NORTH CAROLINA
DEPARTMENT OF TRANSPORTATION

Conventional Density Operator's Manual

Materials and Tests Unit
Field Operations Section

Conventional Density Testing Manual

August 16, 2002
Revised November 4, 2019

North Carolina Department of Transportation
Materials and Tests Unit – Field Operations Section

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Section 1 – Introduction to Density Concepts

Definition of Density

Soil consists of three components: solid particles, air, and water. In engineering applications involving soils, air and water are collectively referred to as voids. In a given amount of soil, the solid particles and the voids occupy a certain amount of space, or volume. Therefore, the volume of a soil mass is the sum of the volume of the solids and the volume of the voids.

The term density has varied meanings in different fields of sciences. For our specific field of study (i.e., the engineering aspect of soils), we will use weight density, which is defined as weight per unit volume (in English units, weight density can have units of pounds per cubic foot). For brevity, the term "density" will refer to weight density unless otherwise specified. Mathematically, the density of soil is obtained as follows:

$$\text{Density} = (W_s + W_a + W_w) / (V_s + V_a + V_w)$$

where

W_s = weight of solids
W_a = weight of air
W_w = weight of water
V_s = volume of solids
V_a = volume of air
V_w = volume of water

Three Phases of Soil

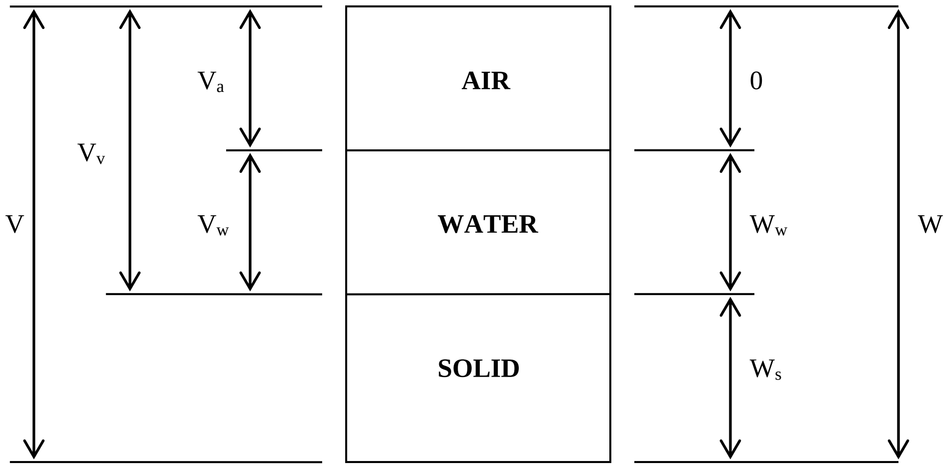


Diagram 1

The weight of air is negligible compared to the weight of water and solids, and for all practical purposes, can be ignored. The volume it occupies, however, is significant. Therefore, for soils engineering purposes, the following mathematical definition of density is acceptable and generally used:

$$\text{Density} = (W_s + W_w) / (V_s + V_a + V_w)$$

It can be noted that water can be present or absent (a completely dry soil). For engineering purposes, a distinction is made between the two values of density with and without water present. Wet density is the density of the soil mass, including the moisture (or water) contained in the void spaces. Dry density is the density of the soil mass without the moisture.

When water is present, the quantity of water relative to the quantity of solids is defined mathematically as its moisture content. Moisture content can be expressed as follows:

$$\text{Moisture content} = W_w / W_s$$

The dry density of a soil mass is what affects its important engineering properties, such as strength, permeability, and compressibility. From an engineering standpoint, we would like to increase the strength, and decrease permeability and compressibility of a soil mass, and these are achieved by increasing dry density.

Definition of Compaction and Optimum Moisture

Compaction is the process by which a soil mass is subjected to compressive forces (in the form of static weights, vibration, blows from heavy objects, or a combination of some or all of these) for the purpose of decreasing the volume of voids, thereby increasing the dry density. Decreasing the volume of voids would mean decreasing the volume occupied by air and water. Water is incompressible, meaning the volume occupied by a given quantity of water cannot be reduced further. However, air is compressible, and in applying compactive effort to a soil mass, it is air whose volume is reduced.

It is an established fact that the amount of water in the soil mass affects how well the air in the same soil mass is squeezed out or compressed. Water acts as a lubricant that allows soil particles to be rearranged during the compaction process. Too little water means too little “lubrication” of the soil particles. However, too much water is also a hindrance to squeezing out or compressing the air, because the water will tend to absorb the energy from the compactive forces. Between having too much and having too little water, there is a quantity of water that will allow the compactive forces to result in the maximum possible dry density. This quantity of water is expressed in terms of the moisture content and is referred to as the soil’s optimum moisture content.

For a particular soil, the optimum moisture is defined as the moisture content at which a soil can be compacted to its maximum dry density with a given compactive effort.

Standardized Tests for Determining Maximum Dry Density

In the definition of optimum moisture, it should be noted that the maximum dry density obtained is for a specific compactive effort. Standardized tests for determining maximum dry density involves varying the moisture content of a soil mass, subjecting the soil mass to a specific compactive effort (which remains the same for the test), and keeping track of the resulting values of dry density. The result is a correlation between moisture content and dry density, which can be plotted. The maximum dry density can then be obtained.

Examples of standardized tests that will be used for our purposes are **AASHTO T 99** and **AASHTO T 180**. These tests (with some NCDOT modifications) are used to establish the maximum dry density of a given soil mass.

Section 2 – Density Specifications

Inspection of Earthwork, Subgrade and Bases on a Construction Project

When inspecting a construction project, a technician must understand the plans, specifications, and any project special provisions. The *NCDOT Construction Manual* can also provide guidance when inspecting soils related items on a project, a technician should become familiar with Divisions listed in the following table:

Classification	Reference Division
Earthwork	Division 2
Subgrade and Bases	Division 5

Table 1 Related Reference Divisions for *NCDOT Construction Manual*

The Goal of Field Density Tests

Field density tests are conducted to indicate if the material being compacted has attained a minimum acceptable value of dry density. This minimum acceptable value is expressed as a percentage of the maximum dry density as determined by a standardized test in which the material is subjected to a predetermined compaction effort. For example, if the test to determine maximum dry density is AASTHO T 99, the density requirement can be expressed as follows:

"The material shall be compacted to at least 95% of the maximum dry density as determined by AASHTO T 99 as modified by the Department."

In the above example, the quantity represented by 95% is what is referred to as percent compaction. Mathematically, percent compaction is the ratio of the in-place dry density of the compacted soil ($\gamma_{\text{in-place}}$) to the maximum dry density as determined by standardized tests (γ_{max}). That is,

$$\text{Percent compaction} = (\gamma_{\text{in-place}}) / (\gamma_{\text{max}})$$

The tests discussed in the sections to follow are aimed towards determining $\gamma_{\text{in-place}}$, γ_{max}, or the ratio itself directly.

Classification of Materials

The testing frequency and density requirements of soil depend on its classification in terms of how it is constructed. These classifications and reference section number from the *NCDOT Standard Specifications for Roads and Structures* are listed in the following table (when inspecting a project, the technician should review these sections if soil or aggregate is being utilized in the construction process):

Classification	Reference Section
Embankment	Section 235
Subgrade	Section 500
Aggregate Stabilized Subgrade	Section 510
Chemically-treated Subgrade	Section 501 (lime) Section 542 (cement)
Aggregate Base Course (ABC)	Section 520
Cement-treated Base Course (CTBC)	Section 540

Table 2 Related Reference Section for *NCDOT Standard Specifications for Roads and Structures*

In general, embankment refers to any layer placed below the subgrade. The subgrade is usually 8-inches thick and refers to the portion of the roadbed prepared as a foundation for the pavement structure (including the curb and gutter). Base Course refers to a layer of planned thickness placed immediately below the pavement or surface course.

Testing Frequency Requirements

The frequency with which a compacted material is checked for density (that is, percent compaction) depends on its classification. The Department requires the following testing frequencies:

- Embankments – one test every 5,000 yd^3 (4,000 m^3) or fraction thereof. Since problems can develop as an embankment is being constructed a technician, should not wait until several layers have been placed to perform a density test. Therefore, the Department recommends the technician should perform a density test on every other lift of an embankment as it is being constructed. NOTE: If an embankment contains rock the technician should attempt to perform a density test using the methods described in Section 3 of this manual (Test 1-A, 1, or 2). However, if an area cannot be tested successfully, a note is made on the density report (M&T Form 504) that states “Too rocky to run”. Exempt (do not perform) density tests from rock embankments (constructed with larger rock boulders or broken pavement) or “rock-lifts”, which cannot be tested by approved methods. If a rock-lift is being placed indicate by placing a note on the density report (M&T Form 504) “Rock-lift”.
- Subgrade – one test every 1,000 linear feet for roads up to 28 feet (8.5 meter) in width; for roads greater than 28 feet in width, one test every 3,000 yd^2 (2,500 m^2).
- Chemically Treated Subgrade (Lime or Cement) – Refer to page 10
- ABC and CTBC – same as subgrade except when there are separate shoulders, in which case take one test every 2,000 linear feet (600 meters).

Density Requirements

The Department has the following density requirements for the various materials:

- Embankment - compacted to at least 95% of the maximum dry density as determined by AASHTO T 99 as modified by the Department.
- Subgrade - compacted to at least 100% of the maximum dry density as determined by AASHTO T 99 as modified by the Department.
- Chemically treated subgrade (lime or cement) - compacted to at least 97% of the maximum dry density as determined by AASHTO T 99 as modified by the Department.
- Aggregate-stabilized subgrade - compacted to at least 100% of the maximum dry density as determined by AASHTO T 99 as modified by the Department.
- Aggregate Base Course (ABC) - compacted to at least 100% of the maximum dry density as determined by AASHTO T 180 as modified by the Department.
- Cement-treated Base Course (CTBC) - compacted to at least 97% of the maximum dry density as determined by AASHTO T 180 as modified by the Department.

Chemical Stabilization

When designing a road, the Engineer must consider vehicle loads supported by the pavement structure. Obviously, these loads are transferred through the pavement structure into the supporting soils. Due to the various types of soils in North Carolina, the Engineer may decide that it is economically necessary to chemically stabilize the subgrade in order to provide the required strength for supporting the roadway. Depending on the type of soil, lime or cement is generally added to stabilize a subgrade.

When adding cement or lime, moisture control is critical to ensure proper hydration. Without proper hydration the chemically stabilized section may not achieve the required design strength and possibly lead to structural failure. Materials and Tests and Geotechnical Engineering Units recommend the following procedures for monitoring chemically stabilized sections for density acceptance and proper moisture control. The procedures and equipment required for monitoring soil densities are similar to those for un-stabilized soils, with the following additions:

1. The Geotechnical Engineering Unit of the Department can provide assistance in the stabilization operation and should be consulted prior to beginning the operation.
2. A moisture-density curve must be established at the beginning of the first day of operation. The sample for performing the curve must be taken after the cement or lime has been mixed in the soil but before water is added. A new moisture-density curve is to be established when a significant change in the soil occurs or upon recommendation by the Engineer. The moisture-density curve should be made available to the Geotechnical Engineer in the field to verify if any adjustment in the moisture content is needed. Once the Contractor is ready for a

density test in the stabilized section, perform a Test 1 (long test) in the area where the sample was obtained for the moisture-density curve. As required with all conventional density testing, 1 out of every 15 tests must be a Test 1 (long test) with a moisture-density curve.

3. Test 1-A (short test) will be performed as outlined in this manual, with the following addition: a 300-gram in-place moisture content sample must be taken prior to compaction. This moisture sample should represent the moisture content of the area as the contractor began compacting the soil. After compaction, a Test 1-A will be performed at the approximate location where the moisture sample was taken. The moisture content will be documented on the density test report for the Test 1-A.
4. The frequency for density acceptance testing will be based on the number of operation(s). An operation is defined as one tanker load. One density test will be required for each operation for the first 4 operations of a day's production. Once the day's production surpasses 4 operations but is less than 8 operations, one density test per 2 operations will be required. Once the day's production surpasses 9 operations, one density test per 3 operations will be required.

    For example:

    The Contractor begins the first chemical stabilization operation at 6:30 a.m. and completes the fourth operation that same day at 1:00 p.m. Each of the first four operations must have a density acceptance test. The Contractor continues production that same day and completes operations 5 through 8 by 4:30 p.m. The chemically stabilized area completed between 1:00 and 4:30 p.m. (operations 5 – 8) would require a total of two density acceptance tests (one test per two operations). The Contractor continues production that same day and completes operations 9 through 12 by 6:30 p.m. The chemically stabilized area completed between 4:30 and 6:30 p.m. (operations 9 – 12) would require a total of one density acceptance test (one test per three operations).

Section 3 – Overview of the Four Field Tests

- Density Test 1-A

  In this test, the compaction of embankments and subgrades consisting primarily of soil in which the moisture content of the soil is not determined for each test.

