – Density In-place by the Sand Cone Method- *procedures*

- Moisture can be determined by use of T 265 (oven method) or D 4643 (Microwave method)
- Calculated to nearest 0.1%

T 191 – Density In-place by the Sand Cone Method-*Calculations*

- Complete Calculations on SFN 59725
- Calculate in - place density to the nearest 0.1 lbs/cubic feet

T 191 – Density In-place by the Sand Cone Method-*Calculations*

Complete calculations as follows:

(V_H) Volume of Test Hole = (Initial Mass - Final Mass - C_C)/D_B

Calculate the volume of test hole to the nearest 0.0001 ft_3.

(M_{DS}) Dry Mass of Material removed from test hole = (Moist Mass removed from test hole/ (1 + (% moisture /100))

T 191 – Density In-place by the Sand Cone Method-*Calculations*

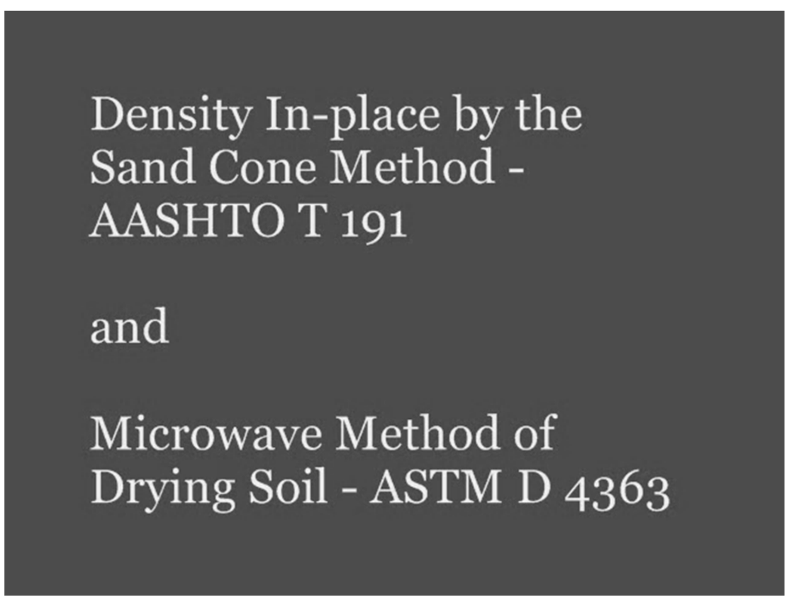
Calculations continued:

Calculate dry mass of material to the nearest 0.01 lbs.

(D_D) Dry Density = M_{DS}/V_H

Calculate in-place dry density to the nearest 0.1 lbs/ft_3.

Sand Cone video



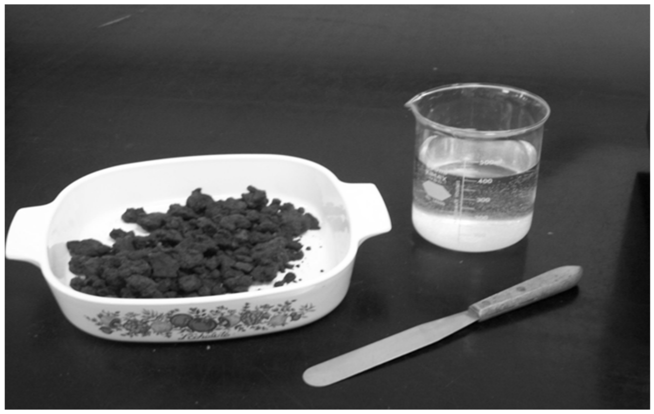
T 191 – Density In-place by the Sand Cone Method-*Calibration*

- All new devices should be calibrated prior to use
- A calibration check should be performed annually as a minimum, or whenever damage or repair occurs.

D 4643 - Microwave Method of Drying Soils

- Minimum power rating of 700 watts
- Proper sample size
- Use a heat sink
- Set power on defrost
- Use a microwave safe dish

D 4643 - Microwave Method of Drying Soils



Heat sink, microwave safe dish, and spatula.

D 4643 - Microwave Method of Drying Soils

- Stir with spatula or glass rod between heating cycles
- Initial drying time of 3 minutes; 1 minute cycles thereafter
- Repeat process until "Constant Weight" is achieved

D 4643 - Microwave Method of Drying Soils

- Soils high in moisture and contain a large portion of clay take longer times to dry
- Initial heating time for this type of soil may be 12 minutes.
- Reduce cohesive samples to ¼" particles to speed drying

T265 - Laboratory Determination of Moisture Content of Soils and D 4643 - Microwave Method of Drying Soils

Calculate and record to 0.1%

$$A = [(B - C)/(C - D)] \times 100$$

A = Percent moisture

B = Mass of original (wet) sample, and container
C = Mass of dry sample, and container
D = Mass of container

T 224 – Correction For Coarse Particles In The Soil Compaction Test

- Scope
  - The method describes a procedure for adjusting densities of soil and soil-aggregates to compensate for differing percentages of oversize particles retained on the No. 4 sieve. Therefore a correction to Method A (moisture-density relation test) is required for the oversize removed

T 224 – Correction for Coarse Particles in the Soil Compaction Test

- Scope
  - This shall be applied to soil-aggregates which contain more than 5% by weight of oversize
  - If there is over 40% oversize another method may be required

For All Worksheets

- Sign
- Date
- If any corrections or change are made – sign/date – or make notation on electronic forms

Field Soils Testing Inspection and Forms

Compaction Inspection

- A number of different soil types may be encountered
- Each soil type may require different handling and/ or compaction techniques

Compaction Inspection

- The compaction Inspector/Tester must be alert to changes from one type of soil to another
- The optimum density and moisture content used may well change and additional lab work will be required

Compaction Inspection

- Every lift must be compacted to the required density before the next lift is placed
- Enough tests must be taken to insure a passing uniform grade
- The tests will be taken at various locations on the fill to insure uniformity

Compaction Inspection

- It is good practice to have a proctor test available for each type of soil.

Duties of a Compaction Inspector

- Principle duty is to take compaction and moisture tests and compare results to the proctor
- Determine location of and offset of compaction tests
- Keep Engineer or Grade Inspector informed of test results at all times
- Alert to changes in soil

Duties of a Compaction Inspector

- Familiar with project plans and specifications
- Have good lines of communication
- Safety
- Keep organized records

Duties of a Compaction Inspector

- You may be required to conduct additional tests whenever you encounter <u>unsatisfactory conditions</u> such as:
  - Spongy surfaces
  - Equipment working unusually hard
  - Appreciable changes in soil color and textures

Failing Compaction Tests

- If test results fall just short of specifications inform the Contractor that:
  - The test failed
  - The inspector should tell the Contractor only <u>why</u> the test failed, **not what to do or how to correct it**

Failing Compaction Tests

If test results are noticeably short of specifications, you should:

- Perform a check test
- Inspect the testing equipment

Failing Compaction Tests

- If the check test results are close to the required maximum density and optimum moisture
- You are sure of your equipment and procedures
- A visual observation of the material leads you to believe that the maximum density and optimum moisture should have been obtained then:
- Perform a one-point proctor

Failing Compaction Tests

- *Do not permit any lifts to be placed over failing lifts*

Uniform Operations

- Frequent compaction tests should be performed at beginning of project
- This will force the Contractor to develop and maintain a uniform operation

Random Numbers

- Locations of test sites are critical
- If the test results conform, at these locations, the rest of the earthwork is assumed to conform, too

Random Numbers

- To help determine representative test locations, we use a table of Random Numbers
- A Random Number has no pattern or sequence in which they occur

Random Numbers

- As an Inspector, you should let the Contractor know that random numbers are being used

Random Numbers

- Random Numbers will help you schedule locations of tests ahead of time
- The Contractor should not know where tests will be taken

Random Numbers

- To locate a test site, you will need a longitudinal coordinate and a lateral coordinate. The longitudinal coordinate is the distance from the end of the test area, and the lateral coordinate is the distance from the edge of the test area

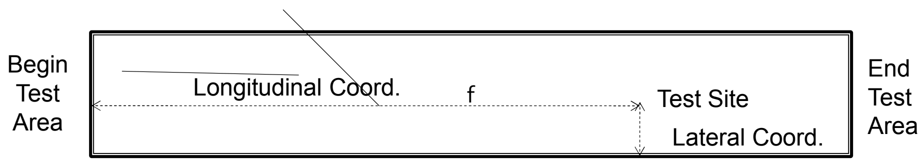


Table of Random Numbers

- A sample table of random numbers is shown below
- A table of Random numbers is located in your Field Sampling and Testing Manual

0.39	0.29	0.26	0.22
0.42	0.82	0.65	0.28
0.33	0.08	0.42	0.55
0.04 0.12	0.43 0.17	0.45 0.52	0.46 0.89

Procedure

- First determine length and width of test area
- Point to a block of numbers on the Random Numbers Table
- Use first line of numbers as multipliers for length and second line of numbers as multipliers for width

Example Problem

- Two test sites are needed in a test area 1,000 feet long and 40 feet wide
- A block of numbers is randomly selected from the previous Table of Random Numbers
- For this example we will use the upper right block.

Example Problem

- The first row of numbers in this block can be used as multipliers for the test area lengths

0.78	0.67	0.25	0.42
0.39	0.29	0.26	0.22
0.42	0.82	0.65	0.28
0.33	0.08	0.42	0.55
0.04 0.12	0.43 0.17	0.45 0.52	0.46 0.89

Example Problem

- The second row of numbers in this block can be used as multipliers for the test area widths

0.78	0.67	0.25	0.42
0.39	0.29	0.26	0.22
0.42	0.82	0.65	0.28
0.33	0.08	0.42	0.55
0.04 0.12	0.43 0.17	0.45 0.52	0.46 0.89

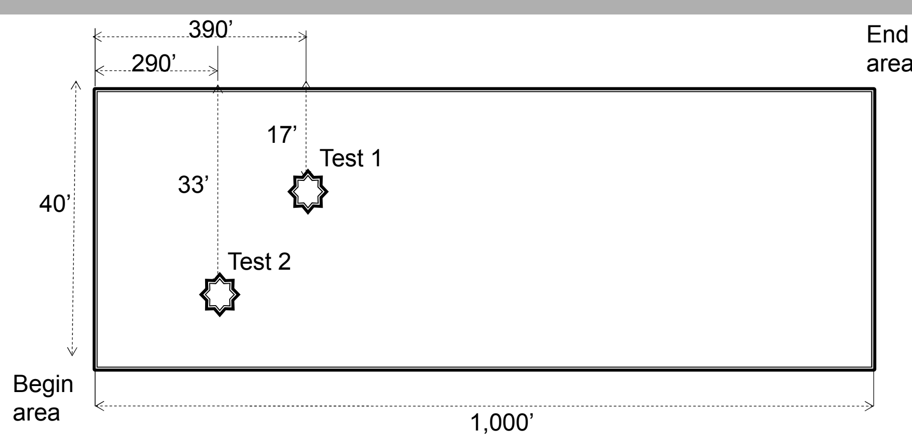
Example Problem

- Your calculations are as follows:

Test Number	Length of Test Area	Random Number	Long .Coord.
1	1,000'	.39	390'
2	1,000'	.29	290'

Test Number	Width of Test Area	Random Number	Lat. Coord.
1	40'	.42	17' (rounded)
2	40'	.82	33' (rounded)

Example Problem



Random Numbers

- An alternative method for determining a random number is the use of a Scientific Calculator

Common Forms and Worksheets Available Online – some in Excel format

- SFN 59724 Sand Cone Correction
- SFN 59725 Density Test Worksheet- Sand Cone method
- SFN 10063 Moisture-Density Relationship Tests
- SFN 2454 Density Test Worksheet – Volume Measure
- 1-Point Curves – found behind T99 and T 180 test procedure in Field Sampling and Testing Manual
- DOT 13942 – Conversion Chart for Speedy Tester

Test Procedures
Chapter 2

Page

ND T 99 AND ND T 180
MOISTURE-DENSITY RELATIONS OF SOILS

Conduct this procedure according to ND T 99 or ND T 180.

The NDDOT modifies this standard to only allow the use of Method A and D. Method D shall only be used in lieu of Method A when there is more than 5% by weight of material retained on the No. 4 sieve.

Method D shall be used without correction for all soil-aggregates which have all materials passing the 3/4" sieve. Corrections must be made according to ND T 224 for all materials which have 30% or less retained on the 3/4" sieve.

If the specified oversized maximum of 30% is exceeded, other methods of compaction control must be used.

Consult the current edition of AASHTO for procedure in its entirety and equipment specification details.

SCOPE

The moisture-density relationship test is also called the Proctor test. This test method determines the relationship between the moisture content and the density of soils compacted in a mold. Two different standards of moisture-density relationships are presently in use by the NDDOT. They vary mainly in the compaction energy applied to the soil in the mold. The two standards and their features are summarized below.

METHOD A

FEATURE	ND T 99	ND T 180
Weight of Compaction Rammer	5.5 lbs	10 lbs
Distance of Drop	12"	18"
Number of Soil Layers	3	5
Diameter of Mold	4"	4"
Soil Passing Sieve Size	No. 4	No. 4
Rammer, Blows/Layer	25	25

METHOD D

FEATURE	ND T 99	ND T 180
Weight of Compaction Rammer	5.5 lbs	10 lbs
Distance of Drop	12"	18"
Number of Soil Layers	3	5
Diameter of Mold	6"	6"
Soil Passing Sieve Size	3/4"	3/4"
Rammer, Blows/Layer	56	56

REFERENCED DOCUMENTS

AASHTO T 99 and T 180 – Moisture Density Relations of Soils
ND T 217 and AASHTO T 217 - Determination of Moisture in Soil by Means of Calcium Carbide Gas Pressure Moisture Tester (Speedy)
ND T 265 and AASHTO T 265 - Laboratory Determination of Moisture Content of Soils
ND D 2167 and ASTM D 2167 - Density and Unit Weight of Soil in Place by the Rubber-Balloon Method
ND D 4643 and ASTM D 4643 - Determination of Moisture Content of Soil by Microwave Oven Heating

APPARATUS

Balance, readable to 0.01 lbs. (5 g)
Oven
No. 4 (4.75 mm) sieve
Mixing tools
Moisture sample cans with lids
Straightedge, 10" long
Knife
Compaction equipment including density mold, base and collar, and compacting rammer and guide

SAMPLE SIZE

Method A - A representative soil sample of approximately 35 lbs (15.9 kg) is required for the Multi-Point Moisture Density Relationship Test, and approximately 7 lbs (3.2 kg) is required for the One-Point Moisture Density Relationship Test.

Method D - A representative soil sample of approximately 125 lbs (55 kg) is required for the Multi-Point Moisture Density Relationship Test, and approximately 25 lbs (11 kg) is required for the One-Point Moisture Density Relationship Test.

PROCEDURE

Multi-Point Moisture Density Relationship - Mechanical and Manual

Record this information on SFN 10063, "Moisture Density Relationship Test." Calculate and record to the accuracy indicated.

If the soil is damp when received, dry until it is easily crumbled under a trowel. It can be air dried or oven dried at a temperature up to 140°F (60°C). Break up the soil chunks so that the entire sample passes through the No. 4 sieve. Avoid reducing the natural size of the particles. Discard any individual particles of material retained on the No. 4 sieve or organic material. Divide the sample into five representative samples of 7 lbs each.

Thoroughly mix the first test sample with water to dampen it approximately four percentage points below optimum moisture. A good indication of a soil being right for the first point is if the soil barely forms a “cast” when squeezed together. Specimen shall be placed in moisture proof container and covered to prevent moisture loss. Mix remaining specimens in the same manner as test sample one, increasing water content by approximately one or two percentage points (not exceeding 2.5%) over each preceding specimen. This can be accomplished by adding approximately 60 mL* of water. Allow soil samples to cure in moisture proof containers for a minimum of 12 hours.

*If using Method D, the water added to the sample must be increased from approximately 60 mL to approximately 215 mL.

Weigh the empty mold without the base plate or collar and record to the nearest 0.01 lb (5 g).

From test sample one: add sufficient material to the mold to produce a compacted layer of approximately 1-3/4" for ND T 99, or 1" for ND T 180. Gently level the soil surface in the mold. *Using a manual compaction rammer or a similar device with a 2" face (50 mm), lightly tamp the soil until it is no longer loose or fluffy. Compact the soil with **25 evenly distributed blows of the compaction rammer. After each layer, trim any soil along the mold walls that has not been compacted with a knife and distribute on top of the layer.