  This test is also known as the "short test" because of the relatively short time required performing this test. This test uses a volumeter with a water-filled balloon to determine both the volume of the soil removed from a roadway test hole and the volume of the same soil after being compacted in a standard compaction mold. The soil is compacted in the mold at optimum moisture, and therefore will yield the maximum dry density. Recall that

  $$\text{Percent compaction} = (\gamma_{\text{in-place}}) / (\gamma_{\text{max}})$$

  In term of the unit weight in the "hole" and the unit weight in the "mold", we have

  $$\text{Percent compaction} = (\gamma_{\text{hole}}) / (\gamma_{\text{mold}})$$

  Since the soil that was taken out of the hole is the same soil compacted in the mold, we can express percent compaction in terms of volume as follows:

  $$\text{Percent compaction} = (V_{\text{mold}}) / (V_{\text{hole}})$$

  Where V_{mold} and V_{hole} are the volume occupied by the soil in the mold and hole, respectively. Because no unit weights are calculated, it is not required to determine the moisture content of the soil.

  Test 1A is intended for use on embankments and subgrades that are predominately soil, that is, with little or no rock or aggregate. When more than 1/3 of the soil (by weight) consists of aggregate larger than approximately ¼ inch in size, performance of the test may be difficult and the accuracy questionable. In this situation, it will be necessary to use Density Test 2, which is designed for soil-aggregate mixtures.

- Density Test 1

  In this test, the compaction of embankments and subgrades consisting primarily of soil in which the moisture content of the soil is determined for each test.

  This test is also known as the “long test” because of the longer amount of time (that is, compared to the “short test”) required to perform this test.
  This test uses a volumeter with a water-filled balloon to determine the volume of soil removed from a roadway test hole. Then the weight of the dry soil removed from the hole is determined by weighing the wet soil and then determining the moisture content. Using the volume of the hole and the dry unit weight, the in-place dry density ($\gamma_{\text{in-place}}$) can be calculated.

  A separate soil sample is compacted in a standard mold at the optimum moisture. The volume occupied by the wet soil in the mold is determined using the volumeter, and then the moisture content determined. The maximum dry density ($\gamma_{\max}$) can be calculated. Then, we have

  $$\text{Percent compaction} = (\gamma_{\text{in-place}}) / (\gamma_{\max})$$

  Test 1 is intended for use on embankments and subgrades that are predominately soil, that is, with little or no rock or aggregate. When more than 1/3 of the soil (by weight) consists of aggregate larger than approximately ¼ inch in size, performance of the test may be difficult and the accuracy questionable. In this situation, it will be necessary to use Density Test 2, which is designed for soil-aggregate mixtures.

- Density Test 2

  In this test, the compaction of embankments and subgrades consisting of a soil-aggregate mixture, (i.e. when more than 1/3 of the soil (by weight) consists of aggregate larger than approximately ¼ inch in size) is determined**.** Soil-aggregate mixtures may be soils naturally containing aggregate or soils stabilized by mechanically adding and mixing aggregate material.

  Test 2 is similar to Test 1 in the sense that percent compaction is calculated as follows:

  $$\text{Percent compaction} = (\gamma_{\text{in-place}}) / (\gamma_{\max})$$

  However, the in-place density of the soil-aggregate mixture is measured using a calibrated steel ring instead of a volumeter. The maximum dry density of soil-aggregate mixtures is determined by AASHTO T 99 Method C or Method D, as modified by the Department. Detailed steps for these procedures are given in Section 7. If a significant amount of aggregate larger than 2 inches is encountered, the accuracy of Test 2 may be questionable.

- Density Test 3

  Test 3 is used to determine the compaction of Aggregate Base Course (ABC), that consist of a mixture of coarse and fine aggregate, with very little soil.

  Again, as in Test 1 and Test 2, percent compaction is calculated as follows:

$$\text{Percent compaction} = (\gamma_{\text{in-place}}) / (\gamma_{\text{max}})$$

  The GeoMaterials Laboratory will provide the value of the dry AASHTO T 180 density (maximum dry density or Unit Weight). The Unit Weight of the ABC can be obtained on the Materials and Tests website or by calling the GeoMaterials Laboratory (919) 329-4150. Only the in-place density of the material will be determined in the field, and this is accomplished using a calibrated steel ring. Details of the procedure for determining the in-place density is given in Section 8 of this manual.

Section 4 – Determination of Optimum Moisture

Standard Moisture-Density Curve – AASHTO T 99

It was previously mentioned that, for a fixed amount of energy applied during the compaction process, there is a correlation between the maximum density to which a soil can be compacted and the moisture content of the soil during compaction (compaction water content).

A standard test has been devised which makes it possible to determine in the laboratory the moisture content that will give maximum density with a given amount of energy. In this test the soil is compacted at a number of different moisture contents (usually in increments of two percent), ranging from dry to wet. The fixed amount of energy according to AASHTO T 99 is applied (25 blows, 12-inch vertical drop using a 5.5-lb hammer), and the dry density and compaction moisture content are determined in each case. The dry densities are plotted against the corresponding compaction moisture contents and a smooth curve is drawn throughout the data points. A minimum of four data points is required for this test. In general, as the moisture content is increased from the dry side, this curve rises to a maximum density and then declines. The highest point on the curve indicates the "Maximum Dry Density" for the soil tested. It is sometimes referred to as the "Standard AASHTO Density". The moisture content corresponding to this maximum density is called the "Optimum Moisture Content".

Equipment Needed

The following equipment is necessary for performing AASHTO T 99.

3-inch auger
Large Spoon
50-pound weight
Graduated cylinder (with graduations in milliliters)
Soil Pan
Pie plate (9" x 1 ½")
Scales (with a 2,000-gram weight)
Frying pan
Steel straight edge
Compaction mold (1/30 ft^3.)
Sample extractor
Compaction rammer (5 ½ pounds, 12-inch drop)
Gas burner (with lighter)
Square shovel

Step-by-step Procedure for Performing AASHTO T 99

1. Level the electronic scale.
2. Verify that the 2,000-gram weight reads as 2,000 grams on the scale, with a +/- 1-gram tolerance.
3. Weigh the empty mold and record.
4. Obtain enough soil to fill the soil pan to 2/3 full (when performing this test in conjunction with Test 1, obtain soil from the test hole).
5. Break up and pulverize the soil.
6. Dry or add water to the soil as necessary and mix for uniform water content. Repeat step 5-6 until water content is judged to be at an appropriate starting point (about 5% dry of optimum).
7. Weigh and set-aside 4,000 grams from the soil in the soil pan. This is the soil that will be used for the test. Discard the rest of the soil in the soil pan.

Steps 8 to 21 will be performed 4 times. Each obtained value of dry density and moisture content will be plotted, resulting in the material's moisture-density curve.

8. Place a first layer in the mold.
9. Apply compactive effort (25 blows, 12-inch drop).
10. Place a second layer in the mold and apply compactive effort.
11. Place a third layer in the mold and apply compactive effort.
12. Scribe around the top (third) layer and then remove the mold collar.
13. The top of the third layer must be ¼ to ½ inches above the top of the mold.
14. Scrape off the excess soil with the straight edge until the surface is flush with the top of the mold. Fill in exposed voids with fine material.
15. Weigh the mold with the soil and record the weight.
16. Extract the soil pill with the sample extractor.
17. Using the straight edge, split the soil pill down the middle lengthwise.
18. Obtain 300 grams of soil from the scrapings. This is the sample for determining the soil's moisture content.
19. Dry the soil. When using a burner, be sure not to overheat the soil.
20. Weigh the dry soil and record.
21. Add 2% water per weight of the soil remaining in the soil pan.
    NOTE: If the test is begun with exactly 4,000 grams of soil and for each "point" a 300-gram moisture sample is removed, the amount of water to be added are as follows: 1st point – none; 2nd point – 80 ml; 3rd point – 75 ml; 4th point – 70 ml. These amounts account for 5 to 10 ml of water lost due to evaporation.
22. Record all data on M&T Form 506 and plot the moisture-density curve.

Using the "Squeeze" Method

The "Squeeze" method is a "short cut" approach for determining the optimum moisture of a soil mass and can be performed with reasonable accuracy by an experienced technician. This method is not applicable to all types of soils but works well when the soil has a significant fraction of cohesive particles (i.e., clay or some silts).

Prior to performing this test on a soil mass, all lumps or clods should be pulverized or broken down as recommended by AASHTO Method T 99. The soil mass should be thoroughly mixed until the moisture is uniform. A handful of loose soil is taken in one hand and firmly squeezed into an elongated mass. The squeezing should be fairly firm and yet not with all one's strength (i.e., not a bone crushing grip).
The soil mass is close to or at optimum moisture if the following are true:

1) The soil mass exhibits cohesion - Release the soil from the hand after squeezing. If the soil mass does not break apart, it is an indication that the soil is at or above "optimum". If the soil mass breaks apart upon releasing the pressure applied, then a small amount of water should be added and thoroughly mixed with the soil until the elongated soil mass will remains intact after release.

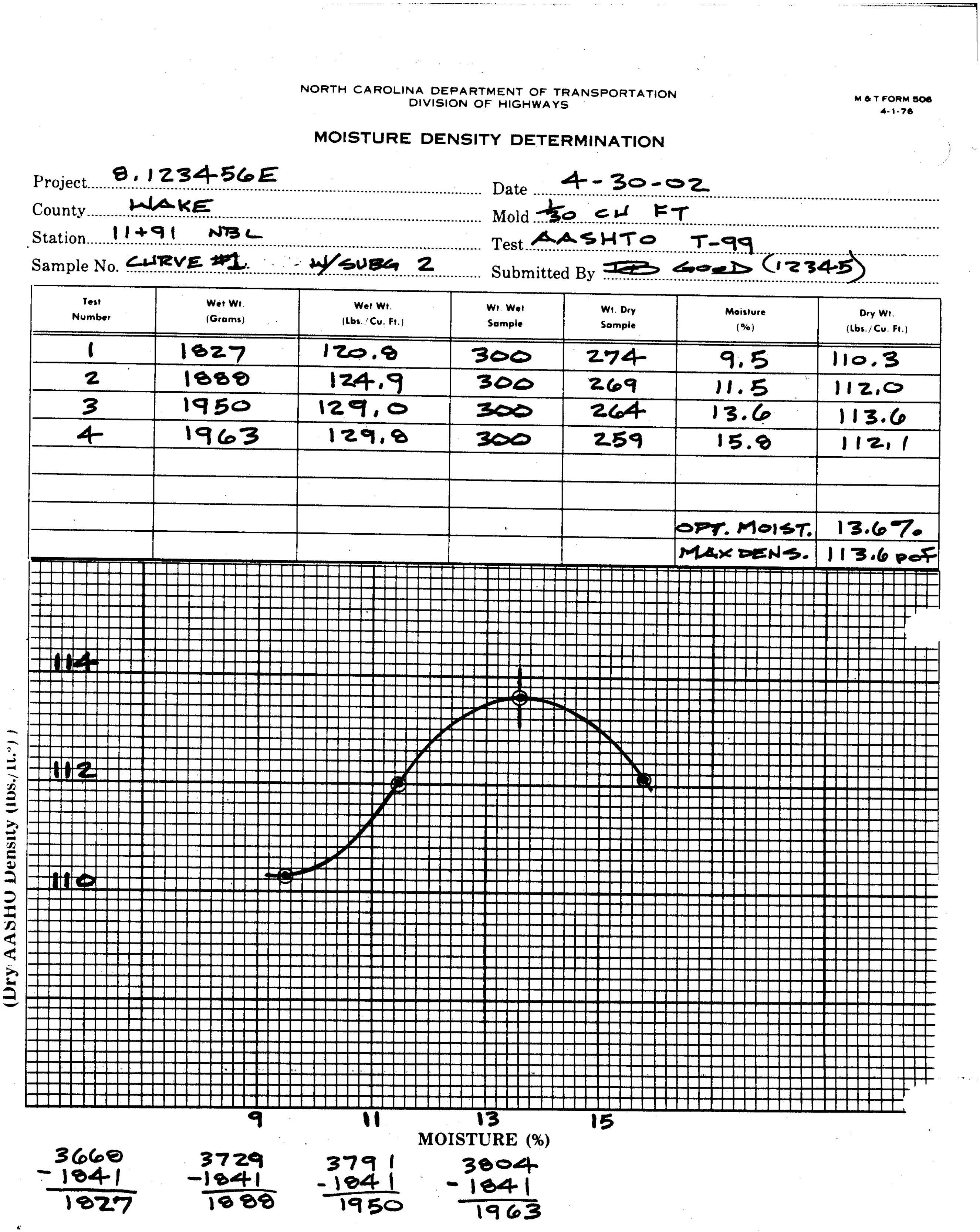
2) The soil mass exhibits cohesion under stress - The elongated mass of soil is tossed 3 or 4 inches into the air using the open palm of one hand. This is repeated two or three times. If the soil mass does not break apart, it is an indication that the soil is at or above "optimum". If the soil mass breaks apart as it is tossed, then a small amount of water should be added and thoroughly mixed with the soil until the elongated soil mass will remain during tossing.