*When completing this process using a mechanical compactor, it is recommended to use a spare or extra replacement rammer.

**If using Method D, compact the soil with **56 evenly distributed blows.

When using a manual compactor, remember to hold the rammer perpendicular to the base of the mold and lift the rammer to its maximum upward position.

Repeat this procedure adding more soil from the same sample each time so that at the end of the last cycle, the top surface of the compacted soil is above the top rim of the mold when the collar is removed.

Remove the collar and trim off the extruding soil level with the top of the mold. In removing the collar, rotate it to break the bond between it and the soil before lifting it off the mold. This prevents dislodging chunks of compacted soil when lifting the collar off. The trimming consists of many small scraping motions with a knife or straightedge.

After trimming the soil level with the top of the mold, clean all loose material from the outside of the mold. Weigh the soil and mold to the nearest 0.01 lb (5 g) and record. Subtract the weight of the mold from this weight and divide the result by the volume of the mold. Record results as wet density in pounds per cubic foot (pcf). Compute and record wet density to the nearest 0.1 pcf.

Wet Weight of Soil = Weight of Mold + Soil – Weight of Mold

Wet Density, pcf = Wet Weight of Soil/Volume of Mold

Remove the soil from the mold and slice through the center vertically. Obtain a representative sample of approximately 100 g from one of the cut faces. Take the sample from the full length of the inside of the soil cylinder. Place the moist sample in a container, cover and weigh. Record the weight of the wet soil. Record this and all moisture weights to the nearest 0.1 g.

Dry the sample to a constant weight according to ND T 265, Laboratory Determination of Moisture Content of Soils.

Calculate the percent moisture to the nearest 0.1%. Compute and record dry density to the nearest 0.1 pcf.

The formula is as follows:

Dry Density, pcf = (Wet Density X 100)/(100 + % Moisture)

Using specimen number two, repeat the compaction procedure previously described. Continue this process, with the remaining samples, until there is a decrease in the wet density per cubic foot.

GRAPH

The objective of this procedure is to determine the maximum dry density and optimum moisture content for this particular soil. Based on the results obtained from conducting consecutive Proctors with changes in moisture, plot each test result on the cross-ruled area on the form with the moisture content plotted on the abscissa (x) and the density on the ordinate (y).

After all the results are plotted, draw a smooth flowing curve through or close to the plotted points. From the peak of the curve, select the maximum dry density and optimum moisture. Report the maximum dry density to the nearest 1-lb./cu.ft. and the optimum moisture to the nearest 0.1%.

NOTES

During compaction, the mold shall rest firmly on a dense, uniform, rigid, and stable foundation or base. This base shall remain stationary during the compaction process. Each of the following has been found to be a satisfactory base on which to rest the mold during compaction of the soil: (1) a block of concrete with a mass not less than 200 lbs (90 kg) supported by a relatively stable foundation; (2) a sound concrete floor; and (3) for field applications such surfaces are found in concrete box culverts, bridges, and pavements.

The moisture-density test is used to establish a value of density on which construction requirements can be based. It is a test conducted on a single identifiable soil and results may vary considerably between different soils.

Make every effort to space the moisture contents no further apart than 2.5% in order to accurately determine the maximum dry density and optimum moisture content.

CALIBRATION

A calibration check of the equipment should be performed annually as a minimum, or whenever damage or repair occurs.

One-Point Moisture Density Relationship with Typical Moisture-Density Curve Method

After analyzing a large number of both ND T 99 and ND T 180 moisture-density curves that generally represent statewide soil types, it was found the curves follow the trends shown on the graphs on the following pages. The graphs with the following procedure may be used in place of performing the entire moisture-density relationship test. It is recommended that the Multi-Point Moisture Density Relationship be used whenever possible.

PROCEDURE

The procedure that follows is written for a test using one sample of approximately 7 lbs (3.2 kg) of material. Thoroughly mix the soil sample with water and dampen

it approximately to, but not over, Optimum Moisture. Conduct a Proctor test as previously described in the Multi-Point Moisture Density Relationship.

GRAPH

Use either of the following graphs, ND T 99 or ND T 180, whichever is appropriate, to locate the point defined by the two values obtained from the Proctor.

If the point lies directly on a curve, follow this curve to its peak and read off the maximum dry density and optimum moisture content. If the point lays in-between two curves, follow the two curves to their peaks and interpolate the maximum dry density and optimum moisture content. Report the maximum dry density to the nearest 1-lb./cu.ft. and report the optimum moisture to the nearest 0.1%.

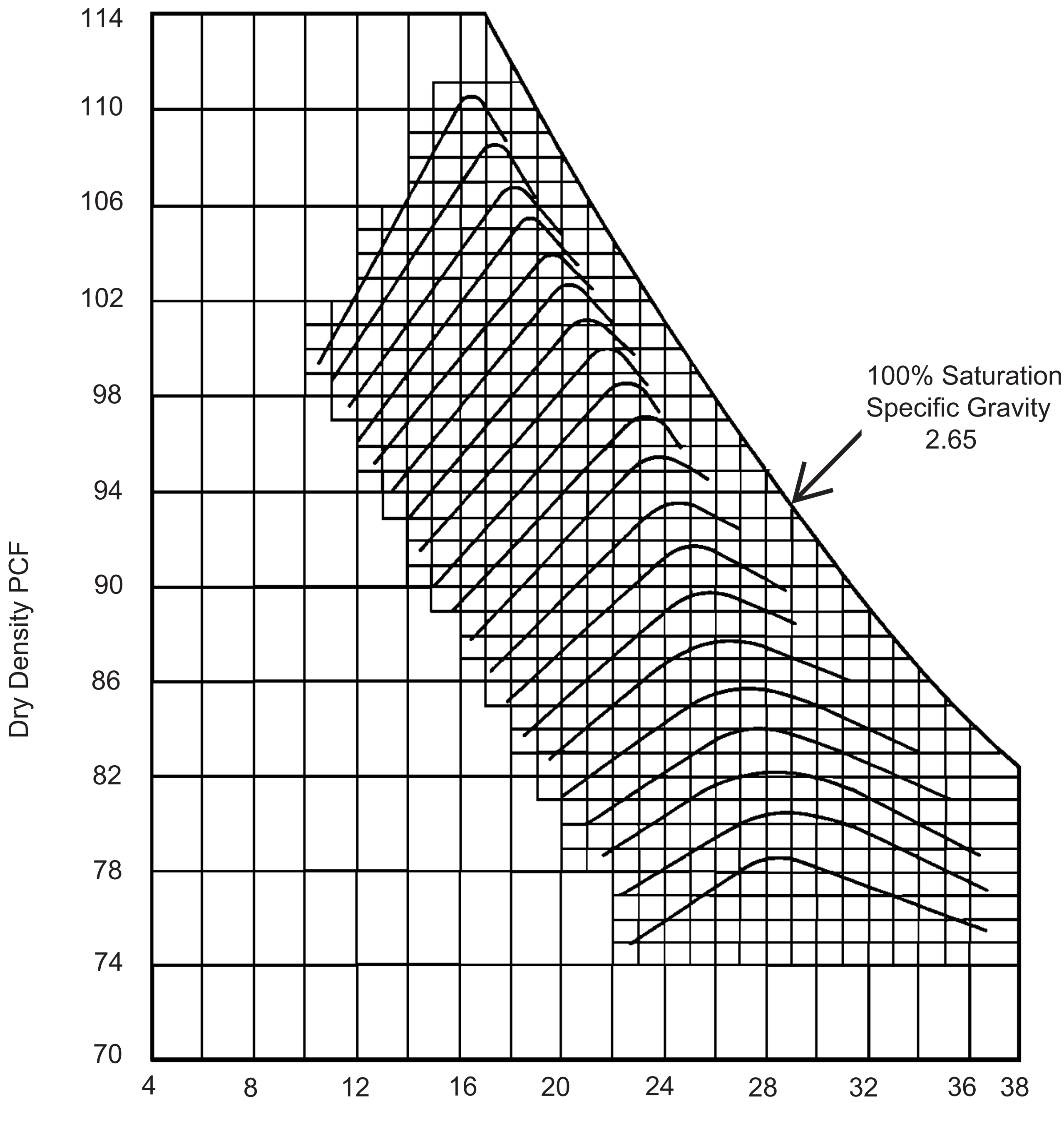
NOTES

When the rubber balloon method is used for the density test, use the same material from the hole for the one-point determination. To get sufficient material, enlarge the hole after the rubber balloon test is complete and use the additional material collected.

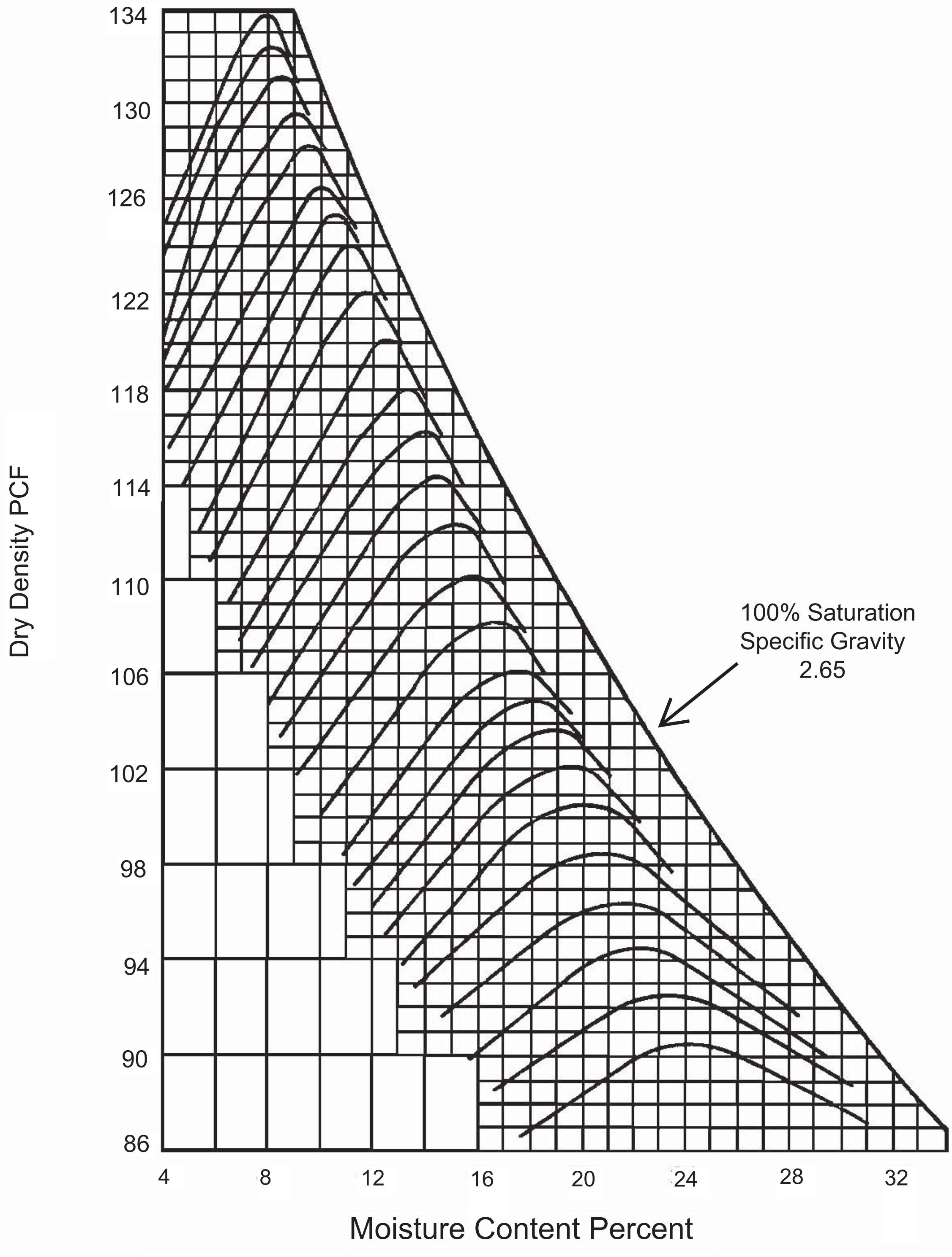
In order to perform the test in conjunction with and at the same location as the in-place density test, there are steel-capped, wooden pedestals available to support the mold base plate. During compaction, place the mold and pedestal on firm level ground.

Perform moisture content test according to ND T 217, Determination of Moisture in Soil by Means of Calcium Carbide Gas Pressure Moisture Tester (Speedy). Or, if there is a field lab available to conduct the moisture determination, obtain the sample in the same manner described previously according to ND D 4643, Determination of Moisture Content of Soil by Microwave Oven Heating, and ND T 265, Laboratory Determination of Moisture Content of Soils.

When using the graphs, a soil on the wet side of optimum could result in a substantial error when selecting the maximum dry density. Most specifications require the moisture content to be at or above optimum, thus it can be assumed that this is the condition that most samples are in. If the sample is judged to be slightly wetter than optimum, dry it to a condition slightly drier than optimum before compacting.



Typical Moisture-Density Relationship Curves for ND T 99 Compaction



Typical Moisture-Density Relationship Curves for T-180 Compaction

ND T 265 - LABORATORY DETERMINATION OF MOISTURE CONTENT OF SOILS

Conduct this procedure according to ND T 265.

Consult the current edition of AASHTO for procedure in its entirety and equipment specification details.

SCOPE

This procedure is used to determine the total moisture content of a soil. The soil is dried to remove all free moisture. This test measures the weight of the moisture removed from the soil.

APPARATUS

Oven
Balance
Sample containers with cover

PROCEDURE

Record all weights to the nearest 0.1 g or 0.1%.

Weigh a clean, dry, and empty container including the cover and record as tare weight.

Determine sample size needed from the table below. The sample obtained must be representative of the soil.

Maximum Particle Size	Minimum Mass of Sample
No. 40 (0.425 mm) sieve	10 g
No. 4 (4.75 mm) sieve	100 g
1/2" (12.5 mm)	300 g
1" (25.0 mm)	500 g
2" (50 mm)	1000 g

Place sample in container and cover to prevent moisture loss. Weigh sample and record as mass of original sample.

To dry sample, remove cover and place in oven at temperature of 230 ± 9°F (110 ± 5°C). A sample allowed to dry overnight, or 15 to 16 hours, is considered dried to a constant weight. Remove the sample from the oven, cover, and allow it to cool before placing on balance. Weigh the sample with cover and record this weight as dry weight.

If the sample is not allowed to dry overnight, place the sample in the oven for a period of time. Remove sample from the oven, cover, and allow to cool before placing on balance. Weigh the sample and record the reading. Repeat the process until two successive readings show a constant weight. Record the final weight as mass of dry sample.

Discard sample after test.

CALCULATIONS

Calculate the percent moisture as follows:

$$A = [(B - C)/(C - D)] \times 100$$

A = Percent moisture
B = Mass of original (wet) sample, and container
C = Mass of dry sample, and container
D = Mass of container

REPORT

Report moisture to the nearest 0.1%.

NOTES

Constant weight is defined as when further drying will cause less than 0.1% additional loss in mass when weighed at specified intervals. Specified weighing interval for oven drying of samples is one hour.

CALIBRATION

Calibration is to be done annually, as a minimum, and whenever damage or repair is needed.

ND D 2167 - DENSITY AND UNIT WEIGHT OF SOIL IN PLACE BY THE RUBBER-BALLOON METHOD

Conduct this procedure according to ND D 2167.

The NDDOT modified the ASTM standard by decreasing the minimum requirement for test hole volume.

Consult the current edition of ASTM for procedure in its entirety and equipment specification details.

SCOPE

This method covers the determination of the in-place soil density of compacted or firmly bonded soil using a rubber-balloon apparatus.

Embankment compaction is controlled by requiring the density of each different soil, after compaction, be a specified minimum percentage of the maximum dry density. The maximum dry density is determined for each different soil on the project. When a particular soil is encountered in the excavation and transferred to and compacted in the embankment, it is tested by the method given in this section to determine its dry density. The in-place dry density is expressed as a percentage of the soils maximum dry density and can be compared to specification requirements.

REFERENCED DOCUMENTS

ND T 217 and AASHTO T 217, Determination of Moisture in Soil by Means of Calcium Carbide Gas Pressure Moisture Tester (Speedy)
ND T 265 and AASHTO T 265, Laboratory Determination of Moisture Content of Soils
ND D 4643 and ASTM D 4643, Determination of Moisture Content of Soil by the Microwave Oven Method

APPARATUS

Rubber-balloon apparatus and base plate
Balance, readable to 0.01 lbs
Pins, shovel, trowel, spoon, hammer, and knife
Auger, 4" diameter
Appropriate size container with lid

PROCEDURE

All information is recorded on SFN 2454. Record the balloon volume readings to 0.00000 cu.ft.