3) There is "coolness of the palm" - When the soil mass is wet or moist enough to stick together, note a sensation on your palm. If the soil is at optimum, you should be able to feel a coolness on your palm as the film of moisture evaporates.

Note that the above observations are true even if the moisture content of the soil mass is above optimum. If it is above optimum, the following additional observation can be made: A very noticeable film of moisture will appear on the hand, and part of the soil grains (excluding clay and silt particles) will adhere to the hand. In this case, the soil is above optimum moisture, and it must be dried back slowly until "optimum" is reached. This will be done by air drying or very low heat (140°F maximum).

Using the "Penny Print" Method

After determining the optimum moisture as outlined above, it can be checked by observing the print and depth of the rammer in the soil while compacting it in the AASHTO mold. When the first layer of soil is placed in the mold and after the 24th blow of the rammer has been struck, place the 25th blow in the center of the mold. Be sure before making the 25th blow that the face of the rammer is free from clinging soil particles and held in as nearly vertical position as possible before being dropped. Observe the print of the rammer in the compacted layer. If the soil is at optimum moisture, a full print of the rammer will be observed and the depth of penetration should be about 1/16 inch in depth (approximately the thickness of a penny). If a full print of the rammer cannot be observed, the soil is too dry. If the rammer penetration exceeds 1/16 inch, the soil is too moist.



NORTH CAROLINA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS

M & T FORM 506
4-1-76

MOISTURE DENSITY DETERMINATION

Project 8.123456E
County WAKE
Station 11+91 NBL
Sample No. CURVE #1 W/SUBG 2

Date 4-30-02
Mold 1/30 CU FT
Test AASHTO T-99
Submitted By JB GOOD (12345)

Test Number	Wet Wt. (Grams)	Wet Wt. (Lbs./Cu. Ft.)	Wt. Wet Sample	Wt. Dry Sample	Moisture (%)	Dry Wt. (Lbs./Cu. Ft.)
1	1827	120.8	300	274	9.5	110.3
2	1888	124.9	300	269	11.5	112.0
3	1950	129.0	300	264	13.6	113.6
4	1963	129.8	300	259	15.8	112.1
					OPT. MOIST.	13.6%
					MAX DENS.	113.6 PCF

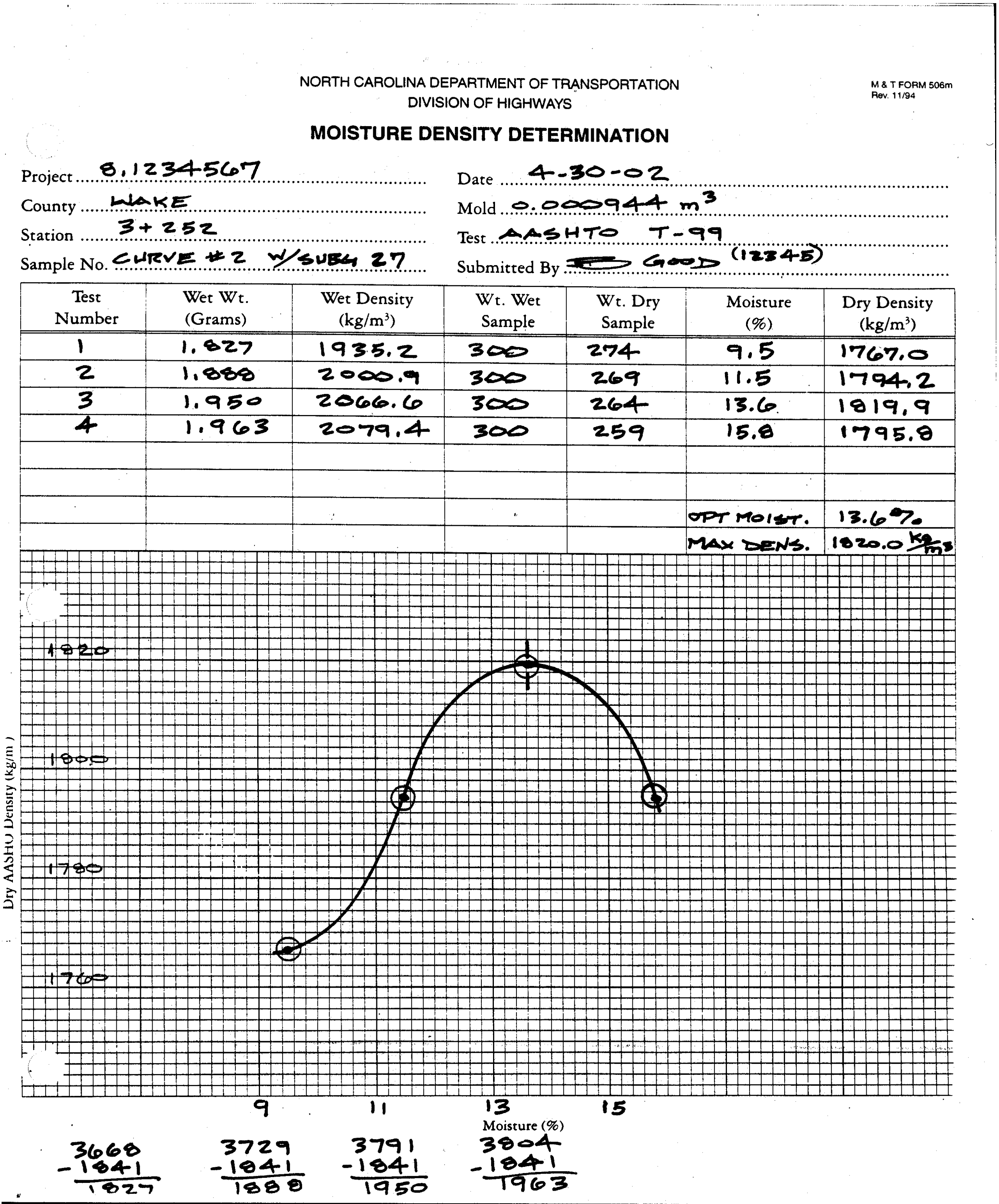
3668
-1841
1827

3729
-1841
1888

3791
-1841
1950

3804
-1841
1963

Figure 1 Example of Moisture-Density Curve AASHTO T-99 (English units)



NORTH CAROLINA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS

M & T FORM 506m
Rev. 11/94

MOISTURE DENSITY DETERMINATION

Project 8,1234567
County WAKE
Station 3+252
Sample No. CURVE #2 W/SUBG 27
Date 4-30-02
Mold 0.000944 m³
Test AASHTO T-99
Submitted By [redacted] GOOD (12345)

Test Number	Wet Wt. (Grams)	Wet Density (kg/m³)	Wt. Wet Sample	Wt. Dry Sample	Moisture (%)	Dry Density (kg/m³)
1	1,827	1935.2	300	274	9.5	1767.0
2	1,888	2000.9	300	269	11.5	1794.2
3	1,950	2066.6	300	264	13.6	1819.9
4	1,963	2079.4	300	259	15.8	1795.8
					OPT MOIST.	13.6%
					MAX DENS.	1820.0 kg/m³

3668
-1841
1827

3729
-1841
1888

3791
-1841
1950

3804
-1841
1963

Figure 2 Example of Moisture-Density Curve AASHTO T-99 (metric units)

Section 5 – Density Test 1-A

Also referred to as the "short test", Test 1-A does not require weighing and drying steps, thereby reducing the possibility of error.

Equipment Needed

The following equipment is necessary for performing of Density Test 1-A.

*Volumeter
3-inch auger
Large spoon
50-pound weight
50-pound saddle weight for volumeter
Soil pan
Steel Straight edge
Small Spatula
Compaction mold (1/30 cubic foot)
Sample extractor
Compaction rammer (5 ½ pounds, 12-inch drop)
Square tip shovel
Water Container (i.e. small squirt bottle or graduated cylinder)
Water

*Base of Volumeter must fit into collar of 1/30 cubic foot mold. If it does not, the bottom needs to be turned down 1/32 of an inch.

Determining the In-place Volume

All loose soil is removed from the surface of the layer and an area of about 15-inches square is brought to a smooth flat and approximately level surface by scraping with the steel straight edge, shovel or other suitable instrument.

The volumeter is placed on the smoothed surface of the soil and its position carefully marked by tracing the outside edge of its base. The 50-pound saddle weight is placed on top of the volumeter. Pressure of 4-psi is applied to the volumeter, a reading is taken and recorded (this is the actual reading on the volumeter scale before the soil is removed from the hole). The volumeter is removed and a hole about four inches in diameter and six inches deep is made in the middle of the circle inscribing the volumeter base. The soil taken from the hole is placed in a pan for later placement in the compaction mold. It is, of course, important that all of the soil removed from the hole be placed in the pan. The volumeter is then placed over the hole at the exact location where the initial reading was taken. The saddle, 50-pound weight and 4-psi air pressure are applied in the same manner as for the initial reading to determine a second reading. The difference between the two readings is the volume of the hole in cubic feet. This is also the "in-place volume" of the sample. In order to obtain the desired accuracy, the volume of the test hole must be between 0.03200 and 0.03500 cubic feet.

Determining the "Compacted Volume"

An initial volume reading of the empty compaction mold with collar attached is determined by averaging three readings of the volumeter using the procedures mentioned earlier. This initial volume reading will remain the same as long as the same volumeter and mold are used and the water level in the volumeter remains the same. If any of these are changed, a new initial volume reading must be taken.

The soil taken earlier from the roadway test hole is needed to obtain the "compacted volume" of the soil in the compaction mold. This soil shall be broken up to the extent that the largest clod (not aggregate) should not exceed ¼-inch in size as determined by visual inspection. Any aggregate present in the sample shall be mixed uniformly with the soil and not thrown out. The optimum moisture of the soil is then estimated using the "squeeze" technique. If the soil appears too wet, it must be dried to approximately optimum moisture. If too dry, water must be mixed with it uniformly until approximate optimum moisture is reached. (See Section 4 - Determination of Optimum Moisture). The prepared soil is divided into approximately three equal parts and compacted in the mold. The compaction is done with the 5-½ pound rammer. Twenty-five (25) drops of the rammer from a 12-inch height are applied to each of the three equal layers. The mold shall be placed on the 50-pound weight or on pavement or similar rigid base while compacting. After the three layers of soil have been compacted, a second volumeter reading is taken of the compaction mold with the collar still attached. The difference between this reading and the reading of the empty mold and collar taken earlier is the "compacted volume" of the soil in cubic feet. The percentage compaction is simply calculated by this formula:

$$\text{Percent Compaction} = \frac{\text{Compacted Volume} \times 100}{\text{In-place Volume}}$$

Or, as earlier expressed in terms of the "hole" and the "mold",

$$\text{Percent compaction} = (V_{\text{mold}}) / (V_{\text{hole}})$$

Step-by-step Procedure for Performing Test 1-A

NOTE: All volumeter readings require 4-psi water pressure; use M&T Form 504 to record your results.