The following chart shows the minimum of test hole volume required.

Maximum Particle Size	NDDOT Minimum Test Hole Volume
1/2"	0.025 cu.ft.
1"	0.03 cu.ft
1½"	0.035 cu.ft.

Select the area of compacted embankment to be tested. Because the surface of a compacted area is generally loose or disturbed due to rolling operations, remove loose material and level off an area slightly larger than the base plate.

Place the base plate over the smoothed area and fasten down with the accompanying pins. Plate must stay in this position and be stable throughout the test.

Place the volume measure on the base plate for the initial reading, noting its position with regard to the base plate. Using the bulb-type pump, and while holding down the volume measure, force the water down into the balloon until resistance is felt. Apply the calibrated pressure and note the reading on the glass cylinder. Record the reading.

Dig a hole with the auger, trowel, or other tools. Hole must be approximately 4" in diameter and 5" deep. Place all of the loosened material from the hole into an aggregate balance pan, or a moisture-tight container if not weighed right away. Clean the sides and bottom of the hole being very careful not to lose any material. Check to be certain that no jagged edges or points remain that may puncture the balloon. Do not disturb the soil around the top edge of the hole.

Place the volume measure on the base plate in the same initial position. Pump the balloon down into the hole and apply the calibrated pressure. Read and record the final reading. The volume of the test hole is determined by the difference between the initial and final reading.

Weigh the soil removed from the hole to the nearest 0.01 lb and record.

Use a representative portion of the soil for moisture determination. Do not use material containing particles large enough to be retained on the No. 4 (4.75 mm) sieve. Moisture can be determined by the use of ND T 217, ND T 265, or ND D 4643.

CALCULATIONS

Complete calculations as follows:

Volume of Hole = Final Reading - Initial Reading

Wet Density = Wet Weight of Soil / Volume of Hole

Dry Density = (Wet Density x 100) / (100 + Percent Moisture)

REPORT

Report dry density to the nearest 0.1 lbs/cu.ft.

CALIBRATION

All new devices should be calibrated prior to being used. A calibration check should be performed annually as a minimum, or whenever damage or repair occurs.

ND T 217 - DETERMINATION OF MOISTURE IN SOIL BY MEANS OF CALCIUM CARBIDE GAS PRESSURE MOISTURE TESTER (SPEEDY)

Conduct this procedure according to ND T 217.

The AASHO standard test procedure specifies for the moisture content to be recorded to the nearest whole number. The NDDOT modification specifies the moisture content to be recorded to the nearest 0.1.

Consult the current edition of AASHTO for procedure in its entirety and equipment specification details.

SCOPE

This test used to determine the moisture content of soils by means of a calcium carbide gas pressure moisture tester in the field. The tester is referred to as the "Speedy". This method shall not be used for granular material having particles retained on the No. 4 (4.75 mm) sieve.

Use care when performing this test and working with the calcium chloride reagent. The reagent has an expiration date and should be verified before using. Tightly close reagent cans when not in use.

Use DOT 13942, "Conversion Chart for the Speedy Tester," to convert the reading on the tester dial.

REFERENCED DOCUMENTS

AASHTO T 217, Determination of Moisture in Soil by Means of Calcium Carbide Gas Pressure Moisture Tester (Speedy)
ND T 265 and AASHTO T 265, Laboratory Determination of Moisture Content of Soils

APPARATUS

Calcium carbide pressure moisture tester, "Speedy," which includes a balance, steel balls, and cleaning brush.

Calcium carbide reagent and scoop to measure reagent.

PROCEDURE

Instructions are written for a 20 to 26 g tester. There are various models of the "Speedy" in use with slight variations in instructions. Some models include 1.25" steel balls, others use 1" steel balls. Manufacturer's instructions may tell you to put the reagent in the body, others the cap. Either method may be used as long as the soil and reagent are not mixed before securing the cover.

Read and follow ND T 217 and the manufacturer's instructions to conduct this test.

The following describes the ND T 217 method for conducting the test.

- Before beginning the test, verify the inside of the body and cap are free from residue of any previous test.
- Place the steel balls into the body.
- Take three full measures of reagent and place in body of vessel. For bulky materials, use three to five measures to ensure adequate coverage.
- Measure your sample. The sample size needed is determined by the manufacturer of your tester.
- Your tester kit may have an electronic balance or a beam balance. For a beam balance, lift into an upright position and add material to the pan. The correct amount of material is determined when the red markings on the balance and beam coincide.
- Place the sample in the cover of the “Speedy”.
- Hold the “Speedy” in a horizontal position and place the cover on the end. Bring the stirrup in position and tighten. This should be completed without the sample and reagent coming in contact with each other.
- Hold vertically so that the material in the cap falls into the “Speedy” body. Return the instrument to a horizontal position, shake to break all lumps, and mix the soil and reagent. Shake with a rotating motion to put the steel balls into ‘orbit’ around the inside circumference. Rotate for 10 seconds, rest for 20 seconds. The rest time allows for dissipation of the heat generated by the chemical reaction. Continue this cycle for a minimum of 3 minutes.
- When the needle stops moving, hold the instrument horizontal at eye level with the dial facing you. Read and record the dial reading to the nearest 0.1.
- Hold tester away from your body. Point the directional release away from you and anyone else, then slowly release the pressure. Avoid breathing the fumes. Empty the contents and examine for lumps. If material contains lumps, repeat the test.

- Thoroughly clean the tester with the brush provided.

CALCULATIONS

The dial reading is percent moisture by wet mass and needs to be converted to dry mass using form DOT 13942.

REPORT

Report the percent moisture to the 0.1%.

NOTES

If the moisture content of the soil sample is greater than the ability for the gauge to read, run the test using a one-half size sample. The dial reading is multiplied by two and then converted to dry mass using DOT 13942.

CALIBRATION

Calibration is to be done annually as a minimum, and whenever damage or repair occurs. This can be accomplished by comparing the “Speedy” results to a sample oven-dried according to ND T 265. Calibration will result in verifying DOT 13942, “Conversion Chart for the Speedy Tester.”

CONVERSION CHART FOR SPEEDY TESTER

North Dakota Department of Transportation, Materials & Research

DOT 13942 (Rev. 05-2000)

WET WT. %	DRY WT. %	WET WT. %	DRY WT. %	WET WT. %	DRY WT. %	WET WT. %	DRY WT. %	WET WT. %	DRY WT. %
1.0	1.0	7.0	7.5	13.0	14.9	19.0	23.5	25.0	33.3
1.1	1.1	7.1	7.6	13.1	15.1	19.1	23.7	25.1	33.5
1.2	1.2	7.2	7.7	13.2	15.2	19.2	23.8	25.2	33.7
1.3	1.3	7.3	7.9	13.3	15.3	19.3	23.9	25.3	33.9
1.4	1.4	7.4	8.0	13.4	15.5	19.4	24.1	25.4	34.0
1.5	1.5	7.5	8.1	13.5	15.6	19.5	24.2	25.5	34.2
1.6	1.6	7.6	8.2	13.6	15.7	19.6	24.4	25.6	34.4
1.7	1.7	7.7	8.3	13.7	15.9	19.7	24.5	25.7	34.6
1.8	1.8	7.8	8.5	13.8	16.0	19.8	24.7	25.8	34.8
1.9	1.9	7.9	8.6	13.9	16.1	19.9	24.8	25.9	35.0
2.0	2.0	8.0	8.7	14.0	16.3	20.0	25.0	26.0	35.1
2.1	2.1	8.1	8.8	14.1	16.4	20.1	25.2	26.1	35.3
2.2	2.2	8.2	8.9	14.2	16.6	20.2	25.3	26.2	35.5
2.3	2.4	8.3	9.1	14.3	16.7	20.3	25.5	26.3	35.7
2.4	2.5	8.4	9.2	14.4	16.8	20.4	25.6	26.4	36.9
2.5	2.6	8.5	9.3	14.5	17.0	20.5	25.8	26.5	36.1
2.6	2.7	8.6	9.4	14.6	17.1	20.6	25.9	26.6	36.2
2.7	2.8	8.7	9.5	14.7	17.2	20.7	26.1	26.7	36.4
2.8	2.9	8.8	9.6	14.8	17.4	20.8	26.3	26.8	36.6
2.9	2.9	8.9	9.8	14.9	17.5	20.9	26.4	26.9	36.8
3.0	3.1	9.0	9.9	15.0	17.6	21.0	26.6	27.0	37.0
3.1	3.2	9.1	10.0	15.1	17.8	21.1	26.7	27.1	37.2
3.2	3.3	9.2	10.1	15.2	17.9	21.2	26.9	27.2	37.4
3.3	3.4	9.3	10.3	15.3	18.1	21.3	27.1	27.3	37.6
3.4	3.5	9.4	10.4	15.4	18.2	21.4	27.2	27.4	37.7
3.5	3.6	9.5	10.5	15.5	18.3	21.5	27.4	27.5	37.9
3.6	3.7	9.6	10.6	15.6	18.5	21.6	27.6	27.6	38.1
3.7	3.8	9.7	10.7	15.7	18.6	21.7	27.7	27.7	38.3
3.8	4.0	9.8	10.9	15.8	18.8	21.8	27.9	27.8	38.5
3.9	4.1	9.9	11.0	15.9	18.9	21.9	28.0	27.9	38.7
4.0	4.2	10.0	11.1	16.0	19.0	22.0	28.2	28.0	38.9
4.1	4.3	10.1	11.2	16.1	19.2	22.1	28.4	28.1	39.1
4.2	4.4	10.2	11.4	16.2	19.3	22.2	28.5	28.2	39.3
4.3	4.5	10.3	11.5	16.3	19.5	22.3	28.7	28.3	39.5
4.4	4.6	10.4	11.6	16.4	19.6	22.4	28.9	28.4	39.7
4.5	4.7	10.5	11.7	16.5	19.8	22.5	29.0	28.5	39.9
4.6	4.8	10.6	11.9	16.6	19.9	22.6	29.2	28.6	40.1
4.7	4.9	10.7	12.0	16.7	20.0	22.7	29.4	28.7	40.3
4.8	5.0	10.8	12.1	16.8	20.2	22.8	29.5	28.8	40.4
4.9	5.2	10.9	12.2	16.9	20.3	22.9	29.7	28.9	40.6
5.0	5.3	11.0	12.3	17.0	20.5	23.0	29.9	29.0	40.8
5.1	5.4	11.1	12.5	17.1	20.6	23.1	30.0	29.1	41.0
5.2	5.5	11.2	12.6	17.2	20.8	23.2	30.2	29.2	41.2
5.3	5.6	11.3	12.7	17.3	20.9	23.3	30.4	29.3	41.4
5.4	5.7	11.4	12.9	17.4	21.1	23.4	30.5	29.4	41.6
5.5	5.8	11.5	13.0	17.5	21.2	23.5	30.7	29.5	41.8
5.6	5.9	11.6	13.1	17.6	21.4	23.6	30.9	29.6	42.0
5.7	6.0	11.7	13.3	17.7	21.5	23.7	31.1	29.7	42.2
5.8	6.2	11.8	13.4	17.8	21.7	23.8	31.2	29.8	42.5
5.9	6.3	11.9	13.5	17.9	21.8	23.9	31.4	29.9	42.7
6.0	6.4	12.0	13.6	18.0	22.0	24.0	31.6	30.0	42.9
6.1	6.5	12.1	13.8	18.1	22.1	24.1	31.8	30.1	43.1
6.2	6.6	12.2	13.9	18.2	22.2	24.2	31.9	30.2	43.3
6.3	6.7	12.3	14.0	18.3	22.4	24.3	32.1	30.3	43.5
6.4	6.8	12.4	14.2	18.4	22.5	24.4	32.3	30.4	43.7
6.5	7.0	12.5	14.3	18.5	22.7	24.5	32.5	30.5	43.9
6.6	7.1	12.6	14.4	18.6	22.9	24.6	32.6	30.6	44.1
6.7	7.2	12.7	14.5	18.7	23.0	24.7	32.8	30.7	44.3
6.8	7.3	12.8	14.7	18.8	23.2	24.8	33.0	30.8	44.5
6.9	7.4	12.9	14.8	18.9	23.3	24.9	33.2	30.9	44.7

ND T 191 – DENSITY OF SOIL IN-PLACE BY THE SAND CONE METHOD

Conduct this procedure according to ND T 191.

Consult the current edition of AASHTO for procedure in its entirety and equipment specification details

SCOPE

This method covers the determination of the in-place density of compacted soil or soil-aggregate mixtures. The in-place dry density is expressed as a percentage of the soils maximum dry density and can be compared to specification requirements.

REFERENCED DOCUMENTS

AASHTO T 19, Bulk Density (“Unit Weight”) and Voids in Aggregate
AASHTO T 191, Density of Soil In-Place by the Sand Cone Method
ND T 265 and AASHTO T 265, Laboratory Determination of Moisture Content of Soils
ASTM D 4643, Determination of Moisture Content of Soil by the Microwave Oven Method

APPARATUS

Sand density apparatus and base plate
Clean, free-flowing sand consisting of -No.10 +No.200
Balance, readable to 0.1 grams
Pins, shovel, trowel, spoon, hammer, and knife
Auger, 4" diameter
Sealable container

EQUIPMENT PREPARATION

Filling the apparatus

1. Place the empty apparatus upright on a firm level surface, close the valve and fill the funnel with sand.

2. Open the valve and keep the funnel at least half full with sand during filling. When the sand stops flowing into the apparatus, close the valve sharply and empty the excess sand.

3. Determine and record the mass of the apparatus filled with sand (m_1).

Determining the mass of sand required to fill the funnel and base plate (Cone Correction)

1. Place the base plate on a clean, level, plane surface. Invert the sand cone filled with sand, and seat the funnel in the recess of the base plate.

2. Open the valve fully and allow the sand to flow until the sand stops flowing.

3. Close the valve sharply, remove the apparatus, and determine the mass of the apparatus and the remaining sand (m_2).

4. The mass of sand required to fill the cone and base plate is calculated by the difference between the initial mass and final mass. Record this mass as the cone correction:

$$(C_c = m_1 - m_2).$$

Where:
C_C = Cone correction
m_1 = Mass of the apparatus filled with sand
m_2 = Mass of the apparatus and remaining sand

Notes:

For each container/bag of sand there will be a unique cone correction and sand calibration factor. Each sand-cone and matched base plate will also have a set of unique cone corrections and bulk sand densities. If more than one sand-cone apparatus is available, the sand-cone and base plate should be marked and the associated correction/density factors recorded.

Vibration of the sand during any mass-volume determination may increase bulk density of the sand and decrease the accuracy of the determination. Appreciable time intervals between the bulk density determination of the sand and its use in the field may result in change in the bulk density caused by a change in the moisture content or effective gradation.

Determining the bulk density of sand (D_B)

1. Replace the sand removed in the funnel determination according to the procedure for filling the apparatus, close the valve, and determine the mass of the apparatus and sand (m_3).

2. Position the calibration container on a clean, level, plane surface. Place the base plate on the calibration container. Invert the apparatus and seat the funnel in the recess of the base plate.

3. Open the valve fully and keep open until the sand stops flowing.

4. Close the valve sharply, remove the apparatus and determine the remaining mass of the apparatus and sand (m_4).

5. Calculate the mass of the sand needed to fill the container, funnel and base plate. Subtract the final mass (Step 4), from the initial mass (Step 1).

6. The mass of the sand needed to fill the container only is determined by subtracting the mass of the cone correction (Step 4) from the total mass required to fill the container with the funnel and base plate (Step 5).

7. Determine the bulk density of the calibration sand (sand calibration factor). Divide the mass of the sand needed to fill the container (Step 6), by the volume of the calibration container as determined according to AASHTO T 19.

   $$D_B = (m_3 - m_4 - C_C)/V_C$$

   Where:
   D_B = *Bulk density of the sand in g/cm*^{3}
   m_3 = *Mass of the apparatus and sand*
   m_4 = *Remaining mass of the apparatus and the sand*
   C_C = *Cone correction*
   V_C = *Volume of the calibration container*

8. Record this factor for future reference.

PROCEDURE

All information is recorded on SFN 59725 and SFN 59724.

Fill testing apparatus with sand and record the total mass.

Select the area of compacted lift to be tested. Because the surface of a compacted area is generally loose or disturbed due to compaction operations, remove loose material and level off an area slightly larger than the base plate.

Place the base plate over the smoothed area and fasten down with the accompanying pins. Plate must stay in this position and be stable throughout the test.

Dig a test hole within base plate opening, with the auger, trowel, or other tools. Soils that are granular require extreme care and may require the digging of a conical-shaped hole. Place all of the loosened material from the hole into an aggregate balance pan, or a moisture-tight container if not weighed right away.

Minimum Test Hole Volumes and Moisture Content Samples Based on Maximum Size

Maximum Particle Size	Minimum Test Hole Volume	Minimum Sample Size for Moisture Content
No. 4 (4.75 mm)	0.025 ft^3	100 g
1/2" (12.5 mm)	0.050 ft^3	250 g
1" (25.0 mm)	0.075 ft^3	500 g
2" (50.0 mm)	0.100 ft^3	1000 g

Place testing apparatus on the base plate and open valve. After the sand has stopped flowing, close the valve; remove apparatus, and record final mass.

Weigh the wet soil or soil-aggregates removed from the hole to the nearest 0.01 lbs and record.

Use a representative portion of the soil for moisture determination. Do not use material containing particles large enough to be retained on the No. 4 (4.75 mm) sieve. Moisture can be determined by the use of ND T 265 or ND D 4643. Calculate moisture to nearest 0.1%.

CALCULATIONS

Complete calculations as follows:

- *(V_H) Volume of Test Hole = (Initial Mass - Final Mass - C_C)/D_B*

  Calculate the volume of test hole to the nearest 0.0001 ft^3.

- *(M_{DS}) Dry Mass of Material removed from test hole = (Moist Mass removed from test hole/[1 + (% moisture /100)]*

  Calculate dry mass of material to the nearest 0.01 lbs.

- *(D_D) Dry Density = M_{DS}/V_H*

  Calculate in-place dry density to the nearest 0.1 lbs/ft^3.

CALIBRATION

All new devices should be calibrated prior to being used. A calibration check should be performed annually as a minimum, or whenever damage or repair occurs.

ND D 4643 - MICROWAVE METHOD OF DRYING SOILS

Conduct this procedure according to ND D 4643.

Consult the current edition of ASTM for procedure in its entirety and equipment specification details.

SCOPE

This procedure is used to determine the total moisture content of a soil. The soil is dried to remove all free moisture. This test measures the weight of the moisture removed from the soil.

APPARATUS

Balance, readable to 0.1 g
Microwave safe dish
Glass rod, spatula or knife
Oven mitts
Heat sink
Microwave oven (It is preferable the microwave oven has a vented chamber, and a power rating of about 700 watts with variable power control.

PROCEDURE

Record all weights to the nearest 0.1 g. Weigh a clean and dry microwave safe dish and record the weight as tare weight.

Determine the sample size needed from the table below. Place the sample in the container and immediately weigh. Record this weight as wet weight.

Sieve Retaining Not More Than About 10% of Sample	Recommended Mass of Moist Specimen
No. 10 (2.0 mm)	100 to 200 g
No. 4 (4.75 mm)	300 to 500 g
3/4" (19 mm)	500 to 1000 g

Place the container in the microwave oven with a heat sink, set power to defrost setting, set timer for 3 minutes and start (See Notes). The 3-minute initial time is a minimum.

When the microwave oven stops, remove from the oven and weigh to the nearest 0.1 g and note. Use a small spatula, glass rod, or knife and carefully mix the soil. Take care not to lose any soil.

Return the container and soil to the oven and reheat for 1 minute. Remove, weigh, and again mix with spatula, glass rod, or knife. Repeat this process until a constant weight has been achieved. Use the final weight to calculate the moisture content. Record this weight as dry weight.

Discard sample after test.

CALCULATIONS

Calculate the percent moisture as follows:

$$A = [(B - C)/(C - D)] \times 100$$

A = Percent moisture
B = Mass of original (wet) sample, and container
C = Mass of dry sample, and container
D = Mass of container

REPORT

Report moisture to the nearest 0.1%.

NOTES

Initial power setting may be higher than defrost. The proper power setting can be determined only through the use of, and experience with a particular microwave.

Soils that are high in moisture and contain a large portion of clay take a longer time to dry. Initial heating time for this type of soil may be 12 minutes. Care should be taken to reduce cohesive samples to 1/4" particles to speed drying and prevent crusting or overheating of the surface while drying the interior.

Constant weight is defined as when further drying will cause less than 0.1% additional loss in mass when weighed at specified intervals. Specified weighing interval for microwave drying is one minute.

CALIBRATION

A calibration check of the equipment should be performed annually as a minimum, or whenever damage or repair occurs.

ND T 224 – CORRECTION FOR COARSE PARTICLES IN THE SOIL COMPACTION TEST

Conduct this procedure according to ND T 224.

The NDDOT requires the use of Method A or D when conducting moisture-density relation tests, therefore, a correction is required for the oversize removed.

When Method D is used, a correction shall be applied to soil-aggregates which contain more than 5% by weight of oversize. When the oversized maximum of 30% is exceeded, other methods of compaction control must be used

Consult the current edition of AASHTO for procedure in its entirety and equipment specification details.

SCOPE

This method describes a procedure for adjusting densities of soil and soil-aggregates to compensate for differing percentages of oversize particles retained on the 19.0 mm (3/4") sieve.

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REFERENCED DOCUMENTS

ND T 99 and ND T 180 and AASHTO T 99 and T 180, Moisture Density Relations of Soils
AASHTO T 224, Correction for Coarse Particles in the Soil Compaction Test
ND T 265 and AASHTO T 265, Laboratory Determination of Moisture Content of Soils
ND D 4643 and ASTM D 4643, Determination of Moisture Content of Soil by Microwave Oven Heating

CALCULATIONS

Calculate the Corrected Moisture Content (MC_T)

$$MC_T = [(MC_F) \times (P_f) + (MC_c) \times (P_c)]/100$$

Where:

- MC_T = *corrected moisture content of combined fine and oversized particles, expressed as a percentage of moisture.*
- MC_F = *moisture content of fine particles, expressed as a percentage of moisture.*
- MC_c = *moisture content of oversized particles, expressed as a percentage*

of moisture (2.0%).

- P_f = *percent of fine particles, by weight.*
- P_c = *percent of coarse particles, by weight.*

Calculate moisture content to nearest 0.1%.

Example of Calculation of Corrected Moisture Content:

10.5% = [(12.0 x 85) + (2.0 x 15)]/100

Calculate the Corrected Dry Density of the Total Sample (D_d)

$$D_d = 100 \times (D_f) \times (k)/[(D_f) \times (P_c) + (k) \times (P_f)]$$

Where:

- D_d = *corrected dry density of combined fine and oversized particles, expressed as lbs/ft^3.*
- D_f = *dry density of fine particles expressed as lbs/ft^3, determined in lab.*
- P_c = *percent of coarse particles, by weight.*
- P_f = *percent of fine particles, by weight.*
- k = *62.4* Bulk Specific Gravity (2.650).*

Calculate in-place dry density to the nearest 0.1 lbs/ft^3.

Example of Calculation of Corrected Dry Density:

127.2 lbs/ft^3 = 100 x 122.0 x 165.4/ [(122.0 x 15) + (165.4 x 85)]

NOTES

Unless the actual moisture content of the oversize particles is known, 2.0% shall be used in calculating corrected moisture. Unless the actual bulk specific gravity of the oversize is known, 2.650 shall be used in calculating corrected dry density.

Each dry density and moisture content shall be calculated and plotted to determine optimum moisture content and maximum dry density, as specified within ND T 99 and ND T 180.

Name:

ND T 99 and T 180 Moisture-Density Relations of Soils

Before performing the test:
Representative soil samples are collected from the field.
Volume of mold must be determined and recorded. Volume is recorded to 0.0000 cu.ft.

Location: Sample size needed and test used will be dependent up on the soil type.

Test Results: Report Maximum Dry Density to 1 cu.ft. Optimum Moisture to 0.1%

Fill in the blanks.

1. **Purpose of test:** Determine the relationship between moisture content and density of soils compacted in a mold. The test will determine the point of a certain percentage of __________ in combination with a prescribed __________ will provide the best soil strength. The "Optimum Moisture" and "Maximum Dry Density" are the numbers used to represent that combination.

2. Record information on SFN 10063

3. Determine which test method will be used, T __________ or T __________, A or D

4. Obtain and prepare the soil sample. Air or oven-dry at __________ if needed.

5. Break up the soil chunks so they pass through a ___________. Divide the sample into 5 representative samples that are approximately seven pounds each (Method A)

6. Add and mix water to the first sample to approximately __________ points below Optimum. A quick test of optimum is to slightly ____________ soil and it will hold the shape (form a cast). There is no predetermined amount of water to begin with.

7. For the remaining samples add the same amount of water used in the first, plus an amount to increase the moisture approximately __________ to __________ % For a seven pound sample add an additional __________ ml of water.

8. Tightly cover each sample and set for a minimum of __________ hours.

9. Verify test area is provides a rigid and __________ foundation or base.

10. Weight the empty mold without the base plate or collar and record to 0.01 lb. Record as ______________.

11. Place the mold onto the base plate and add the __________. Tightly secure.

12. Filter paper may be added to the mold to help prevent soil from sticking to __________ __________.

13. Add soil from the first sample to the mold and __________.

14. Lightly tamp with __________ before using compaction hammer.

15. Place hammer in mold and compact evenly. ___________ blows for 4 inch mold.

16. Remove hammer. Trim soil around edges of mold and spread over top of layer.

17. Add soil and repeat process for each layer. Final layer should be slightly __________ the collar.

18. Carefully remove the collar then trim the soil __________ with the mold. Clean the __________ of the mold.

19. Remove the mold from the base plate. Remove __________ paper if used.

20. Weigh the soil in the mold and record to 0.01 lb and record as __________ of __________ + __________ soil.

21. Extract or remove soil from mold.

22. Slice through the center __________ and remove a ______________ moisture sample of approximately 100 grams.

23. Place in __________ __________ container and cover. Weigh and record to 0.1 gram.

24. Compact, extract and obtain __________ samples of remaining prepared samples.

25. Dry the moisture samples and determine percent moisture of each. Record to 0.1% Complete calculations on worksheet

26. Plot the moisture and dry density results on a graph with smooth curved lines and determine the __________ moisture and __________ dry density. Report ___________ moisture to 0.1% and ___________ dry density to the ___________ number.

Name:

ND D 2167 Density and Unit Weight of Soil In-place by the Rubber-Balloon Method

Before performing the test:
Volume measure calibration must be completed. That value must be noted on tester and that pressure is used for running the test. A proctor test will be completed to determine optimum moisture and maximum dry density.

Location: Test location is determined by Engineer using random method.

Fill in the blanks.

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1. **Purpose of test:** Determine the __________ density of __________ soil. Used as means to measure the compaction efforts provided by contractor. Test results are compared to the ______________ and optimum moisture and maximum dry density for the soil type.

2. Record information on __________

3. Determine the volume of hole needed. Approximate size is __________ diameter by __________ deep if maximum aggregate particle size is ½"

4. Select area to be tested and __________. Remove any __________ material.

5. Place the base plate on smooth and __________ area and fasten securely with __________. Plate must stay _______________ throughout the test.

6. Place the volume measure on the plate.

7. Verify the bulb-type pump is set to __________ the balloon __________ in the volume measure.

8. Pump until the calibration pressure is reached as indicated on the __________. Read the _______________ in the glass cylinder and remove the volume measure.

9. Record that value to the __________ cubic foot. Record as __________ Volume Reading

10. Dig a hole with __________, __________ or other tools.

11. Clean the sides of hole and bottom. Check for __________ edges.

12. Place all loosened material in a ______________ container. __________ if not weighed immediately.

13. Record weight of soil as __________ weight of soil. Record to the __________ pound.

14. Place volume measure on base plate.

15. Pump balloon to the __________ pressure forcing the __________ into the hole.

16. Read level of __________ in glass cylinder.

17. Remove and __________ the bulb-type pump and pump the balloon __________ the volume measure.

18. Record the reading observed to 0.00025. Record as __________ volume reading.

19. Perform initial calculation on worksheet to verify hole volume.

20. Use representative sample of material removed for ________________ determination

Name:

ND T 191 Density In-place by the Sand Cone Method

Before performing the test: Cone Correction factor must be completed and recorded for reference. Bulk density of sand must be determined and recorded for reference.

Location: Test location is determined by Engineer using random method.

Test Results: Report dry density to 0.1 lb cu.ft.

Fill in the blanks.

1. **Purpose of test:** Determine the _______________ of compacted soil or soil-aggregate. Used as means to measure the compaction efforts provided by contractor. Test results are compared to _____________ and the optimum moisture and maximum dry density.
2. Record information on _________
3. Fill in cone correction/calibration factor and Unit Weight and (bulk density) of sand.
4. Place the testing apparatus on a _________ surface to begin preparing for testing.
5. Close valve. Fill _________ with sand.
6. Open valve and continue adding sand to keep at least _________.
7. When sand stops, _________ valve and empty _________ sand.
8. Weigh the apparatus and record as __________________
9. Select area for testing. Remove _________ material, _________ and prepare for testing.
10. Place base plate and _________ with pins.
11. Determine size of test hole needed
12. Dig test hole using _________, trowel, or other tools.
13. Place all loosened material in a _____________ container and cover.
14. Record on form as weight of material _________ _________ _________ _________. Record to 0.01 lb.
15. Place apparatus on base plate and _________ valve.
16. After sand stops flowing. Close valve, remove apparatus and weigh. Record as ________________.
17. Take a _____________ sample from soil taken from the hole and determine moisture content.
18. Perform calculations on worksheet. Calculate __________ to 0.1 lb cu .ft.

Name:

ND T 217 Determination of Moisture in Soils by Means of Calcium Carbide Gas Pressure Moisture Tester (Speedy)

Sample source: test hole, from portion of mold from proctor test, field sample of borrow material

Constant weight: when further drying will cause less than 0.1% additional moisture loss

Fill in the blanks

---

1. **Purpose of test:** Dry soil to remove all __________. Reading on dial of tester is moisture by __________ mass. Convert to __________ mass using conversion chart.

   The size of sample used is determined by ____________ of speedy tester. The sample size is the '__________ weight'. The dial reading is percent __________ by __________ mass and is converted to percent __________ by __________ mass by using the chart provided.

2. The speedy moisture tester should not be used for material that is ___________.

3. Obtain sample. Thoroughly mix.

4. Inspect speedy vessel and __________ to verify they are clean

5. Verify expiration date on reagent can.

6. Weigh soil sample using scale provided. __________ to __________ grams are typical.

7. Add __________ to either vessel or cap. 3 to 5 scoops are used.

8. Add soil sample to either the __________ __________ or vessel.

9. Gently add the __________ __________ to the vessel.

10. Maintain __________ position of speedy vessel while carefully placing cap. Bring __________ up over cap and __________ securely.

11. Raise __________ to mix __________ and __________. Tap the vessel to ensure material has fallen from the cap then return to __________ position.

12. Shake with __________ motion.

13. Shake/rotate __________ seconds. Rest __________ seconds.

14. Continue for minimum of __________ minutes

15. Check the dial reading.

16. If dial is still moving continue cycle of __________ and __________. Once it stops moving read and record to the __________ percent.

17. If dial reading is at maximum, repeat test using __________ size sample. __________ the dial reading.

18. Use DOT form __________ to convert dial reading

19. Empty __________ carefully, pointing __________ from body. Examine for any __________.   If any lumps are found, _______________.   Clean tester.

Name:

ND D 4643 Microwave Method of Drying Soils

Sample source: test hole, from portion of mold from proctor test, field sample of borrow material

Constant weight: Dry is when further drying will cause less than 0.1% additional moisture loss

Fill in the missing answers from each step of the procedure.

1. **Purpose of test:** dry soil to remove moisture. Weight of moisture - difference between wet and dry weight is determined. That weight is used in calculation based on __________ weight and is expressed as __________ moisture in __________ sample.
2. Obtain Sample. Thoroughly __________.
3. Weigh clean, dry container and record to __________ gram.
4. Determine sample size needed. Minimum sample size is __________
5. Place sample in container. __________ and record to 0.1 gram
6. Place container and sample in __________
7. Set power to __________ and set time to approximately __________ minutes and start.
8. Remove, stir and repeat drying cycle. Additional cycle time will vary but may be 1 to 3 minutes
9. When __________ weight is achieved, cover, cool and record as __________
10. Perform calculations. Report to ________________% moisture.