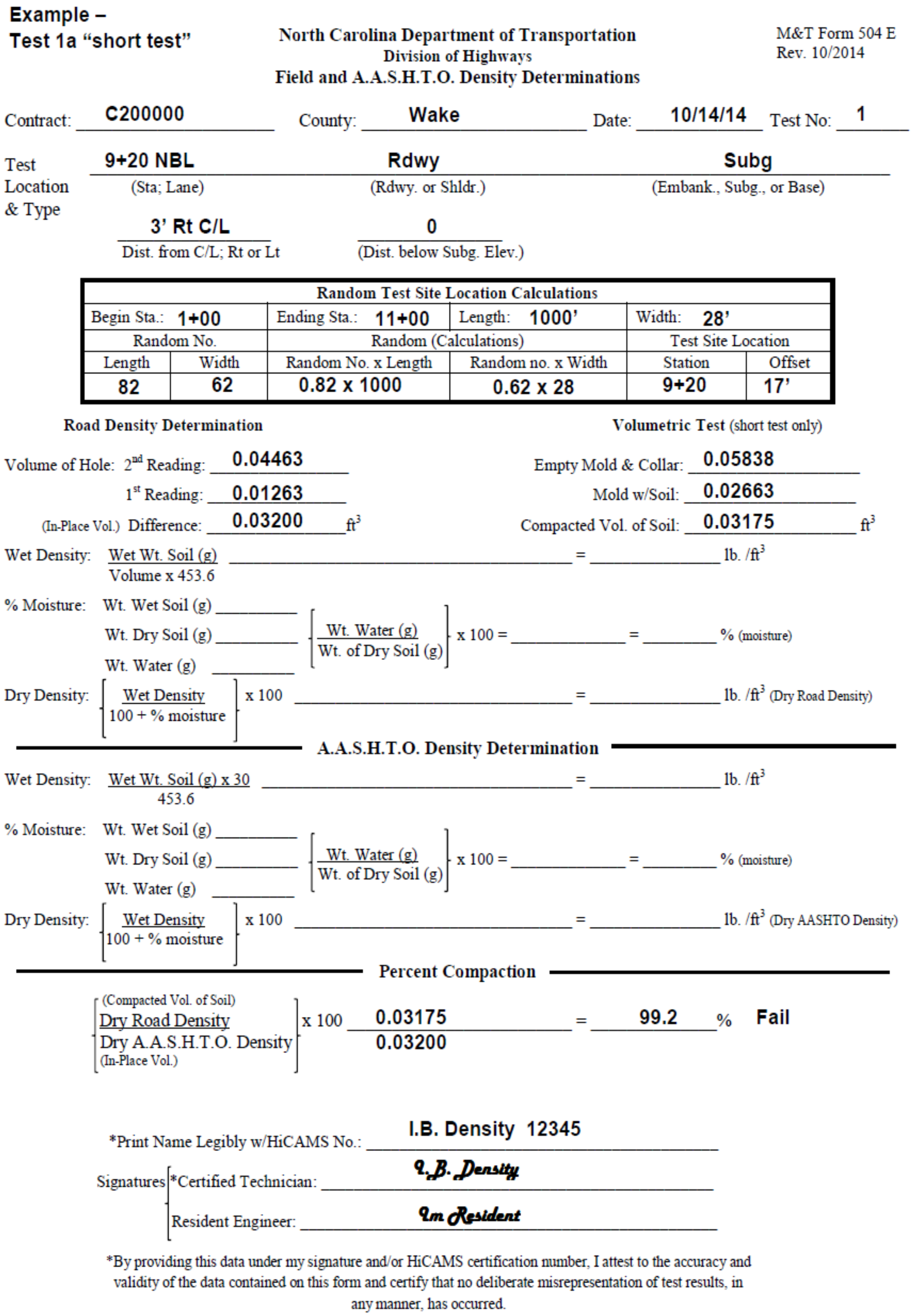
1. Take empty mold and collar reading, applying 4-psi to the volumeter water balloon.
2. Prepare a test site by smoothing the surface (remove soil to get below sheepsfoot indentions or crust if surface has dried out).
3. Level the plate on the test site.
4. Scribe around the edges of the plate, marking the volumeter valve location.
5. Take the first (or "flat") reading.
6. Dig the test hole, starting off with a spoon and continuing with an auger. Soil should be collected on the soil pan
7. When hole is finished, remove loose soil particles from the hole and the plate and include them with the soil collected in step 6.

8. Check for sharp edges in the hole. If there are sharp edges, move to another location and repeat steps 1-8.
9. Take a second reading with the volumeter, positioning the valve at the marked location. The difference is the volume of the hole occupied by the removed soil.
10. If the difference between the second and the first reading is such that the volume of the hole is less than 0.03200 ft^3, the hole is too small. Remove additional soil and repeat steps 8-10.
11. If the difference between the second and the first reading is such that the volume of the hole is greater than 0.03500 ft^3, the hole is too large. Move to a different location and start over.
12. Clean off excess soil from the auger and spoon and include them with the soil in the soil pan.
13. Mix the soil until it has uniform water content.
14. Check for optimum moisture using the "squeeze" method.
15. Dry or add water to the soil as necessary and mix for uniform water content. Repeat step 14-15 until optimum water content is obtained.
16. Move the soil to one side of the pan and divide into three equal layers.
17. Place the first layer in the mold, taking care not to lose any material (place the mold in the soil pan).
18. Apply compactive effort; apply the 25th blow in the center and check for the "penny print."
19. Place the second layer in the mold, including any rocks that were removed from the hole (break up rocks ½ inch or larger; do not pulverize). Apply compactive effort.
20. After compacting the second layer, place all the remaining soil in the mold and apply compactive effort. On the 18th blow, scrape any soil sticking to the rammer and from the inside wall of the mold above the soil layer.
21. Take a second reading on the mold using the volumeter.
22. The difference between the reading taken in step 5 and step 21 is the volume occupied by the soil in the mold.
23. Percent compaction = (volume obtained in step 22) / (volume obtained in step 9)

<u>Sources of Error for Test 1-A</u>

1. Density hole too small or too big for accurate results.
2. Failure to keep volumeter in good working condition.
3. Operator not understanding the significance of <u>Optimum Moisture</u> and <u>Maximum Density</u>
4. <u>Failure to remove all loose material in hole.</u>
5. Dropping rammer more than 12 inches.
6. Applying more or less than 25 blows to layer of soil.
7. Test performed on "crust" of layer.
8. Spilling soil removed from hole. All soil <u>MUST</u> be compacted in mold.
9. <u>Do Not</u> divide in-place volume by compacted volume.
   NOTE: Correct method is as follows:

$$\text{Percent Compaction} = \frac{\text{Compacted Volume}}{\text{In-Place Volume}} \quad \text{x} \quad 100$$



Example –
Test 1a "short test"

North Carolina Department of Transportation
Division of Highways
Field and A.A.S.H.T.O. Density Determinations

M&T Form 504 E
Rev. 10/2014

Contract: C200000 County: Wake Date: 10/14/14 Test No: 1

Test Location & Type:
9+20 NBL (Sta; Lane)
Rdwy (Rdwy. or Shldr.)
Subg (Embank., Subg., or Base)
3' Rt C/L (Dist. from C/L; Rt or Lt)
0 (Dist. below Subg. Elev.)

Random Test Site Location Calculations					
Begin Sta.: 1+00		Ending Sta.: 11+00	Length: 1000'	Width: 28'	
Random No.		Random (Calculations)		Test Site Location	
Length	Width	Random No. x Length	Random no. x Width	Station	Offset
82	62	0.82 x 1000	0.62 x 28	9+20	17'

Road Density Determination

Volume of Hole: 2nd Reading: 0.04463
1st Reading: 0.01263
(In-Place Vol.) Difference: 0.03200 ft³

Volumetric Test (short test only)

Empty Mold & Collar: 0.05838
Mold w/Soil: 0.02663
Compacted Vol. of Soil: 0.03175 ft³

Wet Density: $\frac{\text{Wet Wt. Soil (g)}}{\text{Volume x 453.6}}$ ______ = ______ lb. /ft³

% Moisture: Wt. Wet Soil (g) ______
Wt. Dry Soil (g) ______ $\left[\frac{\text{Wt. Water (g)}}{\text{Wt. of Dry Soil (g)}}\right]$ x 100 = ______ = ______ % (moisture)
Wt. Water (g) ______

Dry Density: $\left[\frac{\text{Wet Density}}{\text{100 + \% moisture}}\right]$ x 100 ______ = ______ lb. /ft³ (Dry Road Density)

A.A.S.H.T.O. Density Determination

Wet Density: $\frac{\text{Wet Wt. Soil (g) x 30}}{453.6}$ ______ = ______ lb. /ft³

% Moisture: Wt. Wet Soil (g) ______
Wt. Dry Soil (g) ______ $\left[\frac{\text{Wt. Water (g)}}{\text{Wt. of Dry Soil (g)}}\right]$ x 100 = ______ = ______ % (moisture)
Wt. Water (g) ______

Dry Density: $\left[\frac{\text{Wet Density}}{\text{100 + \% moisture}}\right]$ x 100 ______ = ______ lb. /ft³ (Dry AASHTO Density)

Percent Compaction

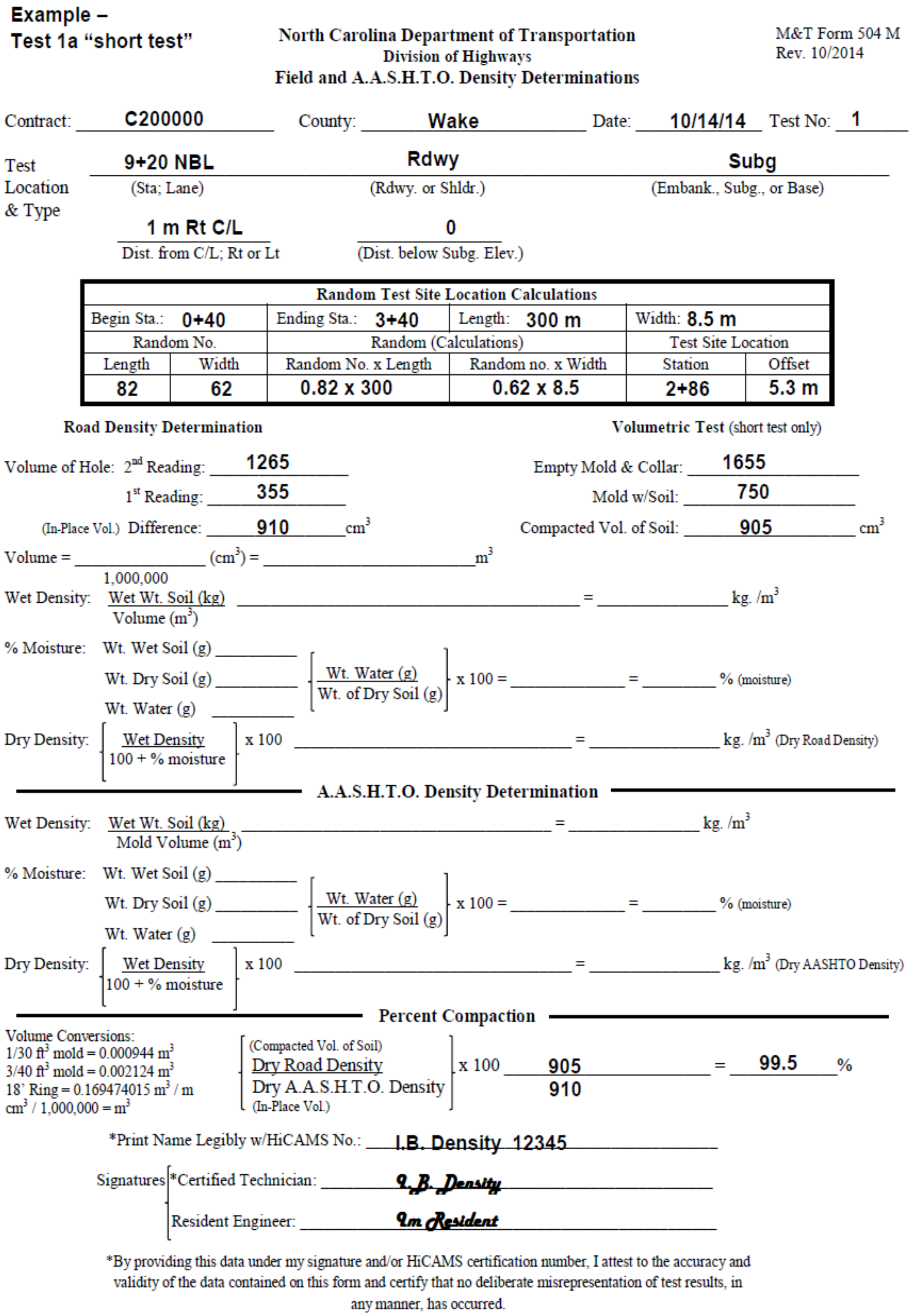
(Compacted Vol. of Soil)
$\left[\frac{\text{Dry Road Density}}{\text{Dry A.A.S.H.T.O. Density}}\right]$ x 100 $\frac{0.03175}{0.03200}$ = 99.2 % **Fail**
(In-Place Vol.)

*Print Name Legibly w/HiCAMS No.: I.B. Density 12345

Signatures
*Certified Technician: I.B. Density
Resident Engineer: Im Resident

*By providing this data under my signature and/or HiCAMS certification number, I attest to the accuracy and validity of the data contained on this form and certify that no deliberate misrepresentation of test results, in any manner, has occurred.

Figure 3 Example of Test 1-A "Short Test" (English units)



Example –
Test 1a "short test"

North Carolina Department of Transportation
Division of Highways
Field and A.A.S.H.T.O. Density Determinations

M&T Form 504 M
Rev. 10/2014

Contract: C200000 County: Wake Date: 10/14/14 Test No: 1

Test Location & Type
9+20 NBL (Sta; Lane)
Rdwy (Rdwy. or Shldr.)
Subg (Embank., Subg., or Base)
1 m Rt C/L (Dist. from C/L; Rt or Lt)
0 (Dist. below Subg. Elev.)