Name:

ND T 265 Laboratory Determination of Moisture Content of

Sample source: test hole, from portion of mold from proctor test, field sample of borrow material

Constant weight: Dry is when further drying will cause less than 0.1% additional moisture loss

Fill in the blanks.

---

1. **Purpose of test:** dry soil to remove moisture. Weight of moisture - difference between wet and dry weight is determined. That weight is used in calculation based on __________ weight and is expressed as __________ moisture in total sample.
2. Obtain Sample. Thoroughly mix.
3. Weigh clean, dry container and cover and record. Record to 0.1 gram. Record as __________ __________.
4. Determine sample size needed. Size needed is determined by __________ __________ size.
5. Place sample in container and __________. Weigh and record.
6. Record weight to __________ gram.
7. Remove cover and place in the __________.
8. Set oven temperature to __________ ± __________
9. Dry overnight or to __________ weight.
10. __________ to __________ hours is considered dried to constant
11. Remove from oven, __________ and __________ then weigh. Record as __________ __________ to 0.1 gram
12. Perform calculations. Report to __________ moisture.

Chapter 3

Standard Specifications for Road and Bridge Construction

NDDOT
North Dakota
Department of Transportation

Prepared by

NORTH DAKOTA DEPARTMENT OF TRANSPORTATION
BISMARCK, NORTH DAKOTA

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DEPUTY DIRECTOR FOR ENGINEERING
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Adopted October 2014

SECTION 203
EXCAVATION AND EMBANKMENT

203.01 DESCRIPTION

This work consists of the excavation, haul, placement, disposal, and compaction of embankment material.

A. **Common Excavation.**
Common excavation consists of excavation within the right of way, not otherwise classified.

B. **Rock Excavation.**
Notify the Engineer if detached rock having a volume of 0.5 cubic yard or larger are discovered or if rock excavation methods are required for the excavation of material or boulders.

Rock excavation methods include:

– Blasting, before material can be excavated and removed; or

– Material that requires a heavy-duty dozer-mounted rippers or dozer blades to break the material into chunks of more than 1 cubic foot, before material can be excavated and removed.

C. **Shale Excavation.**
Notify the Engineer if shale excavation is required before performing the excavation.

Shale excavation includes:

– Excavating material that is laminated, fissile, or sedimentary material that is principally composed of fine-grained particles; or

– Material that requires a heavy-duty dozer-mounted rippers or dozer blades to break the material into chunks of 1 cubic foot or less, before material can be excavated and removed.

D. **Muck Excavation.**
Notify the Engineer if muck excavation is required.

Muck excavation consists of the excavation and disposal of saturated mixtures of soils and organic matter that are unsuitable for use as embankment. The Engineer will classify the excavation as muck excavation when the material cannot be excavated using the methods that the Contractor is using to perform the majority of the surrounding excavation.

E. **Borrow Excavation.**
Borrow Excavation consists of excavation, haul, placement, and compaction of embankment material obtained from locations outside the right of way.

203.02 EQUIPMENT

Equipment	Section
Vibratory Sheepsfoot/Pad Foot/Extended Pad Foot Rollers	151.02 E

Use sheepsfoot rollers with feet that exert a ground pressure of at least 250 psi.

Material used for embankment construction may be hauled in trucks or in scrapers.

If scrapers are used to haul material, construct an earthen ramp across existing roadways. Construct the ramp to a depth that will protect the existing pavement structure from damage and in a manner that will allow the roadway to be used by traffic at all times. Remove the ramp each day when hauling operations cease. Provide flagpersons, as specified in Section 704, “Temporary Traffic Control” for each direction that traffic crosses the ramp. Construct and remove the ramp at no additional cost to the Department.

203.03 MATERIALS

Reserved.

203.04 CONSTRUCTION REQUIREMENTS

A. **General.**
Place all available common excavation before using borrow excavation.

If disposing of rocks and boulders bury them under a minimum of 1 foot of soil at approved locations.

1. **Haul.**
Average haul is the average distance which, in stations, excavation in excess of that deposited within the station must be hauled.

    Free haul is the average haul for the project.

    Overhaul is authorized hauling in excess of the free haul distance, if the haul is also beyond the designated balance points.

    If overhaul is authorized, allow the Engineer 6 hours before and after hauling operations to take measurements to determine the volume of overhaul excavation.

2. **Rock Subcut.**
Excavate rock to a minimum depth of 6 inches and a maximum depth of 12 inches below subgrade.

3. **Roadway Obliteration.**
Obliterate the roadway by removing the roadway surface material, structures, and appurtenances, filling in the ditches, grading, placing topsoil, and seeding. Restore to match surrounding ground contours.

4. **Coal.**
Remove coal to a depth:

    – 6 feet below the subgrade profile between the graded shoulders; and

    – 1 foot below the final surface elevation from the graded shoulders and the top of the backslopes.

B. **Topsoil.**
Remove topsoil to its full depth or a depth up to 6 inches, whichever is less,

from all excavation and embankment areas. Do not remove the subsoil or other deleterious material with topsoil. Stockpile the removed topsoil.

Construct topsoil stockpiles with 4:1 or flatter slopes, if located within the clear zone. Place topsoil piles at acceptable locations outside of the grading limits or if necessary, outside the right of way at no additional cost to the Department. If stockpiling topsoil outside the right of way, submit a copy of the agreement negotiated with the landowner 10 days before constructing topsoil stockpiles.

Scarify the surface to a depth of 2 inches before replacing topsoil.

Uniformly spread the stockpiled topsoil over the disturbed areas within the right of way.

1. **Topsoil – Wetland.**
   Strip a minimum of 6 inches of topsoil from wetland area. Separately stockpile the wetland topsoil at a height no greater than 3 feet.

   Spread a minimum of 6 inches of wetland topsoil at the mitigation site.

2. **Topsoil – Imported.**
   Provide imported topsoil consisting of friable, fertile soil of loamy character, containing an amount of organic matter normal to the region, capable of sustaining healthy plant life, and reasonably free from subsoil, roots, heavy or stiff clay, stones larger than 2 inches in greatest dimension, noxious weeds, sticks, brush, litter, and other deleterious matter. Provide the topsoil from a site outside the right of way. Spread the topsoil uniformly to a minimum depth of 6 inches. Use all existing stockpiled topsoil before importing topsoil.

C. **Subcut.**
Use an excavator with a smooth cutting edge to minimize disturbance of underlying soils. Do not scarify the bottom of the subcut. Do not operate construction equipment in the subcut area.

Compact aggregate according to Section 203.04 E.2, “Compaction Control, Type A.” The moisture content of the aggregate at the time of compaction shall be not less than 2.0 percentage points below, nor more than 3.0 percentage points above the optimum moisture content.

D. **Borrow Excavation.**

1. **General.**
   Schedule work in borrow areas to allow any utility company to relocate, adjust, or remove their facilities.

   Do not place waste or excess material in borrow area without obtaining an agreement with the landowner for the placement of the material. Submit a copy of the agreement with the landowner before placing waste or excess material in borrow area.

   Shape the borrow area to drain after excavation is complete. Flatten slopes to a minimum of 8:1, except if blending into steeper slopes.

   Obliterate and reshape access route.

   Seed all disturbed areas to match adjacent vegetation.

Replace fence to its original condition. Ensure livestock is confined when fencing is removed or altered.

Obtain a borrow source if no Department optioned borrow is provided. The Engineer will allow Contractor furnished borrow unless the Department optioned borrow area is mandatory.

Compact borrow as specified in Section 203.04 E.2, “Compaction Control, Type A.”

2. **Department Optioned Borrow.**
Identify the legal owners of the borrow area at the time the material is being removed. Use county records for the identification of land owners. Include the names of any other parties having a legal interest in the property. Provide this information to the Engineer.

Notify the landowner in writing if exercising the Department’s option, including the removal plan and location of the access route.

Submit a copy of the written notification and any other agreements negotiated with the landowner 10 days before starting operations in borrow area.

The Department will be responsible for utility relocations and costs of relocations.

Remove, stockpile, and spread topsoil as specified in Section 203.04 B, “Topsoil.” Use seed as specified in the Contract, if no seed is specified use Class II seed mixture as specified in Section 251.03, “Materials.”

Submit a copy of the landowner’s release and receipt of payment, after the borrow area has been restored to a satisfactory condition.

If the work is performed in more than 1 calendar year, pay the landowner for the material removed the first calendar year by December 31 of that year. If a payment arrangement different from the Department’s option is negotiated with the landowner, submit a copy of the agreement.

If a material shortage or other problems occur in the Department optioned area and the Engineer directs that borrow be furnished from an alternate site, the Department will pay for:

– Topsoil and seeding on the basis shown for the Department optioned area;

– Costs in excess of what would be incurred in the Department optioned area; and

– Haul will be measured as specified in Section 203.05 H, “Haul.”

3. **Contractor Furnished Borrow.**
The Engineer will determine if the material is suitable for the specified use.

Before work begins in the pit, furnish the names of the legal owners and the names of other parties having a legal interest in the borrow areas.

Submit a copy of the borrow agreement.

After the borrow area has been restored to satisfactory condition, obtain a release and receipt of payment from the legal owners and furnish copies to the Engineer.

Utility adjustments shall be the Contractors responsibility.

E. **Embankment Construction.**

1. **General.**
Do not place rocks, broken concrete, or other solid materials in embankment areas where piling is to be driven. Do not place any rocks larger than 4 inches in its longest dimension in the top 1 foot of the finished grade.

Do not use frozen material in embankment construction. Do not place material on frozen ground.

Use motor graders to spread material to a uniform thickness before compacting. Continuously level and manipulate the material to obtain uniform soil distribution. Operate construction equipment uniformly over the entire surface of each lift. Compact each lift to specified density and obtain the proper moisture content before placing the next lift.

Compact private drives, minor road approaches, and other parts of the embankment outside the roadbed as specified in Section 203.04 E.4, "Compaction Control, Type C."

Bench existing embankment if placing new material against slopes 4:1 or steeper. Do not bench with steps less than 24 inches in width. Begin each horizontal cut at the intersection of the original ground and the vertical sides of the previous cuts. Recompact excavated material along with new embankment material.

If the excavated material consists predominantly of rock too large to be placed in 12 inch lifts, place the material uniformly in thicknesses up to the average rock size, but no thicker than 2 feet. Do not use rock fill in the top 2 feet of the finished subgrade.

If placing rock fill over a structure, cover the structure with a minimum of 2 feet of compacted earth or other approved material before placing rock fill.

If placing and compacting material at structures, place and compact the material in lifts not to exceed 12 inches of loose material. During placement and compaction, ensure that each side is brought up within 12 inches of the other at all times.

Compact without placing excessive pressure against the structure when placing embankment is required only on one side of a structure.

Ensure the fill adjacent to a bridge abutment is no higher than the berm elevation in front of the abutment until the superstructure is in place.

2. **Compaction Control, Type A.**
Construct all fills, excluding rock fills, with moisture and density controls. Place embankment in lifts not to exceed 12 inches of loose material.

Manipulate substandard areas by working the soil until the specified density and uniform moisture content are achieved.

Compact material as specified in Section 203.04 E.2.a, “ND T 180” unless the contract specifies otherwise.

a. **ND T 180.**
Compact material to at least 90 percent of the maximum dry density with a moisture content no less than the optimum moisture and no more than 5.0 percentage points above the optimum moisture. The Engineer will determine the maximum dry density and optimum moisture content as specified in ND T 180.

b. **ND T 99.**
Compact material to at least 95 percent of the maximum dry density with moisture content no less than 4.0 percentage points below the optimum moisture, and no more than 5.0 percentage points above the optimum moisture. The Engineer will determine the maximum dry density and optimum moisture content as specified in ND T 99.

3. **Compaction Control, Type B.**
Construct embankment in lifts not to exceed 12 inches of loose material, except for rock fills and the first layer of fills over swampy ground.

Uniformly compact each lift by operating grading equipment and rollers over the entire area. Use a sheepsfoot roller until the roller pads penetrate the surface a maximum of 0.5 inch.

Use separate dumping and compacting areas.

4. **Compaction Control, Type C.**
Construct embankment in lifts not to exceed 8 inches of loose material over the full width of the proposed embankment section, except for rock fills and the first layer of fills over swampy ground.

Uniformly compact each lift by operating grading equipment over the entire area.

F. **Approach Foreslope Reconstruction and Flatten Ditch Block Slopes.**
Perform topsoil work for excavation and embankment areas as specified in Section 203.04 B, “Topsoil.”

Compact embankment material as specified in Section 203.04 E.3, “Compaction Control, Type B.”

Place Class II seed mixture as specified in Section 251.02, “Equipment;” 251.03, “Materials;” and 251.04, “Construction Requirements.”

Place mulch as specified in Section 253.02, “Equipment;” 253.03, “Materials;” and 253.04, “Construction Requirements.”

G. **Guardrail Embankment.**
Compact embankment material as specified in Section 203.04 E.2, “Compaction Control, Type A.”

Perform topsoil work as specified in Section 203.04 B, “Topsoil.”

Seed with Class II seed mixture as specified in Section 251.02, “Equipment”; 251.03, “Materials”; and 251.04, “Construction Requirements.”

SECTION 709
GEOSYNTHETICS

709.01 DESCRIPTION

This work consists of furnishing and installing geosynthetics.

709.02 EQUIPMENT

Reserved.

709.03 MATERIALS

Item	Section
Geosynthetics	858

709.04 CONSTRUCTION REQUIREMENTS

A. **General.**
Package, label, identify, handle, and store geosynthetic according to ASTM D 4873. Wrap each geosynthetic roll with a material that will protect the roll, including the ends of the rolls, from damage due to shipment, water, sunlight, and contaminants. Maintain protective wrapping during periods of shipment and storage. Store geosynthetic onsite elevated off the ground.

Deliver the geosynthetic to the project and submit a certificate of compliance at least 21 days before its incorporation into the work.

Overlap or sew the joints. Overlap as required for the specific geosynthetic type. If sewing joints use Kevlar, polypropylene, or polyester thread. Use a 401 stitch conforming to Federal Standard No. 751a for all seams. Use SSn-2 overlapping "J" seams for field seams. Sew all seams with two parallel stitch lines spaced approximately 1/4 inch apart. Place the outside stitch 1 inch from the edge of the geosynthetic. Sew seams that meet the strength requirements for the specific geosynthetic type. Furnish a sewn seam sample that has the same geosynthetic material, thread, seam spacing and number, and field seam overlap distance that will be used in the work.

Type D3 geosynthetics may be constructed using welded seams.

Install geosynthetic only after receiving approval from the Engineer. Place the geosynthetic on a surface that is smooth and free of stones, sticks, and other debris or irregularities that could damage the geosynthetic. Manually pull the geosynthetic taut to remove wrinkles. Do not operate construction equipment directly on the geosynthetic. If sewn, place geosynthetic with all seams up.

After laydown, cover geosynthetic material within 5 days. Remove and replace material that is not covered within 5 days.

B. **Geosynthetic Drainage Material (Type D).**
Secure geosynthetic using the manufacturer's recommended methods. After securing geosynthetic material in place, deposit the aggregate using methods that will not tear, puncture, or reposition the geosynthetic. Do not drop aggregate on

the geosynthetic from a height greater than 3 feet.

C. **Geosynthetic Geogrid (Type G).**
Unroll geogrid parallel to the centerline of the road. Do not drag the geogrid across the underlying material. Use geogrid widths that produce overlaps of parallel rolls at the centerline and at the shoulders and so that no overlaps are required along wheel paths.

Overlap the geogrid a minimum of 30 inches at all splices or joints. Construct joints at the end of a roll so the previous roll laps over the subsequent roll in the direction of the cover material placement. Mechanically tie transverse joints at 3-foot intervals, and longitudinal joints at 15-foot intervals. Place pins or staples at all corners and at 15-foot intervals along all edges, before placing cover material on the geogrid.

Stagger end overlaps at least 10 feet from other end overlaps in parallel rolls. On curves, the geogrid may be cut to conform to the curves.

Patch damaged areas of geogrid. Place a patch that overlaps the damaged area by 36 inches on all sides. Align the apertures of the patch and the underlying grid. Mechanically tie the patch to the underlying grid.

Place the first lift of material over geogrid installed on subgrade to a depth of 10 inches of loose material. Place the first lift of material over geogrid installed on aggregate base to a depth of 6 inches of loose material.

Use low ground pressure equipment to spread the initial lift of material. If rutting occurs, fill the ruts with additional material before placing the subsequent lift. Do not blade out ruts. Do not turn construction equipment on the first layer of material.

D. **Geosynthetic Reinforcement (Type R).**
Unroll geosynthetic parallel to the centerline of the road. Place the geosynthetic taut and pin the geosynthetic using pins at least 6 inches in length. Place pins at all corners and at 15-foot intervals along all edges, before placing material on the geosynthetic.

Overlap the geosynthetic a minimum of 30 inches at all splices or joints. Construct joints at the end of a roll so that the previous roll laps over the subsequent roll in the direction of the material placement.

Patch damaged areas by overlapping the tear a minimum of 36 inches with geosynthetic and secure the perimeter of the patch area with pins or staples.

Place a 6-inch loose initial lift of material above the geosynthetic. Use low ground pressure equipment to spread the initial lift of material. If rutting occurs, fill the ruts with additional material before placing the subsequent lift. Do not blade out ruts. Do not turn construction equipment on the first layer of material.

E. **Geosynthetic for Riprap (Type RR).**
Place geosynthetic with the longest dimension parallel to the direction of water flow. Place overlaps so the upstream strip overlaps the downstream strip. Overlap splices and joints at least 18 inches. Overlap splices and joints placed underwater at least 36 inches. Pin or staple all overlaps at 3-foot intervals.

Patch damaged areas by overlapping the tear a minimum of 36 inches with geosynthetic and secure the perimeter of the patch area with pins or staples.

Material placed to protect against wave action may be unrolled parallel or perpendicular to the water's edge. Sew all joints that are parallel to the water's edge.

F. **Geosynthetic Separation Material (Type S).**
Unroll the geosynthetic in line with the placement of the new material. Do not drag the geosynthetic across the underlying material. Use geosynthetic widths that produce overlaps of parallel rolls at the centerline and at the shoulders and so that no overlaps are required along wheel paths.

Overlap the geosynthetic a minimum of 18 inches at all splices or joints. Construct joints at the end of a roll so that the previous roll laps over the subsequent roll in the direction of the material placement.

Patch damaged areas by overlapping the tear a minimum of 36 inches with geosynthetic and secure the perimeter of the patch area with pins or staples.

Secure the geosynthetic using the manufacturer's recommended methods.

Place the initial lift of material above the geosynthetic to a depth of 9 inches of loose material. When placing the initial lift of material, limit construction equipment in size and weight so rutting in the initial lift is less than 3 inches. If rutting occurs, fill the ruts with additional material before placing the subsequent lift. Do not blade out ruts. Do not turn construction equipment on the first layer of material.

709.05 METHOD OF MEASUREMENT

The Engineer will measure, completed and in place, as specified in Section 109.01, "Measurement of Quantities" and as follows:

The Engineer will not measure overlaps, drainage trenches, or cutoffs.

709.06 BASIS OF PAYMENT

Pay Item	**Pay Unit**
Geosynthetic Material Type __	Square Yard

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 714
CULVERTS, STORM DRAINS, EDGEDRAINS, AND UNDERDRAINS

714.01 DESCRIPTION

This work consists of installing culverts, storm drains, edgedrains, and underdrains.

714.02 EQUIPMENT

Reserved.

714.03 MATERIALS

A. **Culverts and Storm Drains.**

Item	Section
Concrete Culvert and Storm Drain Pipe	830.01 A
Reinforced Concrete Culvert and Storm Drain Pipe	830.01 B
Metallic (Zinc or Aluminum Coated Corrugated Steel Culverts, Storm Drains, and Underdrains	830.02 B
Smooth Wall Steel Pipe Culverts	830.02 F
Polymer Coated Corrugated Steel Pipe	830.02 C
Corrugated Polyethylene Culverts	830.03 F
Geosynthetic Material – Type S2	858.01

Provide mortar consisting of a mixture of one part Portland Cement to two parts mortar sand, and sufficient water to furnish proper consistency.Where placing new end sections on existing pipe, identify whether the type of end section needed is male or female.

B. **Underdrains.**

Item	Section
Perforated, Corrugated Polyethylene	830.03 A.4

Table 714-01
Underdrain Aggregate Gradation

Sieve Size	Percent Passing
3/8 Inch	100
No. 4	95 – 100
No. 16	45 – 80
No. 50	10 – 30
No. 100	0 – 10
No. 200	0 – 3

C. **Bridge Approach Drains.**

Item	Section
Plastic Pipe (perforated and non-perforated)	830.03 A.4
Geosynthetic Material – Type D1	858

Table 714-02
Bridge Approach Drain Gradation

Sieve Size	Percent Passing
1 inch	100
3/4 inch	90 – 100
3/8 inch	20 – 55
No. 4	0 – 10
No. 8	0 – 5
No. 200	0 – 1.0

D. **Edgedrains.**

Item	Section
Class 43 Aggregate	816.03
Perforated, Corrugated, P.E. Pipe	830.03 A.4
PVC Discharge Pipe	830.03 A.3
Geosynthetics	858

The shale and L.A. abrasion requirements will not be required for Class 43 Aggregate.

E. **Structural Plate Pipe.**
Material shall meet Section 830.02, "Metal Pipe."

714.04 CONSTRUCTION REQUIREMENTS

If the existing drainage facilities become inoperable before the new drainage system is functioning, provide sufficient temporary pumping and drainage facilities to keep the roadway drained. Include the cost of providing sufficient temporary pumping and drainage in the price bid for other items.

Dispose of unsuitable or excess excavation at an approved location.

A. **General.**

1. **Bedding.**
   Construct bedding for approach pipes to meet the conduit manufacturer's recommendations.

   Tamp bedding material in place under both haunches of the pipe up 15 percent of the total height by hand-held air-operated, mechanical tampers

2. **Laying Pipe.**
   Begin laying pipe at the downstream end. Place the pipe in contact with the shaped bedding throughout its full length. Place bell or groove ends of rigid pipe and outside circumferential laps of flexible pipe facing upstream.

3. **Joining Pipe.**
   Provide rigid pipe with bell and spigot or tongue and groove joints. Join pipe sections so the ends are fully entered and the inner surfaces are flush and even. Wrap joints on concrete pipes in Type S2 geotextile fabric.

   Install pipe ties on all joints on concrete pipes, including the end section joint.

4. **Relaid Pipe.**
   Clean all salvaged pipe of foreign material before reinstallation.

   Furnish connecting devices or seals needed to join pipe or end sections.

5. **Deflection Testing.**
   Test all metal and thermoplastic pipe used for mainline and paved intersecting roadways for deflection a minimum of 30 days after the pipe is installed. Pass a 9-point mandrel or other approved object through the pipe to check for deflection. Use a mandrel with a diameter not less than 95 percent of the inside diameter of the pipe. If the mandrel cannot be passed through the pipe, replace the pipe.

   The Engineer will visually inspect thermoplastic pipe under unpaved approaches for deflection. If the Engineer sees any deflection, the Engineer will require the Contractor to pass a 9-point mandrel or other approved object through the pipe to check for deflection. Use a mandrel with a diameter not less than 95 percent of the inside diameter of the pipe. If the mandrel cannot be passed through the pipe, replace the pipe.

   Perform the deflection test under the observation of the Engineer.

6. **Connection to Manholes, Inlets, and Pipes.**
   If connections required to a manhole, inlet barrel, or pipe entrance, connect pipe by cutting the opening and grouting in the connecting pipe.

7. **Compaction Control for Aggregate.**
   Compact aggregate according to Section 203.04 E.2, “Compaction Control, Type A” The moisture content of the aggregate at the time of compaction shall be not less than 2.0 percentage points below, nor more than 3.0 percentage points above the optimum moisture content.

8. **Compaction Control for Non-Aggregate Material.**
   If Common Excavation Type A is specified, follow the compaction requirements in Section 203.04 E.2, “Compaction Control, Type A.” If Common Excavation Type B is specified, follow the compaction requirements in Section 203.04 E.3, “Compaction Control, Type B.”

   Use a maximum lift thickness of 6 inches.

9. **Construction Cover.**
   Meet the pipe manufacturer’s recommendation cover requirements during construction operations.

   Repair or remove and replace any pipe damaged by construction traffic.

CERTIFICATION

I hereby certify the attached supplemental specifications effective on October 1, 2015.

/S/ 6/1/15

Bob Fode, P.E., Director
Office of Project Development

Date

North Dakota
Department of Transportation

Use low ground pressure equipment to spread the initial lift of material. If rutting occurs, fill the ruts with additional material before placing the subsequent lift. Do not blade out ruts. Do not turn construction equipment on the first layer of material.

714.04 A.1 Bedding **PAGE 379** **10/01/15**

Delete the first paragraph from Section 714.04 A.1.

714.04 A.6 Connection to Manholes, Inlets, and Pipes **PAGE 380** **10/01/15**

Replace Section 714.04 A.6 with the following:

6. Connection to Manholes, Inlets, and Pipes.
If connections are required to a manhole, inlet barrel, or pipe entrance, connect pipe by cutting the opening and grouting in the connecting pipe.

714.04 A.7 Compaction Control for Aggregate **PAGE 380** **10/01/15**

Replace Section 714.04 A.7 with the following:

7. Compaction Control for Aggregate.
Compact aggregate according to Section 203.04 E.2, “Compaction Control, Type A” The moisture content of the aggregate at the time of compaction shall be not less than 2.0 percentage points below, nor more than 3.0 percentage points above the optimum moisture content.

Compact aggregate for approach pipes according to the conduit manufacturer’s recommendation

Use a maximum lift thickness of 6 inches.

714.04 A.8 Compaction Control for Non-Aggregate Material **PAGE 380** **10/01/15**

Replace Section 714.04 A.8 with the following:

8. Compaction Control for Non-Aggregate Material.
If Common Excavation Type A is specified, follow the compaction requirements in Section 203.04 E.2, “Compaction Control, Type A”. If Common Excavation Type B is specified, follow the compaction requirements in Section 203.04 E.3, “Compaction Control, Type B”.

Compact material for approach pipes according to the conduit manufacturer’s recommendations.

748.03 MATERIALS **PAGE 393** **10/01/15**

Add the following item to the table:

Impervious Membrane Cure	810.01 B.1 or 810.01 B.2

FIELD SAMPLING AND TESTING MANUAL

SECTION 200

EARTHWORK

SECTION 200
TABLE OF CONTENTS

All test procedures used within and referred to in the section can be found under "Testing Procedures" of this manual. The test procedures are listed in the following order: AASHTO, ASTM, and NDDOT. Any modifications will be listed at the beginning of each test procedure.

Blank copies of the forms referred to in the section will be found numerically at the end of the section. The most current edition of these forms should be used. These forms are found on the NDDOT internet website, or you may duplicate the ones behind each section.

SECTION 203

EXCAVATION AND EMBANKMENT

203 DESCRIPTION

This work consists of excavation, haul, placement and compaction of embankment, and disposal, if necessary, of material encountered within the limits of work necessary for construction of the roadway. Excavation in this section will be classified as "Common Excavation," "Rock Excavation," "Muck Excavation," or "Borrow".

203.1 ACCEPTANCE SAMPLES AND TESTS

Field Laboratory Testing: The Engineer or Representative conducts a minimum of one moisture and density test, including a proctor test, of each compacted lift per 1500 feet of roadway. Conduct tests according to AASHTO T 217, “Determination of Moisture in Soil by Means of Calcium Carbide Gas Pressure Moisture Tester (Speedy),”* ASTM D 2167, “Density and Unit Weight of Soil in Place by the Rubber-Balloon Method,” AASHTO T 191, “Density of Soil In-Place by the Sand Cone Method,” and AASHTO T 99 or T 180, “Moisture-Density Relations of Soils.” Record information on the following forms: SFN 2454, “Density Test Worksheet – Volume Measure,” or SFN 59725, “Density Test Worksheet – Sand Cone Method,” and SFN 10063, “Moisture-Density Relationship Tests.”

Take additional tests at locations as directed by the Engineer or Representative, such as, mainline culvert installations, etc. Compare the results derived from these tests to the curves developed from proctor testing according to AASHTO T 99 or T 180, “Moisture-Density Relations of Soils,” or the one-point curve chart. Record information on SFN 2454, “Density Test Worksheet – Volume Measure,” or SFN 59725, “Density Test Worksheet – Sand Cone Method.”

Establish a new compaction curve for each change of soil type encountered in the embankment. Determine the moisture-density relationship for each change of soil type by either the five-point proctor test or the one-point proctor test. Test according to AASHTO T 99 or T 180, “Moisture-Density Relations of Soils,” or the one-point curve chart. Record information on SFN 10063, “Moisture-Density Relationship Tests.” Compare the data developed from this testing to the results of the in-place moisture-density testing. Transfer the results to SFN 2454, “Density Test Worksheet – Volume Measure,” or SFN 59725, “Density Test Worksheet – Sand Cone Method.”

203.2 INDEPENDENT ASSURANCE (IA) SAMPLES AND TESTS

District Laboratory Testing: The District Materials Coordinator or Representative conducts a minimum of one moisture and density test, including a proctor test, for each three miles of roadway, or a minimum of one test per 200,000 cubic yards. The moisture test is conducted according to AASHTO T 217, “Determination of Moisture in Soil by Means of Calcium Carbide Gas Pressure Moisture Tester (Speedy).”* The density test is conducted according to ASTM D 2167, “Density and Unit Weight of Soil in Place by the Rubber-Balloon Method,” or AASHTO T 191, “Density of Soil In-Place by the Sand Cone Method.” The proctor test is conducted according to AASHTO T 99 or T 180 “Moisture-Density Relations of Soils.” Record information on SFN 2454, “Density Test Worksheet – Volume Measure,” or SFN 59725, “Density Test Worksheet – Sand Cone Method,” and SFN 10063, “Moisture-Density Relationship Tests.”

Take one random width measurement for each three miles between the shoulder lines. No width measurement is required for a length less than one mile. Record on SFN 13889, “Project Records Samples/Tests Report.” If an NHS system project, submit a copy of SFN 13889, “Project Records Samples/Test Reports,” to the FHWA at the completion of the project.

* Field applications typically require the use of the “Speedy” to determine soils moisture content, but it may be practical to use AASHTO T 265, “Laboratory Determination of Moisture Content,” or ASTM D 4643, “Microwave Method of Drying Soils,” in its place. However, acceptance testing and Independent Assurance (IA) testing must be completed using the same soils moisture determination method.

Materials and Research Division Testing: No specified number of tests is required. The Materials and Research Division will perform moisture-density relationship tests according to AASHTO T 99 or T 180, “Moisture-Density Relations of Soils,” if requested to do so by the District Materials Coordinator.

SECTION 210

STRUCTURAL EXCAVATION, STRUCTURAL FILL, AND FOUNDATION PREPARATION

210 DESCRIPTION

Structural excavation consists of the excavation and ordinary backfill required for installation of box culverts and bridges.

Structural fill shall consist of furnishing and placing select backfill material as shown on the Plans or as otherwise directed.

Foundation preparation consists of site preparation for installation of a box culvert or bridge.

210.1 ACCEPTANCE SAMPLES AND TESTS

Field or District Laboratory Testing: The Engineer, or Representative, must obtain one aggregate sample for sieve analysis of select backfill or foundation fill for every 2,500 cubic yards or fraction thereof. The samples shall be obtained from the point of placement, according to AASHTO T 2, “Sampling of Aggregates,” and tested according to AASHTO T 27, “Sieve Analysis of Fine and Coarse Aggregates.” Compute the sieve analysis results on SFN 9987, “Aggregate Sample Worksheet.”

If moisture and density control is required, material shall be tested according to Section 714.2 of the Field Sampling and Testing Manual.

210.2 INDEPENDENT ASSURANCE SAMPLES AND TESTS

District Laboratory Testing: The District Materials Coordinator or Representative must obtain one aggregate sample for sieve analysis of select backfill or foundation fill, per project. The samples are obtained according to AASHTO T 2, “Sampling of Aggregates,” and tested according to AASHTO T 27, “Sieve Analysis of Fine and Coarse Aggregates.” Compute the sieve analysis results on SFN 9987, “Aggregate Sample Worksheet.”

Materials and Research Division Testing: No specified number of tests is required.

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SECTION 230

RESHAPING ROADWAY AND SUBGRADE PREPARATION

230 DESCRIPTION

This work consists of scarifying, shaping, compacting, and maintaining the subgrade, or reshaping an existing roadway before constructing a base, or surface course.