Random Test Site Location Calculations

Begin Sta.: 0+40		Ending Sta.: 3+40	Length: 300 m	Width: 8.5 m	
Random No.		Random (Calculations)		Test Site Location	
Length	Width	Random No. x Length	Random no. x Width	Station	Offset
82	62	0.82 x 300	0.62 x 8.5	2+86	5.3 m

Road Density Determination

Volume of Hole: 2^{nd} Reading: 1265
1^{st} Reading: 355
(In-Place Vol.) Difference: 910 cm^3

Volume = ______ (cm^3) = ______ m^3
1,000,000

Wet Density: Wet Wt. Soil (kg) / Volume (m^3) ______ = ______ kg. /m^3

% Moisture: Wt. Wet Soil (g) ______
Wt. Dry Soil (g) ______ [Wt. Water (g) / Wt. of Dry Soil (g)] x 100 = ______ = ______ % (moisture)
Wt. Water (g) ______

Dry Density: [Wet Density / 100 + % moisture] x 100 ______ = ______ kg. /m^3 (Dry Road Density)

Volumetric Test (short test only)

Empty Mold & Collar: 1655
Mold w/Soil: 750
Compacted Vol. of Soil: 905 cm^3

A.A.S.H.T.O. Density Determination

Wet Density: Wet Wt. Soil (kg) / Mold Volume (m^3) ______ = ______ kg. /m^3

% Moisture: Wt. Wet Soil (g) ______
Wt. Dry Soil (g) ______ [Wt. Water (g) / Wt. of Dry Soil (g)] x 100 = ______ = ______ % (moisture)
Wt. Water (g) ______

Dry Density: [Wet Density / 100 + % moisture] x 100 ______ = ______ kg. /m^3 (Dry AASHTO Density)

Percent Compaction

Volume Conversions:
1/30 ft^3 mold = 0.000944 m^3
3/40 ft^3 mold = 0.002124 m^3
18' Ring = 0.169474015 m^3 / m
cm^3 / 1,000,000 = m^3

[(Compacted Vol. of Soil) Dry Road Density / Dry A.A.S.H.T.O. Density (In-Place Vol.)] x 100 905 / 910 = 99.5 %

*Print Name Legibly w/HiCAMS No.: I.B. Density 12345

Signatures
*Certified Technician: I.B. Density
Resident Engineer: Im Resident

*By providing this data under my signature and/or HiCAMS certification number, I attest to the accuracy and validity of the data contained on this form and certify that no deliberate misrepresentation of test results, in any manner, has occurred.

Figure 4 Example of Test 1-A "Short Test" (metric units)

Section 6 – Density Test 1

Also referred to as the "long test", Test 1 calculates percent compaction using values of unit weights and requires weighing and drying steps. The proper steps should be followed to reduce the possibility of error.

Equipment Needed

The following equipment is necessary for performing Density Test 1.

Volumeter
3-inch auger
Large Spoon
50-pound weight
50-pound saddle weight for volumeter
Soil Pan
Pie plate (9" x 1 ½")
Scales (with 2,000-gram weight)
Small Spatula
Frying pan
Steel straight edge
Compaction mold (1/30 ft^3)
Sample extractor
Compaction rammer (5 ½ pounds, 12-inch drop)
Water container (i.e. small squirt bottle or graduated cylinder)
Water
Gas burner (with lighter)
Square tip shovel

Determining the In-place Dry Density

All loose soil is removed from the surface of the layer and an area about 15 inches square is brought to a smooth, flat and approximately level surface by scraping with a steel straight edge or other suitable instrument.

The volumeter is placed on the smoothed surface of the soil, and a 50-pound saddle weight is placed on top of the volumeter. Air is applied to a pressure of 4-p.s.i. and an initial reading is taken. (This is the actual reading on the volumeter scale before the soil is removed). A mark is made on the soil surface tracing the outside of the volumeter base so that it may be placed in the same place after removal of soil.

A hole is made in the center of the circle on the volumeter base approximately four inches in diameter and six inches deep. The soil is removed and placed in a container for weighing and for determination of moisture content. It is, of course, important that all of the soil that is removed from the hole be placed in the container.

The volumeter is placed over the hole in the same position as when the initial reading was taken, and the volume of the hole measured. The 50-pound saddle weight and the 4-p.s.i. air pressure shall be applied in the same manner as described for determining the initial reading. The difference between the second reading and the first reading is the volume of the hole in cubic feet. In order to obtain the desired accuracy, the volume of the test hole should not be less than 0.02750 cubic feet.

The soil that was removed from the hole is weighed and its moisture content determined by drying a sample weighing 300-grams. Care must be exercised in drying the sample to avoid overheating. Overheating a soil sample may affect the moisture content. To prevent overheating, the soil shall be dried over a low flame and shall be frequently stirred. The sample shall be removed from the flame immediately when it appears to be dry. The dry weight of the soil removed from the hole can then be determined. And, knowing the volume occupied by the soil, as measured with volumeter, the in-place density in pounds per cubic feet of the compacted soil can be calculated.

The in-place density of the soil is calculated by use of the following formula:

$$\text{Wet Density (lb./cu. ft.)} = \frac{\text{Wet Wt. of Soil (grams)}}{453.6 \text{ x Vol. of Hole}}$$

$$\text{Moisture Content} = \frac{(\text{Wet Wt.} - \text{Dry Wt.}) \text{ x } 100 = \% \text{ Moisture}}{\text{Dry Wt.}}$$

$$\text{Dry Density (lb./cu. ft.)} = \left(\frac{\text{Wet Density}}{100 + \text{Moisture Content}}\right) \text{ x } 100$$

Determining the Maximum Dry Density

The expression “AASHTO Method T 99” refers to the description of a testing procedure, adopted as a standard by the American Association of State Highway and Transportation Officials, for compacting a sample of soil to determine its maximum dry density. The moisture content at which this maximum dry density is obtained is referred to as the “optimum moisture content” of the soil. This maximum dry density is also referred to as the “AASHTO Density”. All references to AASHTO T 99 in these procedures are to the test method adopted by AASHTO in 1993 (designated as AASHTO T 99-93). The use of a tapered mold is recommended.

The test procedure outlined below is a modification of the AASHTO Test Method T 99 for field use in that the soil is compacted at a moisture content estimated to be the optimum for that soil. As previously mentioned, an experienced operator using the “squeeze” method, can determine the optimum moisture of a soil within +/- 2.0 %, which is within the variation acceptable in practice. In order to simplify the compaction test procedure for field use, the standard procedure is revised to eliminate the necessity of running the entire moisture-density curve. See Section 4, “Determination of Optimum Moisture”.

Modified Moisture-Density Test

The soil used in determining the in-place density is also used in performing the compaction test. The portion of soil used in determining the moisture content of the soil is discarded and if more soil is needed it may be obtained from the sides of the hole uniformly from top to bottom. Approximately four to five pounds of soil are sufficient for completing the test.

The soil should be mixed and kneaded until the largest clod (not aggregate) does not exceed approximately ¼-inch in size as determined by visual inspection. Any aggregate present in the soil should be mixed uniformly and used in both the moisture and AASHTO Density Determination (break up rock ½ inch or larger; do not pulverize). The mass of soil is now examined visually for the correct moisture content. If it appears too wet, the soil is dried to approximately optimum as determined by visual inspection. If it appears too dry, water is mixed with it uniformly until estimated optimum moisture is obtained.

The prepared soil is divided into three parts and compacted in the mold in three approximately equal layers. The exact amount of soil in each part should be such that when compacted, all three parts will fill the mold (excluding the collar) to a point not to exceed ½ inches above the top, which is then struck off with the steel straight edge.

The compaction is performed with a compaction rammer weighing 5-½ pounds with a 12-inch drop. Twenty-five blows of the rammer are applied to each of the three layers. The mold shall be placed on a 50-pound weight, pavement or on a similar rigid base while compacting. After the compacted soil is struck off with the steel straight edge, it shall be extracted from the mold, weighed and split to obtain 300 grams or more of soil in order to determine the moisture content. The same precautions should be observed in drying the sample as pointed out previously in this procedure. The constant 453.6 is a conversion factor that converts grams to pounds. All weights recorded during the test procedure are in grams, but the final answer is recorded in pounds; therefore, the wet weight of the soil is divided by 453.6 to convert the units from grams to pounds (453.6 grams = 1 pound). The weight and moisture content are determined and the dry density is calculated by use of the following formulas:

$$\text{Wet Density (lb. / cu. ft.)} = \frac{\text{Wt. of Wet Soil in grams x 30}}{453.6}$$

$$\text{Moisture Content} = \frac{\text{Wet Weight - Dry Weight} \quad \text{x} \quad 100}{\text{Dry Weight}}$$

$$\text{Dry Density (lb. / cu. ft.)} = \frac{(\quad \text{Wet Density} \quad) \ \text{x} \ 100}{(\ 100 + \text{Moisture Content}\ )}$$

$$\text{Compaction (\%)} = \frac{\text{(Dry Density of Soil In-Place) x } 100}{\text{(Dry Density of Soil Compacted in Mold)}}$$

The constant 30 comes from the fact that, in computing the wet density we use a 1/30 cubic foot mold. The weight of material in the mold is multiplied by a factor of 30 which is the reciprocal of 1/30.

Step-by-step Procedure for Performing Test 1

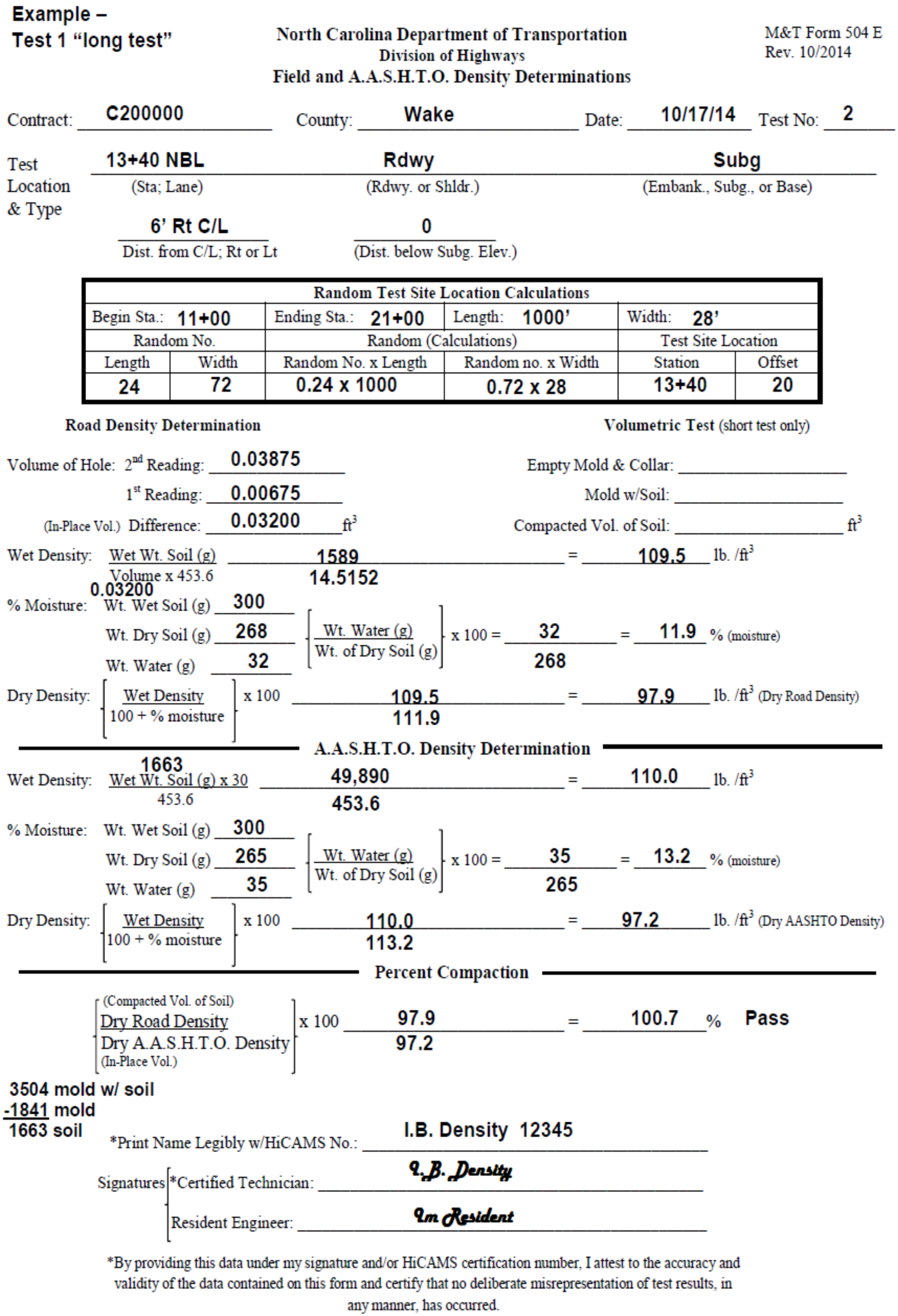
NOTE: All volumeter readings require 4-psi water pressure; use M&T Form 504 to record your results.