230.1 ACCEPTANCE SAMPLES AND TESTS

Field Laboratory Testing: The Engineer or Representative conducts a minimum of one moisture and density test for each compacted lift per 1500 feet of roadway. Conduct moisture test according to AASHTO T 217, "Determination of Moisture in Soil by Means of Calcium Carbide Gas Pressure Moisture Tester (Speedy)."* Conduct the density test according to ASTM D 2167, "Density and Unit Weight of Soil in Place by the Rubber-Balloon Method," or AASHTO T 191, "Density of Soil In-Place by Sand-Cone Method." Record information on SFN 2454, "Density Test Worksheet – Volume Measure," or SFN 59725, "Density Test Worksheet – Sand Cone Method." Conduct additional tests at locations as directed by the Engineer or Representative.

If work consists of embankment widening, then testing shall be conducted on each side of roadway or embankment that is widened. Each widened portion shall be considered a separate roadway.

230.2 INDEPENDENT ASSURANCE (IA) SAMPLES AND TESTS

District Laboratory Testing: The District Materials Coordinator or Representative conducts a minimum of one moisture and density test, including a proctor test, for each three miles of roadway. Conduct these tests according to AASHTO T 217, "Determination of Moisture in Soil by Means of Calcium Carbide Gas Pressure Moisture Tester (Speedy),"* ASTM D 2167, "Density and Unit Weight of Soil in Place by the Rubber-Balloon Method," or AASHTO T 191, "Density of Soil In-Place by Sand-Cone Method," and AASHTO T 99 or T 180, "Moisture-Density Relations of Soils." Record information on SFN 2454, "Density Test Worksheet – Volume Measure," or SFN 59725, "Density Test Worksheet – Sand Cone Method," and SFN 10063, "Moisture-Density Relationship Test."

For Type C subgrade preparation, perform proctor tests for each soil change encountered with a minimum of one test for every three miles of roadway.

Frequency of testing shall not differ when conducting embankment widening.

* Field applications typically require the use of the “Speedy” to determine soils moisture content, but it may be practical to use AASHTO T 265, “Laboratory Determination of Moisture Content,” or ASTM D 4643, “Microwave Method of Drying Soils,” in its place. However, acceptance testing and Independent Assurance (IA) testing must be completed using the same soils moisture determination method.

Materials and Research Division Testing: No specified number of tests is required. The Materials and Research Division will perform moisture-density relationship tests according to AASHTO T 99 or T 180, “Moisture-Density Relations of Soils,” if requested to do so by the District Materials Coordinator.

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SECTION 709

GEOTEXTILE MATERIALS

709 DESCRIPTION

This section relates to field sampling of geotextile material.

709.1 DEFINITIONS

1. **Lot**: The NDDOT considers a lot to be a shipment of material delivered to the location of work. If there is documentation showing that the shipment came from different production plants or was manufactured using different materials or procedures, the different parts of the shipment will be considered separate lots.

2. **Samples**: For geotextile, the samples are taken from the shipping units (i.e., rolls of fabric) making up a lot. The property variables of the samples must represent the entire lot. These samples will be submitted for acceptance testing.

3. **Certificate of Compliance**: As outlined and detailed in Section 106.01 of *NDDOT Standard Specifications,* it states that the material fully comply with the Contract requirements.

709.2 DOCUMENTATION

The Engineer or designated field personnel shall obtain a valid Certificate of Compliance from the contractor and verify that it meets the requirements in Section 858 of NDDOT Standard Specifications. If the material properties stated on the Certificate do not meet the specifications, the material is not acceptable. If it is verified that the properties stated on the Certificate comply with Section 858, the Engineer shall contact Materials and Research for inquires on historical test information. If any of the criteria listed below are met, then the Engineer may elect to proceed with sampling.

- If the material is unknown to the NDDOT, or has a history of test failures, samples will be required.
- If a significant quantity of geotextile material is being used, or the project has been selected for random testing, samples may be required.
- If the Engineer is concerned about the quality of the geotextile, or that the Certificate does not represent the material on site, sampling and testing may be ordered at the direction of the Engineer.

709.3 GENERAL PROCEDURES

A. Sampling Overview

1. Sampling Frequency: To determine the number of samples to obtain for acceptance testing, consider the total units (i.e., rolls) of the lot or lots delivered to the work location. All geotextiles shall be sampled randomly. Refer to the following table (Table A) for lot sampling frequency.

Table A

Numbers of Rolls in the Lot	Number of Samples Selected
1 to 2	1
3 to 8	2
9 to 27	3
28 to 64	4
65 to 125	5
126 to 216	6
217 to 343	7
344 to 512	8
513 to 729	9
730 to 1000	10
1000 or more	11

2. Sample Size: When cutting a sample from a geotextile roll, do not sample the first 3 feet or the last 3 feet of the roll. Obtain a sample extending the width of the roll and approximately 6 feet in length.

B. Sewn Geotextiles

- Samples shall be taken of geotextiles which have been joined by a sewn-seam. Tests will be completed to verify that the requirements stated in Section 858 of *NDDOT Standard Specifications* are met.

- Sample size shall be a minimum 6 feet in length and 3 feet on each side of the sewn-seam.

- Sampling frequency: Take a minimum of one sample per project. Further sampling shall be at the discretion of the Project Engineer.

C. Precut Geotextiles

- Individual rolls may be cut to pre-selected widths prior to delivery to the project. Each of these cut portions must be labeled in a manner that allows identification of its original position within the previous full-width roll.

The contractor shall provide lists identifying the original full-width rolls and the portions cut from those rolls.

- The contractor is responsible for assuring all portions of the original rolls are readily accessible and identifiable for sampling. Sampling is conducted by taking the required sample length of each portion as if it were the original roll. The composition of these cut portions are considered one sample.

- The total number of original rolls shall be used to determine how many samples are needed and is determined from Table A.

D. Sample Identification

Field samples submitted to Materials and Research for testing shall include the following:

1. A valid Certificate of Compliance conforming to Section 106.01 of *NDDOT Standard Specifications*.

2. Samples shall have the following information physically attached to each sample.

    a) Project number
    b) Sampled by
    c) Date sampled
    d) Manufacturer’s name
    e) Product name or style
    f) Assign a unique number to identify the sample (whether provided or created).

SECTION 714

CULVERTS, STORM DRAINS, EDGE DRAINS, AND UNDERDRAINS

714 DESCRIPTION

This work consists of constructing culverts, storm drains, edge drains, and underdrains and shall include excavation and backfilling.

714.1 ACCEPTANCE SAMPLES AND TESTS

- **Metallic (Zinc or Aluminum) Coated Corrugated Steel Culverts, Corrugated Aluminum Alloy Culverts, and Smooth-Wall Steel Pipe Culverts:** Accept all of these materials by certification. The certification must show the project number, contractor, kind of material, size, gauge, quantity of material, and must state that the listed materials conform to the requirements outlined in the applicable specifications. Do not install pipe that is not covered by an approved certification. After the material has been delivered to the project, the Engineer will examine it for the following markings and record the information in his diary or the Pipe Book:

    1. Location of the installation - Sta., etc.
    2. Name of sheet manufacturer.
    3. Brand name and type of base material.
    4. Galvanized sheet thickness.
    5. Weight of coating.
    6. Coating lot numbers.
    7. AASHTO or ASTM specification number.
    8. Diameter and lengths.

    Also examine each item for damage in transit and general workmanship. Document the reason for rejection. The following defects are specified as constituting poor workmanship and the presence of any or all of them in any individual culvert pipe constitute rejection:

    1. Uneven laps.
    2. Elliptical shaping - unless ordered in this shape.
    3. Variation from straight centerline.
    4. Ragged or diagonal sheared edges.
    5. Loose, unevenly lined or spaced rivets or spot welds.
    6. Poorly formed rivet heads or loose seams.
    7. Unfinished ends.
    8. Illegible brands.
    9. Lack of rigidity.
    10. Bruised, sealed, or broken spelter coating.
    11. Dents, bends, or holes in the metal itself.

- **Concrete Pipe:** Refer to the section “Quality Assurance Program for Prestressed and Precast Concrete Products” in this manual.

- **Plastic, PVC, and Polyethylene Pipe:** Pipes manufactured from these materials are accepted by certification.

- **Underdrain Granular Fill Material:**

  Field Laboratory Testing: The Engineer obtains one sample for every 15,000 lineal feet placed for sieve analysis. Obtain the sample according to AASHTO T 2, “Sampling of Aggregate,” split the sample according to AASHTO T 248, “Reducing Samples of Aggregate to Testing Size,” and run the sieve analysis according to AASHTO T 11, “Materials Finer than No. 200 Sieve in Mineral Aggregate by Washing,” and AASHTO T 27, “Sieve Analysis of Fine and Coarse Aggregates.” Obtain a minimum of two samples per project.

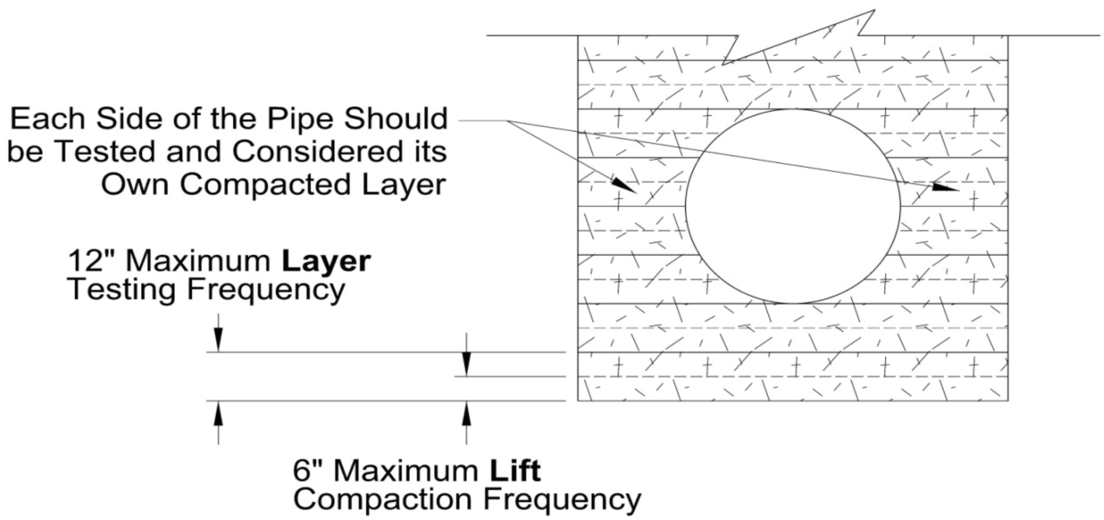
- **Grates, Frames, and Boxes:** These items are accepted by certification.

714.2 ACCEPTANCE SAMPLES AND TESTS FOR COMPACTION CONTROL FOR PIPE BACKFILL

The Engineer, or Representative, must obtain one aggregate sample for sieve analysis of select backfill or foundation fill for every source used. The samples are obtained according to AASHTO T 2, “Sampling of Aggregates,” and tested according to AASHTO T 27, “Sieve Analysis of Fine and Coarse Aggregates.” Compute the sieve analysis results on SFN 9987, “Aggregate Sample Worksheet.”

The Engineer, or Representative, must conduct a minimum of one moisture and density test for each layer of compacted aggregate. A layer of compacted aggregate is defined by a thickness of 12 inches and a maximum length of 200 lineal feet. The width shall be defined by the trench width except each side of the pipe shall be considered as separate layers.

The sketch on page 3 of this section illustrates the testing and compaction intervals.



Conduct tests according to ASTM D 4643, "Determination of Water Content of Soil by Microwave Oven Method"; AASHTO T 255, "Total Evaporable Moisture of Aggregate by Drying"; AASHTO T 191, "Density of Soil In-Place by Sand-Cone Method"; or AASHTO D 2167, "Density and Unit Weight of Soil in Place by the Rubber-Balloon Method."

Compare the results derived from these tests to the compaction curve developed from a multi-point Proctor test derived from AASHTO T 180, "Moisture-Density Relations of Soils." Establish a new compaction curve for each type of material encountered.

714.3 INDEPENDENT ASSURANCE SAMPLES AND TESTS COMPACTION CONTROL FOR PIPE BACKFILL

The District Materials Coordinator, or Representative, must conduct a moisture and density test at a minimum rate of one test for every 1,000 lineal feet or fraction thereof. Independent assurance testing must be completed using the same tests conducted for acceptance. For quantities less than 1,000 lineal feet, no specified number of tests is required. It shall be to the District Materials Coordinators discretion to make this determination.

A minimum of one comparison Proctor test shall be conducted according to AASHTO T 180, "Moisture-Density Relations of Soils," for every source used. For a quantity less than 1,000 lineal feet, no specified number of tests is required.

714.4 INDEPENDENT ASSURANCE (IA) SAMPLES AND TESTS FOR UNDERDRAIN

Granular Fill Material:

District Laboratory Testing: The District Materials Coordinator obtains one sample from each project for sieve analysis. Obtain the sample according to AASHTO T 2, “Sampling of Aggregate,” split the sample according to AASHTO T 248, “Reducing Samples of Aggregate to Testing Size,” and run the sieve analysis according to AASHTO T 11, “Materials Finer than No. 200 Sieve in Mineral Aggregate by Washing,” and AASHTO T 27, “Sieve Analysis of Fine and Coarse Aggregate.”

MATERIALS AND RESEARCH MEMORANDUM 1-2010

TO: District Materials Coordinators

FROM: Ron Horner
Materials & Research Engineer

DATE: May 20, 2010

SUBJECT: Use of Nuclear Gauges on Soils or Aggregates

The use of nuclear gauges by consulting firms will be allowed under the following conditions:

- The use of the gauges shall be limited to soil and aggregate density testing only. Testing must be conducted according to AASHTO T 310 "In-Place Density and Moisture Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)."
- The firm providing the testing shall provide calibration data for nuclear gauges. Nuclear gauges must be calibrated and verified according to Annex A1, A2, and A3 of AASHTO T 310.
- Nuclear gauges contain radioactive materials. Users must follow all applicable safety regulations and protocol required by North Dakota State Health Department.

The in-place density data acquired from each gauge must be compared to conventional methods of determining dry density. The conventional density tests are rubber balloon and sand cone. Oven dry, Speedy, and microwave are used for obtaining moisture content. A series of five (5) side by side comparisons shall be conducted at the beginning of each project. The average of the moisture content tests shall be compared to the nuclear gauge results. If the average differentiates by less than 1.0%, the nuclear gauge may be used without correction. However, if the gauge results differ by more than 1.0%, a correction shall be applied. If the in-place wet density results differ by more than 1.0 lbs/cu.ft, a correction shall be applied as well.

This correlation shall be verified with a single test for every 50 nuclear gauge tests. If the verification differentiates by over 0.5% or 0.5 lbs/cu.ft, a new correction factor shall be established as previously described.

Independent assurance shall be conducted using the conventional in-place density methods.

If you have any questions, please contact Scott Wutzke at 701-328-6902.

Chapter 4

Worksheets and One –Point Graphs

Complete SFN 10063 and graph the points.
Complete SFN 2454
Complete SFN 59725

MOISTURE-DENSITY RELATIONSHIP TESTS

North Dakota Department of Transportation, Materials & Research Division

SFN 10063 (Rev. 01-2009)

Project Number	PCN	Station	Depth Below Grade
Soil Testing Class Worksheet	12345	240+50	1 ft
Offset From Centerline: 6' NB		Type of Soil: Sandy	
AASHTO Designation: T 180	Date: 7/2/2013	Test Number: 4	

Density

Determination No.			1	2	3	4	5
A.	Volume of Mold	cu. ft.	0.0333	0.0333	0.0333	0.0333	0.0333
B.	Weight of Mold + compacted soil	lbs.	8.34	8.55	8.66	8.62	8.59
C.	Weight of Mold	lbs.	4.10	4.10	4.10	4.10	4.10
D.	Weight of Compacted Soil = B - C	lbs.	4.24	4.45			
E.	Wet density = D/A	lbs./cu. ft.	127.3	133.6			
F.	Dry density = $\frac{E \times 100}{100 + L}$	lbs./cu. ft.	116.0	119.7			

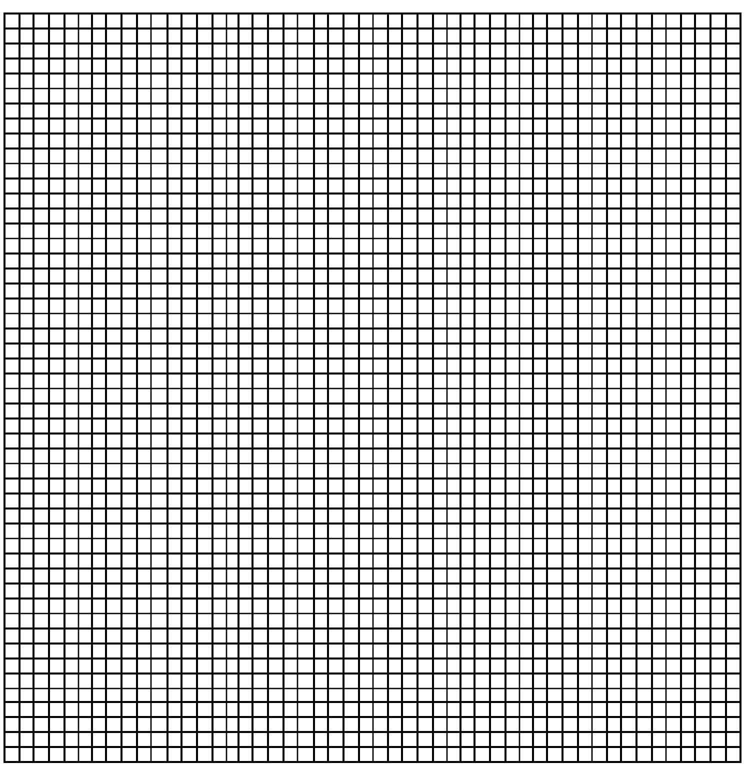
AASHTO T99 or T180 Tested by JM

Moisture Content

Container No.			10	11	12	13	14
G.	Wet Weight + Container	gms.	147.3	157.4	150.8	145.6	144.5
H.	Dry Weight + Container	gms.	137.6	145.0	137.3	131.0	129.5
I.	Moisture Loss = G - H	gms.	9.7	12.4			
J.	Weight of Container	gms.	37.8	37.7	37.8	37.6	37.1
K.	Dry Weight of Soil = H - J	gms.	99.8	107.3			
L.	% Moisture (I/K) x 100						

ASTM D4643 AASHTO T217, or T-265 Tested by JM

Density - lbs./cu. ft.



% Moisture

Max. Dry Density	lbs./cu. ft.
Optimum Moisture	%

Remarks:

DENSITY TEST WORKSHEET - VOLUME MEASURE

North Dakota Department of Transportation, Material & Research Division
SFN 2454 (Rev. 02-2009)

Project Number	PCN	Date	Tested By
Soils Field Testing Worksheet		22-Feb-12	

Section		Item	Unit					
TEST IDENTIFICATION		Test No.		1	2	3		
		Time		7:30 AM	12:15 PM	4:30 PM		
		Station						
		Offset from Centerline						
		Lane						
		Depth below finished grade	ft.					
IN-PLACE TEST VOLUME MEASURE	a	Final volume reading	cu.ft.	0.03350	0.04600	0.03525		
	b	Initial volume reading	cu.ft.	0.00525	0.01850	0.00725		
	c	Volume of hole = a - b	cu.ft.	0.02825				
	d	Wet weight of soil	lbs.	3.58	3.58	3.73		
	e	Wet density = d/c	lbs./cu.ft.	126.7	130.2	133.2		
	f	Moisture	%	11.9				
	g	Dry Density = (e X 100) /(100+f)	lbs./cu.ft.	113.2	110.8	115.7		
MOISTURE-DENSITY RELATIONSHIP TEST		AASHTO procedure		180	180	180		
		Test No. (Proctor test)		1	2	3		
		Station						
		Offset from centerline						
		Depth below finished grade						
	h	Maximum dry density	lbs./cu.ft.	124	124	124		
	i	Optimum moisture	%	10.2	10.2	10.2		
REQUIRED MOIS.-DENS.	k	Required % maximum dry density		90	90	90		
	l	% Maximum dry density = (g/h) X 100		91.3	89.3	93.3		
	m	Required moisture	%	10.2-15.2	10.2-15.2	10.2-15.2		
	n	Moisture = f	%	11.9				
MOISTURE DETERMINATION		Container ID		2	3	1		
	p	Wet weight + container	gms.	548.65	623.85	624.9		
	q	Dry weight + container	gms.	512.77	562.15	570.55		
	r	Moisture loss = (p - q)	gms.	35.88				
	s	Tare weight of container	gms.	210.54	210.5	210.5		
	t	Dry weight of soil = (q - s)	gms.	302.23				
	f	Moisture = (r/t) X 100	%	11.9				

Remarks:

SAND CONE CORRECTION FACTOR

North Dakota Department of Transportation, Materials and Research Division

SFN59724 (03-2011)

Project Number	PCN	Date	Tested By

Trial	1	2	3
A Wt. of jar, cone, and sand (before) lbs.	14.984	14.992	14.980
B Wt. of jar, cone, and sand (after) lbs.	11.414	11.424	11.408

Trial	C^1	C^2	C^3
C Wt. of sand in cone and ring (A - B)	3.570	3.568	3.572

Cone Correction Factor (Cc) = $\frac{(C^1 + C^2 + C^3)}{3}$

Cc = 3.570 lbs

Note: all weights shall be recorded to the nearest .001 lbs. Three weights should not vary by more than 0.01 lbs.

SAND BULK DENSITY DETERMINATION

Trial	1	2	3
D Wt. of jar, cone, and sand (before) lbs.	14.984	14.992	14.980
E Wt. of jar, cone, and sand (after) lbs.	4.270	4.336	4.262
F Wt. of sand in cone, ring, and density apparatus (D - E)	10.714	10.656	10.718
G Wt. of sand in density apparatus (F - Cc)	7.144	7.086	7.148

Trial	D^1	D^2	D^3
Bulk Density = (G ÷ Density apparatus volume)	95.2	94.5	95.3

Bulk Density Sand (Db) = $\frac{(D^1 + D^2 + D^3)}{3}$

Db = 95.0 lbs./cu.ft

DENSITY TEST WORKSHEET - SAND CONE METHOD

North Dakota Department of Transportation, Materials and Research Division

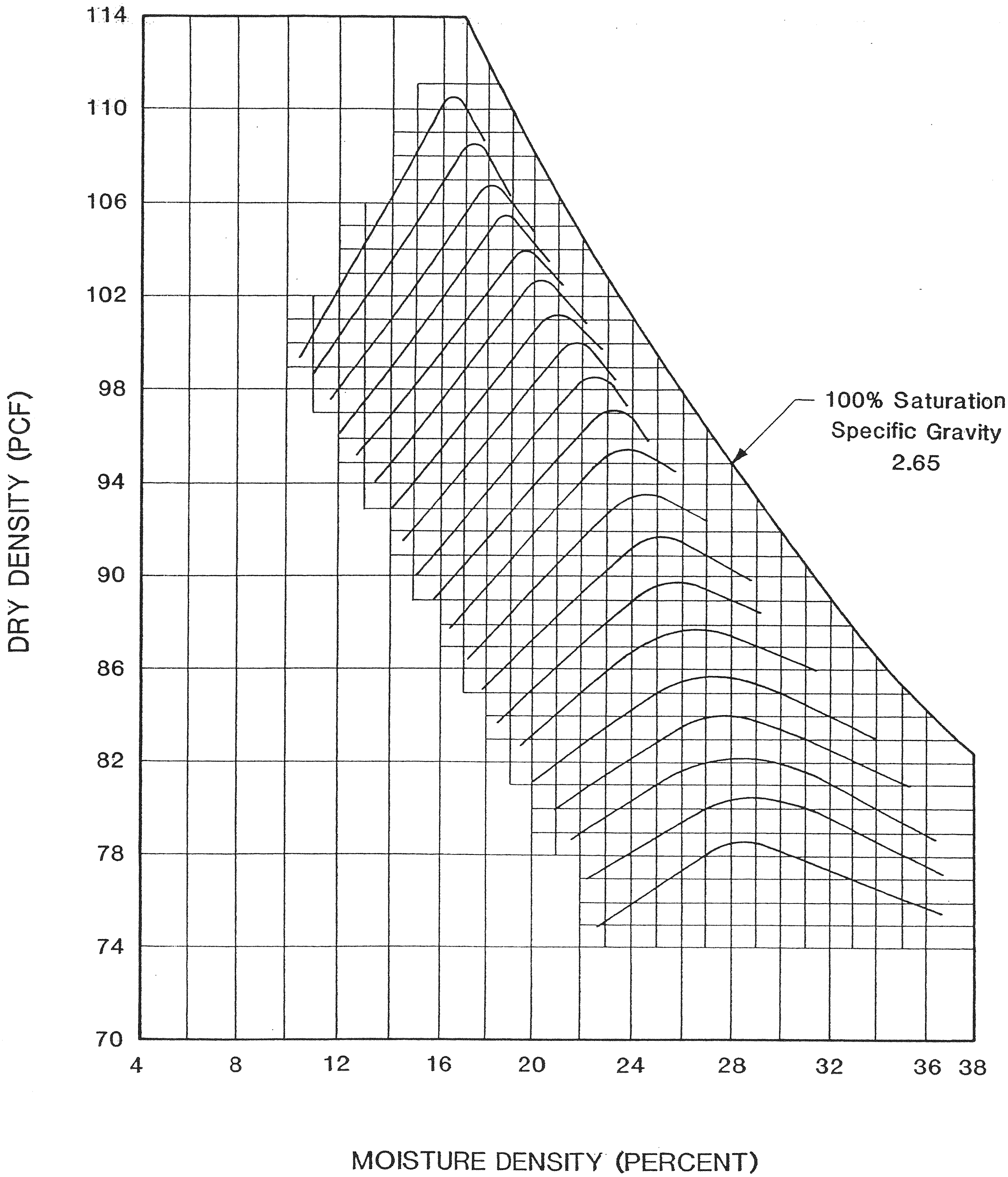
SFN 59725 (03-2012)

Project Number	PCN	Date	Tested By
Pipe Installation Spec 714.03	18002	5/21/2012	

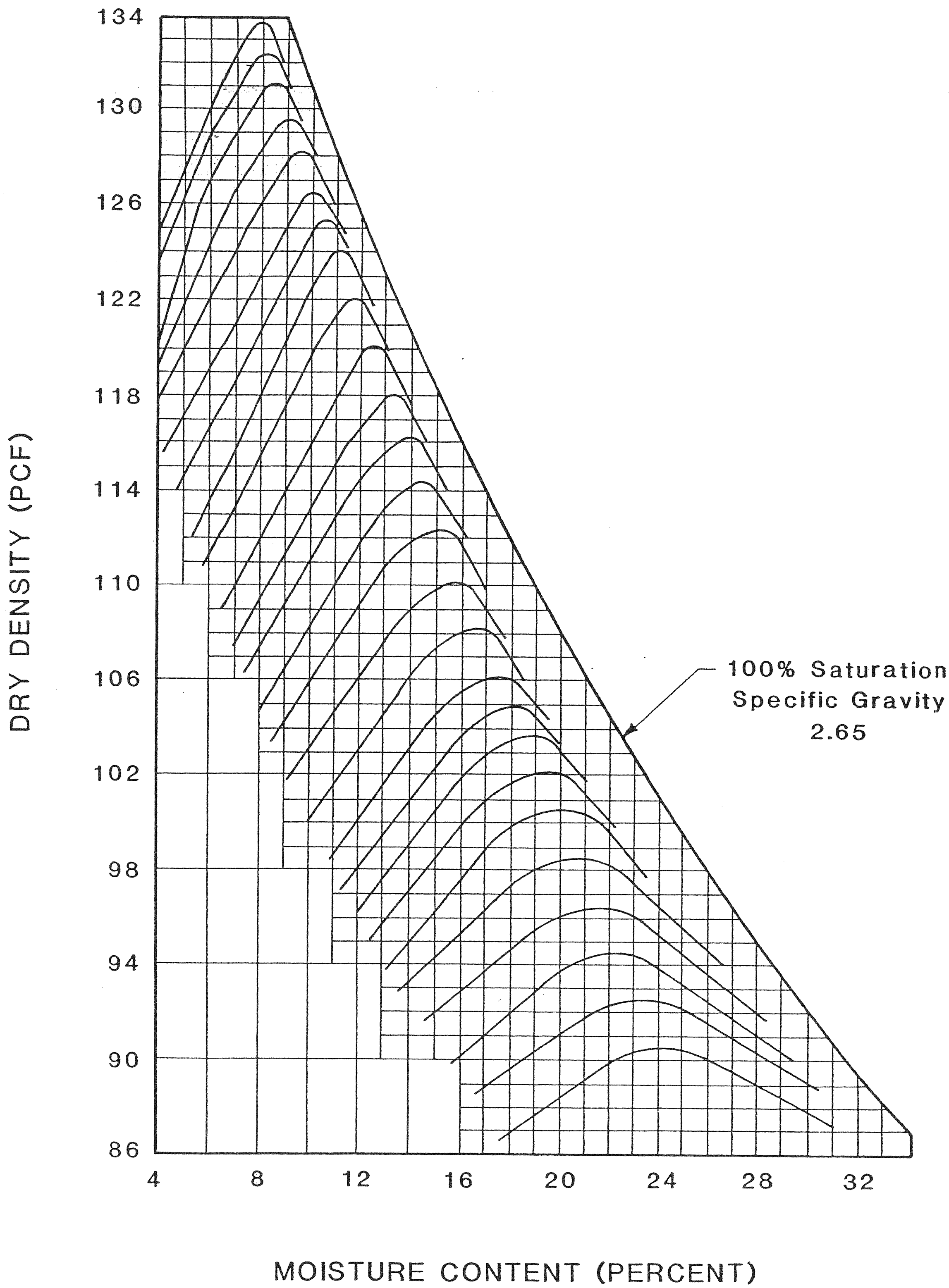
TEST IDENTIFICATION		**Test No.**	14	15	16	17	18
		Time	1900	1925	1945	2000	2015
		Station	240+50	240+50	240+50	240+50	240+50
		Offset from centerline	12	10	8	6	4
		Lane	NB	NB	NB	NB	NB
		Depth below finished grade ft.	5.5	5.0	4.5	4.0	3.5
IN- PLACE DRY DENSITY DETERMINATION	a	Unit Weight of Sand (pcf) SFN 59724	95.0	95.0	95.0	95.0	95.0
	b	Wt. material removed from test hole (lbs)	6.44	6.43	6.4	6.3	6.16
	c	Initial sand weight (lbs)	15.52	15.65	15.1	15.33	15.5
	d	Final sand weight (lbs)	6.82	6.91	6.70	6.60	6.60
	e	Wt. sand in funnel and hole = c - d	8.70	8.74			8.65
	f	Cone calibration factor (lbs) SFN 59724	3.884	3.884	3.884	3.884	3.884
	g	Wt. sand in hole = e - f (lbs)	4.82	4.86			4.77
	h	Volume of test hole = g/a (cu.ft.)	0.0507	0.0511			0.0502
	i	Wet Density = b/h (lbs/cu.ft.)	127.03	125.79			122.79
	j	Dry Density = i/(100+p) x 100 (lbs/cu.ft.)	116.0	114.5			111.1
		Moisture Determination					
	k	Wet weight + container	261.3	246.1	321.9	330.3	277.3
	l	Dry weight + container	248.8	234.5	305.5	312.7	262.1
	m	Moisture loss = k - l	12.5	11.6			15.2
	n	Tare weight of container	117.4	117.4	117.4	117.4	117.4
	o	Dry weight of soil = l - n	131.4	117.1			144.7
	p	Moisture Percentage = (m/o) x 100 (%)	9.5	9.9			10.5

Moisture-Density Relationship Test		AASHTO Procedure	T180				
		Test No. (Proctor Test)	1				
		Station					
		Offset from centerline					
		Depth below finished grade					
	q	Maximum Dry Density	126	126	126	126	126
		Optimum Moisture	10.5	10.5	10.5	10.5	10.5

REQUIRED MOIS-DENS.		Required % Maximum Dry Density	90%	90%	90%	90%	90%
		% Maximum Dry Density = (j/q) X 100	92.4%	91.2%	92.3%	91.1%	88.5%
		Required Moisture	8.5-13.5	8.5-13.5	8.5-13.5	8.5-13.5	8.5-13.5
		Moisture = p	9.5	9.9	8.7	9.0	10.5



Typical Moisture-Density Relationship Curves for T-99 Compaction



Typical Moisture-Density Relationship Curves for T-180 Compaction

QR Codes for common web links

NDDOT Field Sampling and Testing Manual

NDDOT Standard Specifications

NDDOT Forms

NDDOT Technician Registry

NDDOT Materials and Research Web Page

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