1. Level the electronic scale.
2. Verify that the 2,000-gram weight reads as 2,000 grams on the scale, with a ±1 - gram tolerance.
3. Weigh the empty mold and record.
4. Prepare a test site by smoothing the surface (remove soil to get below sheepsfoot indentions or crust if surface has dried out).
5. Level the plate on the test site.
6. Scribe around the edges of the plate, marking the volumeter valve location.
7. Take the first or "flat" reading.
8. Dig the test hole, starting off with a spoon and continue with an auger. Soil should be collected on the soil pan.
9. When hole is finished, remove loose soil particles from the hole and the plate and include them with the soil collected in step 8.
10. Check for sharp edges in the hole. If there are sharp edges, move to another location and repeat steps 1-9.
11. Take a second reading with the volumeter, positioning the valve at the marked location. The difference is the volume of the hole occupied by the removed soil.
12. If the difference between the second and the first reading is such that the volume of the hole is less than 0.02750 ft^3, the hole is too small. Remove additional soil and repeat steps 10 - 11.
13. Clean off excess soil from the auger and spoon and include them with the soil in the soil pan.
14. Place all soil in the pie plate. Record the weight of the soil.
15. Place the soil back in the soil pan and mix the soil until it has uniform water content.
16. Obtain 300 grams of soil. This is the sample for determining the in-place moisture content.
17. Dry the soil. When using a burner, be sure not to overheat the soil.
18. Weigh the dry soil and record.
19. Remove additional soil from the hole and place in the soil pan.
20. Break up and pulverize the soil.
21. Check for optimum moisture using the "squeeze" method.
22. Dry or add water to the soil as necessary and mix for uniform water content. Repeat until optimum moisture content is obtained.
23. Place a first layer in the mold.
24. Apply compactive effort; apply the 25th blow in the center and check for the "penny print."
25. Place a second layer in the mold and apply compactive effort.
26. Place a third layer in the mold and apply compactive effort.

27. Scribe around the top (third) layer and then remove the mold collar.
28. The top of the third layer must be ¼ to ½ inches above the top of the mold.
29. Scrape off the excess soil with the straight edge until the surface is flush with the top of the mold.
30. Weigh the mold with soil and record the weight.
31. Extract soil pill with the sample extractor.
32. Using the straight edge, split the soil pill down the middle lengthwise.
33. Obtain 300 grams of soil from the center of pill by scraping from top to bottom. This is the sample for determining the soil's estimated optimum moisture content (as judged by density technician).
34. Dry the soil. When using a burner, be sure not to overheat the soil.
35. Weigh the dry soil and record.
36. Using the data recorded, follow the steps on M&T Form 504 for obtaining percent compaction.
37. Compare Optimum Moisture and Maximum Dry Density of Test 1 to the Optimum Moisture and Maximum Dry Density determined by the Moisture Density Curve (Tolerances should be within: Optimum Moisture +/- 2.0 %; Maximum Dry Density +/- 2.0 pounds per cubic foot)

Sources of Error for Test 1

1. Density hole too small for accurate results.
2. Failure to thoroughly mix soil for moisture test.
3. Failure to keep volumeter in good working condition.
4. Cutting off more than ½ inch of soil after AASHTO mold is made.
5. Operator not understanding the significance of Optimum Moisture and Maximum Density.
6. Failure to remove all loose material in hole.
7. Dropping rammer more than 12 inches.
8. Scales not level.
9. Applying more or less than 25 blows to layer of soil.
10. Carelessness in removing soil from mold before weighing.
11. Test performed on "crust" of layer.



Example –
Test 1 "long test"

North Carolina Department of Transportation
Division of Highways
Field and A.A.S.H.T.O. Density Determinations

M&T Form 504 E
Rev. 10/2014

Contract: C200000 County: Wake Date: 10/17/14 Test No: 2

Test Location & Type

13+40 NBL (Sta; Lane) Rdwy (Rdwy. or Shldr.) Subg (Embank., Subg., or Base)

6' Rt C/L (Dist. from C/L; Rt or Lt) 0 (Dist. below Subg. Elev.)

Random Test Site Location Calculations					
Begin Sta.: 11+00		Ending Sta.: 21+00	Length: 1000'	Width: 28'	
Random No.		Random (Calculations)		Test Site Location	
Length	Width	Random No. x Length	Random no. x Width	Station	Offset
24	72	0.24 x 1000	0.72 x 28	13+40	20

Road Density Determination

Volume of Hole: 2nd Reading: 0.03875

1st Reading: 0.00675

(In-Place Vol.) Difference: 0.03200 ft^3

Volumetric Test (short test only)

Empty Mold & Collar: ____

Mold w/Soil: ____

Compacted Vol. of Soil: ____ ft^3

Wet Density: Wet Wt. Soil (g) / Volume x 453.6 = 1589 / 14.5152 = 109.5 lb. $/ft^3$

0.03200

% Moisture: Wt. Wet Soil (g) 300

Wt. Dry Soil (g) 268

Wt. Water (g) 32

[Wt. Water (g) / Wt. of Dry Soil (g)] x 100 = 32 / 268 = 11.9 % (moisture)

Dry Density: [Wet Density / 100 + % moisture] x 100 109.5 / 111.9 = 97.9 lb. $/ft^3$ (Dry Road Density)

A.A.S.H.T.O. Density Determination

Wet Density: Wet Wt. Soil (g) x 30 / 453.6 = 49,890 / 453.6 = 110.0 lb. $/ft^3$

1663

% Moisture: Wt. Wet Soil (g) 300

Wt. Dry Soil (g) 265

Wt. Water (g) 35

[Wt. Water (g) / Wt. of Dry Soil (g)] x 100 = 35 / 265 = 13.2 % (moisture)

Dry Density: [Wet Density / 100 + % moisture] x 100 110.0 / 113.2 = 97.2 lb. $/ft^3$ (Dry AASHTO Density)

Percent Compaction

[(Compacted Vol. of Soil) Dry Road Density / Dry A.A.S.H.T.O. Density (In-Place Vol.)] x 100 97.9 / 97.2 = 100.7 % Pass

3504 mold w/ soil
-1841 mold
1663 soil

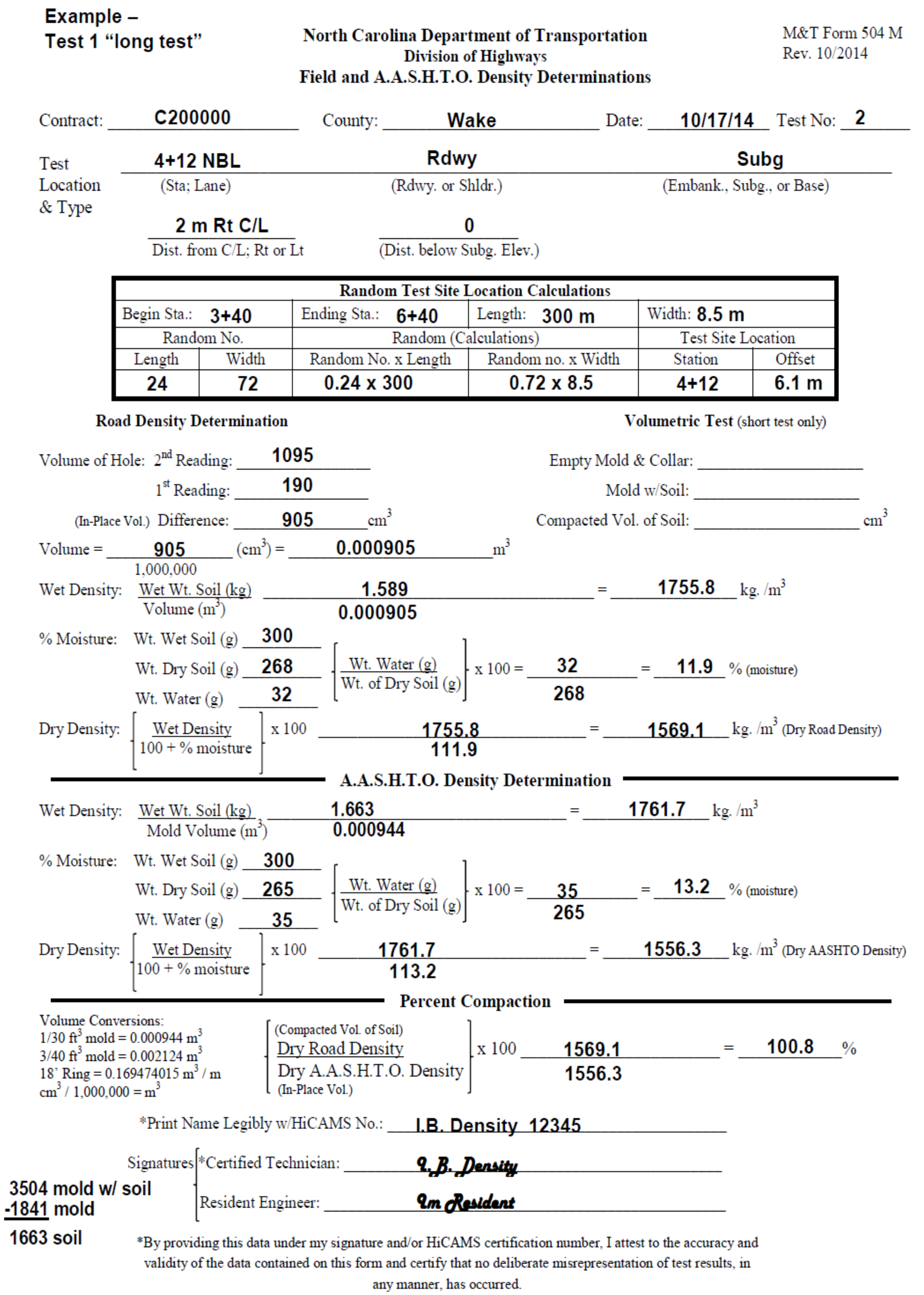
*Print Name Legibly w/HiCAMS No.: I.B. Density 12345

Signatures *Certified Technician: I.B. Density

Resident Engineer: Im Resident

*By providing this data under my signature and/or HiCAMS certification number, I attest to the accuracy and validity of the data contained on this form and certify that no deliberate misrepresentation of test results, in any manner, has occurred.

Figure 5 Example of Test 1 "Long Test" (English units)



Example –
Test 1 "long test"

North Carolina Department of Transportation
Division of Highways
Field and A.A.S.H.T.O. Density Determinations

M&T Form 504 M
Rev. 10/2014

Contract: **C200000** County: **Wake** Date: **10/17/14** Test No: **2**

Test Location & Type
4+12 NBL (Sta; Lane)
Rdwy (Rdwy. or Shldr.)
Subg (Embank., Subg., or Base)
2 m Rt C/L Dist. from C/L; Rt or Lt
0 (Dist. below Subg. Elev.)

Random Test Site Location Calculations					
Begin Sta.: **3+40**		Ending Sta.: **6+40**	Length: **300 m**	Width: **8.5 m**	
Random No.		Random (Calculations)		Test Site Location	
Length	Width	Random No. x Length	Random no. x Width	Station	Offset
24	**72**	**0.24 x 300**	**0.72 x 8.5**	**4+12**	**6.1 m**

Road Density Determination

Volume of Hole: 2nd Reading: **1095**
1st Reading: **190**
(In-Place Vol.) Difference: **905** cm^3

Volume = $\frac{905 \ (\text{cm}^3)}{1{,}000{,}000}$ = **0.000905** m^3

Wet Density: $\frac{\text{Wet Wt. Soil (kg)}}{\text{Volume (m}^3)}$ $\frac{1.589}{0.000905}$ = **1755.8** kg. /m^3

% Moisture: Wt. Wet Soil (g) **300**
Wt. Dry Soil (g) **268**
Wt. Water (g) **32**

$\left[\frac{\text{Wt. Water (g)}}{\text{Wt. of Dry Soil (g)}}\right]$ x 100 = $\frac{32}{268}$ = **11.9** % (moisture)

Dry Density: $\left[\frac{\text{Wet Density}}{100 + \text{\% moisture}}\right]$ x 100 $\frac{1755.8}{111.9}$ = **1569.1** kg. /m^3 (Dry Road Density)

Volumetric Test (short test only)

Empty Mold & Collar: ____________________
Mold w/Soil: ____________________
Compacted Vol. of Soil: ____________________ cm^3

A.A.S.H.T.O. Density Determination

Wet Density: $\frac{\text{Wet Wt. Soil (kg)}}{\text{Mold Volume (m}^3)}$ $\frac{1.663}{0.000944}$ = **1761.7** kg. /m^3

% Moisture: Wt. Wet Soil (g) **300**
Wt. Dry Soil (g) **265**
Wt. Water (g) **35**

$\left[\frac{\text{Wt. Water (g)}}{\text{Wt. of Dry Soil (g)}}\right]$ x 100 = $\frac{35}{265}$ = **13.2** % (moisture)

Dry Density: $\left[\frac{\text{Wet Density}}{100 + \text{\% moisture}}\right]$ x 100 $\frac{1761.7}{113.2}$ = **1556.3** kg. /m^3 (Dry AASHTO Density)

Percent Compaction

Volume Conversions:
1/30 ft^3 mold = 0.000944 m^3
3/40 ft^3 mold = 0.002124 m^3
18' Ring = 0.169474015 m^3 / m
cm^3 / 1,000,000 = m^3

(Compacted Vol. of Soil)
$\left[\frac{\text{Dry Road Density}}{\text{Dry A.A.S.H.T.O. Density}}\right]$ x 100 $\frac{1569.1}{1556.3}$ = **100.8** %
(In-Place Vol.)

*Print Name Legibly w/HiCAMS No.: **I.B. Density 12345**

Signatures
*Certified Technician: I. B. Density
Resident Engineer: Im Resident

3504 mold w/ soil
-1841 mold
1663 soil

*By providing this data under my signature and/or HiCAMS certification number, I attest to the accuracy and validity of the data contained on this form and certify that no deliberate misrepresentation of test results, in any manner, has occurred.

Figure 6 Example of Test 1 "Long Test" (metric units)

Section 7 – Density Test 2

Test 2 is used to calculate the degree of compaction of embankments, subgrades or soil bases that contain or have been stabilized by an admixture of aggregate material (density Tests 1 and 1-A should not be used for this type of material). The procedure for Test 2 is outlined below.

Equipment Needed

The following equipment is necessary for the performance of Density Test 2.

Calibrated steel ring (18" outside diameter and 4 ½ inches to 9 inches deep)
Small pick
Scoop
Scales (with 2,000-gram weight)
Gas burner (with lighter)
Frying pan
Ruler
Straight edge (36 inches long)
Large Spoon
Bucket (10-quart capacity)
Compaction mold (3/40 cubic foot = 0.075 cubic foot volume)
Compaction rammer (5 ½-pounds, 12-inch drop)
Steel straight edge
Hammer
Wood block (4x4 hard wood recommended)

Determining the In-place Dry Density

The calibrated steel ring is placed over the area to be tested and the material within the ring is carefully loosened with the pick and removed with the scoop. The material removed is placed in the bucket for weighing. As the material is removed, the ring is lowered to the full depth of the layer by placing a wooden block on top of the ring and striking it with a hammer.

After all material has been removed, the ring is removed, and the thickness of the layer is carefully measured to the nearest one-sixteenth by placing a straight edge across the top of the hole and taking five or more measurements along opposing diameters (Refer to Diagram 2).

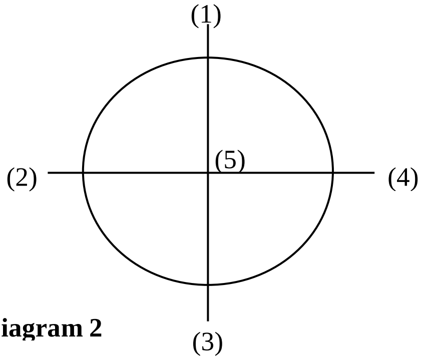


Diagram 2

From these measurements, the average depth of the hole is determined. Although the steel ring has an outside diameter of 18 inches, which theoretically would occupy a volume of 0.147 cubic feet per inch of depth, it has been found that its effective diameter is 18.3 inches, and it actually occupies a volume of 0.152 cubic feet per inch of depth. The volume in cubic feet occupied by the material is calculated by multiplying the average depth of the layer in meter by 0.152. Average depth of layer x 0.152 = cubic feet of material. The wet density of the layer is calculated by dividing the weight of the material removed by its volume.

$$\text{Wet Density (lb./cu. ft.)} = \frac{\text{Wet Wt. of Material (pounds)}}{\text{Volume of Material (cu. ft.)}}$$

The moisture content of the material is determined by weighing out a minimum of 1,000 grams of the material and drying it out over the gas burner. To prevent overheating, the soil shall be dried over a low flame and shall be frequently stirred. The sample shall be removed from the flame immediately when it appears to be dry. The moisture content in percentage of the dry material is calculated by the following formula:

$$\text{Moisture Content} = \frac{(\text{Wet Wt. - Dry Wt.})}{\text{Dry Wt.}} \times 100$$

The dry density of the layer is calculated using the following formula:

$$\text{Dry Density (lb./cu. ft.)} = \frac{(\text{Wet Density}) \times 100}{(100 + \text{Moisture Content})}$$

Determining the Maximum Dry Density

The expression “AASHTO Method T 99” refers to the description of a testing procedure, adopted as a standard by the American Association of State Highway and Transportation Officials for compacting a sample of soil to determine its dry density. The method, as described, has four alternate procedures that provide for soils with and without coarse aggregate, compacted in six-inch and four-inch diameter molds. The test not only determines the greatest density of which the soil may be compacted by the prescribed compaction effort but determines the proper moisture content required to obtain this maximum density, called the “Optimum Moisture” content. This requires that a complete moisture density curve be run on the material. The field compaction test described below is a modification of the standard test in that the soil is compacted in the mold only once at a moisture content estimated to be optimum. It has been found that an experienced operator using visual inspection can estimate the optimum moisture content. The optimum moisture can be estimated within a narrow range, which is within the variation acceptable in practice. In order to simplify the compaction test procedure for field use, the standard procedure is revised to eliminate the need of running the entire moisture density curve (See Section 4, Determination of Optimum Moisture).

A representative portion of the material obtained from the in-place density test is used in the field compaction test. Since the volume of the material obtained from the in-place density test is more than is needed for the field compaction test, it must be thoroughly mixed and reduced in quantity by quartering. It is very important that the portion selected for the field compaction test contain a representative amount of coarse aggregate, as the quantity of this fraction influences the unit weight (density) appreciably. About 12 pounds of soil-aggregate will be required for the test. If the material appears wetter than optimum, it should be dried to estimated optimum; if too dry, water should be uniformly mixed with the material until the estimated optimum moisture is obtained.

The prepared soil-aggregate is divided in three parts of about four pounds each and compacted in the 3/40 cubic foot mold in three approximate equal layers. The amount of soil-aggregate in each part should be such that all three parts will fill the mold, after compaction, to a point ¼ to ½ inch above the top of the mold, which is struck off with a steel straight edge.

The compaction is done with a rammer that weighs 5-½ pounds and drops 12 inches. Each of the three layers is compacted by 56 blows of the rammer with the mold placed on a 50-pound weight, pavement, or similar rigid flat base while compacting.

After the compacted soil aggregate is struck off with the steel straight edge, it shall be extracted from the mold, weighed and split to obtain 1,000 grams of soil in order to determine the moisture content. The same precautions should be observed in drying the sample as pointed out previously in this procedure. The weight and moisture content are determined and the dry unit weight (dry density) and percent compaction are calculated by the following formulas:

$$\text{Wet Density (lb. / cu. ft.)} = \frac{\text{Wt. of Wet Soil-Aggregate (grams) x 13.33}}{453.6}$$

$$\text{Moisture Content} = \frac{(\text{Wet Wt. - Dry Wt.})}{(\text{Dry Wt.})} \times 100$$

$$\text{Dry Density (lb. / cu. ft.)} = \frac{(\text{Wet Density})}{(100 + \text{Moisture Content})} \times 100$$

$$\text{Compaction \%} = \frac{(\text{Dry Density of Soil-Aggregate In-Place})}{(\text{Dry Density of Compacted Soil-Aggregate})} \times 100$$

The constant 13.33 comes from the fact that, in computing the wet density we use a 3/40 cubic foot mold. The weight of material in the mold is multiplied by a factor of 13.33 which is the reciprocal of 3/40 or 40 ÷3 = 13.3333.

The constant 453.6 is a conversion factor that converts grams to pounds. All weights recorded during the test procedure are in grams, but the final answer is recorded in pounds; therefore, the wet weight of the soil is divided by 453.6 to convert the units from grams to pounds (453.6 grams = 1 pound).

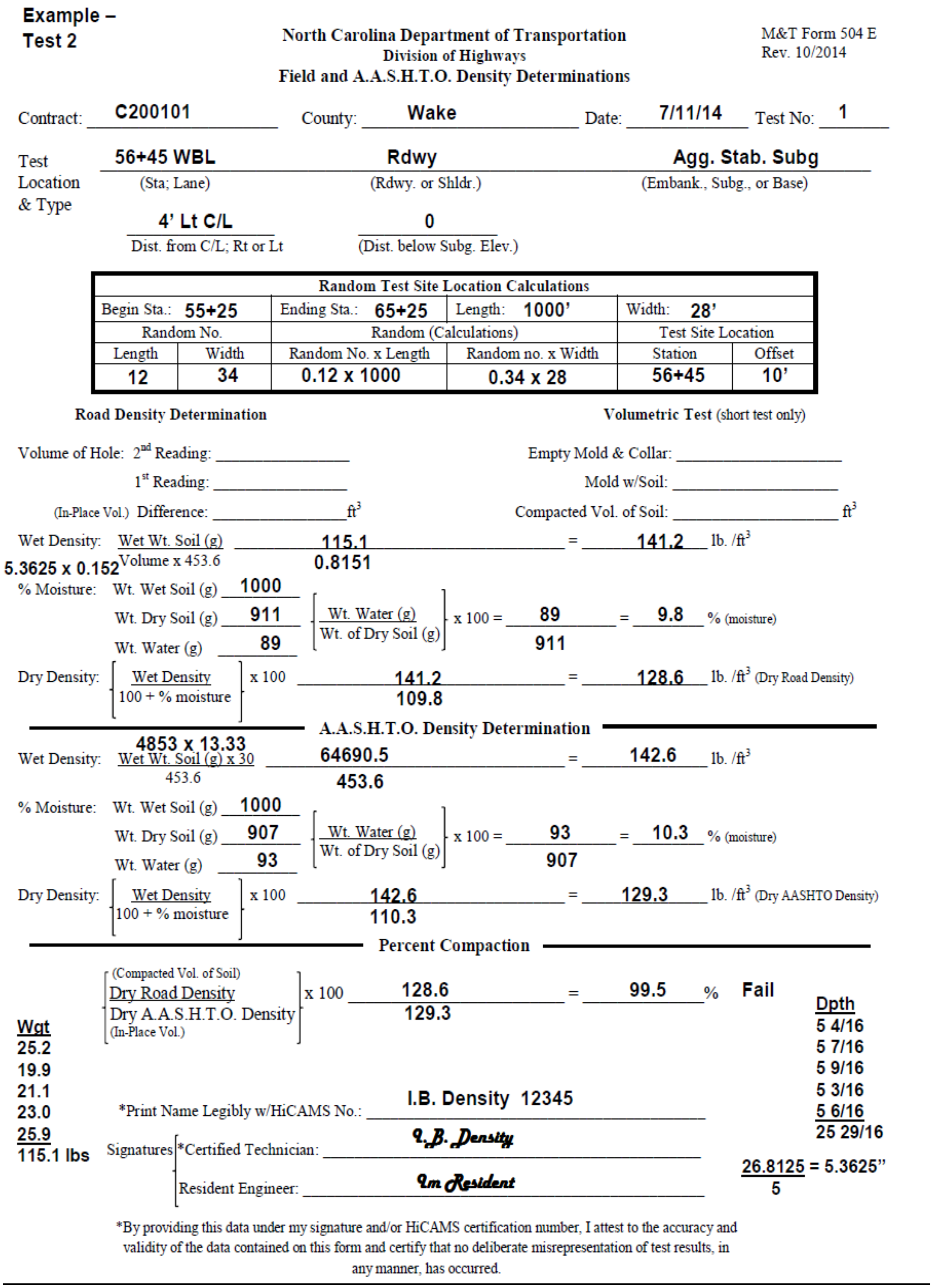
Step-by-step Procedure for Performing Test 2

1. Level the scale.
2. Verify that the 2,000-gram weight reads as 2,000 grams on the scale, with a ±1 -gram tolerance.
3. Tare the bucket.
4. Place the sampling ring on the surface of the layer to be tested.
5. Using the pick loosen the material on the surface within the ring.
6. Remove the material and place in the bucket. Repeat steps 5 - 6 until bucket is 2/3rds full.
7. Weigh the material and record.
8. Dump the material on the ground (but do not discard!)
9. Lower the ring through the layer by striking the top of the wood block with a hammer.
10. Repeat steps 5 - 9 until the ring rests on the top of the next layer.
11. Take five measurements of the depth of the hole: one at the center of the hole and at four points equally spaced along the edge of the hole (that is, a measuring point is 90 degrees from an adjacent measuring point). All measurements will be to the nearest 16th of an inch. Calculate the average of the 5 readings – this will be the "depth" of the hole used for calculations.
12. Using a shovel, thoroughly mix the material dumped on the ground.
13. Quarter down the material and re-mix. Do this twice (the purpose of quartering is to obtain a representative sample).
14. Obtain a 1,000-gram moisture sample. This is the sample for determining the in-place moisture content of the material.
15. Dry the soil. When using a burner, ensure soil is not overheated.
16. Weigh the dry soil and record.
17. Obtain material from the quartered-down portion, and place in the soil pan until it is about 2/3 full.
18. Check for optimum moisture using the "squeeze" method.
19. Dry or add water to the soil as necessary and mix for uniform moisture content. Repeat until optimum moisture is achieved.
20. Place a first layer in the mold (NOTE: a 3/40 ft^3 mold should be used for this test).
21. Apply compactive effort (NOTE: For this test, apply 56 blows per layer); apply the 56th blow in the center and check for the "penny print."
22. Place a second layer in the mold and apply compactive effort.
23. Place a third layer in the mold and apply compactive effort.
24. Scribe around the top (third) layer and then remove the mold collar.
25. The top of the third layer must be ¼ to ½ inches above the top of the mold.
26. Scrape off the excess soil with the straight edge until the surface is flush with the top of the mold. Fill in voids with fine material and re-smooth the surface.
27. Weigh the mold with the soil and record the weight.
28. Extract the soil pill.
29. Using the straight edge, split the soil pill down the middle lengthwise.
30. Obtain 1,000 grams of material by scraping from top to bottom of half the pill. This is the sample for determining the soil's moisture content.

31. Dry the soil. When using a burner, ensure not to overheat soil.
32. Weigh the dry soil and record.
33. Using the data recorded, follow the steps on M&T Form 504 for obtaining percent compaction.

Sources of Error for Test 2

1. Failure to take representative sample for making AASHTO mold.
2. Carelessness in measuring depth of density hole.
3. Scales not level.
4. Carelessness in drying soil.
5. Carelessness in removing soil from mold before weighing.
6. Applying more or less than 56 blows to layer of material.
7. Operator not understanding the significance of Optimum Moisture and Maximum Density



Example –
Test 2

North Carolina Department of Transportation
Division of Highways
Field and A.A.S.H.T.O. Density Determinations

M&T Form 504 E
Rev. 10/2014

Contract: C200101
County: Wake
Date: 7/11/14
Test No: 1

Test Location & Type:
56+45 WBL (Sta; Lane)
Rdwy (Rdwy. or Shldr.)
Agg. Stab. Subg (Embank., Subg., or Base)
4' Lt C/L (Dist. from C/L; Rt or Lt)
0 (Dist. below Subg. Elev.)

Random Test Site Location Calculations					
Begin Sta.: 55+25		Ending Sta.: 65+25	Length: 1000'	Width: 28'	
Random No.		Random (Calculations)		Test Site Location	
Length	Width	Random No. x Length	Random no. x Width	Station	Offset
12	34	0.12 x 1000	0.34 x 28	56+45	10'

Road Density Determination

Volume of Hole: 2nd Reading: ________
1st Reading: ________
(In-Place Vol.) Difference: ________ ft³

Volumetric Test (short test only)

Empty Mold & Collar: ________
Mold w/Soil: ________
Compacted Vol. of Soil: ________ ft³

Wet Density: Wet Wt. Soil (g) / Volume x 453.6 — 115.1 / 0.8151 = 141.2 lb. /ft³
5.3625 x 0.152

% Moisture: Wt. Wet Soil (g) 1000
Wt. Dry Soil (g) 911
Wt. Water (g) 89
[Wt. Water (g) / Wt. of Dry Soil (g)] x 100 = 89 / 911 = 9.8 % (moisture)

Dry Density: [Wet Density / 100 + % moisture] x 100 — 141.2 / 109.8 = 128.6 lb. /ft³ (Dry Road Density)

A.A.S.H.T.O. Density Determination

Wet Density: Wet Wt. Soil (g) x 30 / 453.6 — 4853 x 13.33 — 64690.5 / 453.6 = 142.6 lb. /ft³

% Moisture: Wt. Wet Soil (g) 1000
Wt. Dry Soil (g) 907
Wt. Water (g) 93
[Wt. Water (g) / Wt. of Dry Soil (g)] x 100 = 93 / 907 = 10.3 % (moisture)

Dry Density: [Wet Density / 100 + % moisture] x 100 — 142.6 / 110.3 = 129.3 lb. /ft³ (Dry AASHTO Density)

Percent Compaction

[(Compacted Vol. of Soil) Dry Road Density / Dry A.A.S.H.T.O. Density (In-Place Vol.)] x 100 — 128.6 / 129.3 = 99.5 % **Fail**

Wgt	Dpth
25.2	5 4/16
19.9	5 7/16
21.1	5 9/16
23.0	5 3/16
25.9	5 6/16
115.1 lbs	25 29/16

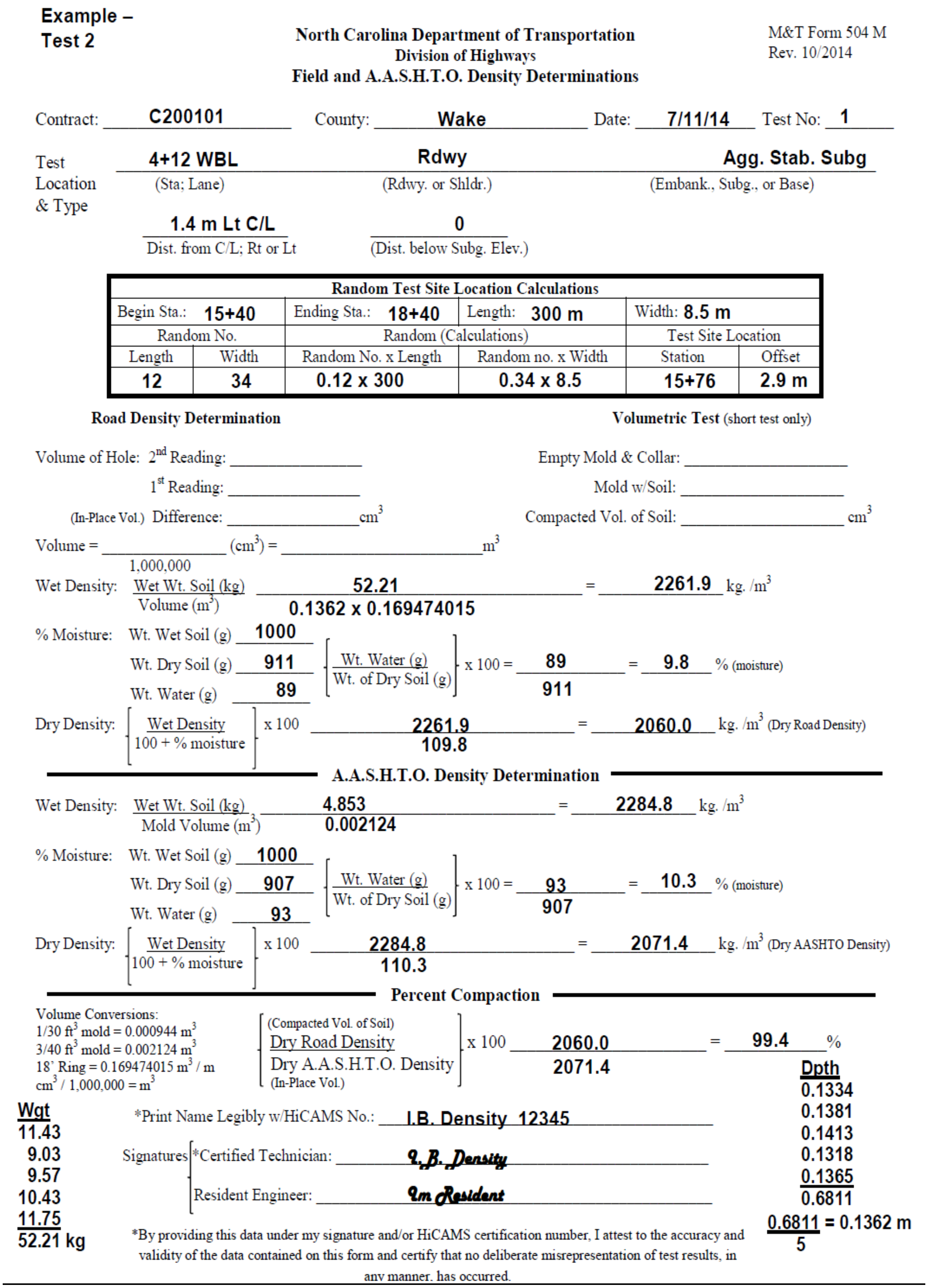
26.8125 / 5 = 5.3625"

*Print Name Legibly w/HiCAMS No.: I.B. Density 12345

Signatures
*Certified Technician: I. B. Density
Resident Engineer: Im Resident

*By providing this data under my signature and/or HiCAMS certification number, I attest to the accuracy and validity of the data contained on this form and certify that no deliberate misrepresentation of test results, in any manner, has occurred.

Figure 7 Example of Test 2 (English units)



Example – Test 2

North Carolina Department of Transportation
Division of Highways
Field and A.A.S.H.T.O. Density Determinations

M&T Form 504 M
Rev. 10/2014

Contract: **C200101** County: **Wake** Date: **7/11/14** Test No: **1**

Test Location & Type

4+12 WBL (Sta; Lane)

Rdwy (Rdwy. or Shldr.)

Agg. Stab. Subg (Embank., Subg., or Base)

1.4 m Lt C/L Dist. from C/L; Rt or Lt

0 (Dist. below Subg. Elev.)

Random Test Site Location Calculations					
Begin Sta.: **15+40**		Ending Sta.: **18+40**	Length: **300 m**	Width: **8.5 m**	
Random No.		Random (Calculations)		Test Site Location	
Length	Width	Random No. x Length	Random no. x Width	Station	Offset
12	**34**	**0.12 x 300**	**0.34 x 8.5**	**15+76**	**2.9 m**

Road Density Determination

Volume of Hole: 2nd Reading: ____

1st Reading: ____

(In-Place Vol.) Difference: ____ cm^3

Volume = ____ (cm^3) / 1,000,000 = ____ m^3

Wet Density: Wet Wt. Soil (kg) / Volume (m^3) = **52.21** / **0.1362 x 0.169474015** = **2261.9** kg. $/m^3$

% Moisture: Wt. Wet Soil (g) **1000**

Wt. Dry Soil (g) **911**

Wt. Water (g) **89**

[Wt. Water (g) / Wt. of Dry Soil (g)] x 100 = **89** / **911** = **9.8** % (moisture)

Dry Density: [Wet Density / 100 + % moisture] x 100 = **2261.9** / **109.8** = **2060.0** kg. $/m^3$ (Dry Road Density)

Volumetric Test (short test only)

Empty Mold & Collar: ____

Mold w/Soil: ____

Compacted Vol. of Soil: ____ cm^3

A.A.S.H.T.O. Density Determination

Wet Density: Wet Wt. Soil (kg) / Mold Volume (m^3) = **4.853** / **0.002124** = **2284.8** kg. $/m^3$

% Moisture: Wt. Wet Soil (g) **1000**

Wt. Dry Soil (g) **907**

Wt. Water (g) **93**

[Wt. Water (g) / Wt. of Dry Soil (g)] x 100 = **93** / **907** = **10.3** % (moisture)

Dry Density: [Wet Density / 100 + % moisture] x 100 = **2284.8** / **110.3** = **2071.4** kg. $/m^3$ (Dry AASHTO Density)

Percent Compaction

Volume Conversions:
1/30 ft^3 mold = 0.000944 m^3
3/40 ft^3 mold = 0.002124 m^3
18" Ring = 0.169474015 m^3 / m
cm^3 / 1,000,000 = m^3

[(Compacted Vol. of Soil) Dry Road Density / Dry A.A.S.H.T.O. Density (In-Place Vol.)] x 100 = **2060.0** / **2071.4** = **99.4** %

Wgt
11.43
9.03
9.57
10.43
11.75
52.21 kg

Dpth
0.1334
0.1381
0.1413
0.1318
0.1365
0.6811

0.6811 / **5** = 0.1362 m

*Print Name Legibly w/HiCAMS No.: **I.B. Density 12345**

Signatures *Certified Technician: I. B. Density

Resident Engineer: Im Resident

*By providing this data under my signature and/or HiCAMS certification number, I attest to the accuracy and validity of the data contained on this form and certify that no deliberate misrepresentation of test results, in any manner, has occurred.

Figure 8 Example of Test 2 (metric units)

Section 8 – Density Test 3

When the base course material is predominantly soil, the procedure outlined under Density Test 1 or 1-A shall be used. Coarse aggregate base course, that is, those soils having a high percentage of stone or gravel, will require a different procedure for the measurement of the degree of compaction. As in the determination of the degree of compaction of embankments and subgrades, the in-place density of each base course layer must be measured. The maximum dry density of Aggregate Base Course (ABC) will not be determined in the field. The GeoMaterials Laboratory performs an AASHTO T 180 moisture-density curve annually on ABC from quarries that are approved to sell material to the Department. The maximum dry density (or Unit Weight) and optimum moisture are maintained in a database and can be accessed by visiting the Materials and Tests website or calling the GeoMaterials Laboratory. When ABC material used on a particular project comes from a known source or quarry, the value of its maximum dry density as furnished by the GeoMaterials Laboratory will be reasonably constant for that source. However, if the date since previous AASHTO T 180 test was performed is approaching 12 months, a technician should routinely visit the Materials and Tests website to monitor the Unit Weight. Once the Unit Weight is updated, the new maximum dry density and optimum moisture content should be used as the Target Density. If a Contractor elects to use ABC from more than one source, care should be taken to avoid mixing the materials. While the ABC material is being placed a method of identifying the location of each material is necessary since the Unit Weight and optimum moisture of each material may be different.

Equipment Needed

The following equipment is necessary for the performance of Density Test 3.

Calibrated steel ring (18” outside diameter and 4 ½ inches to 9 inches deep)
Small pick
Scoop
Scales (with 2,000-gram weight)
Gas burner (with lighter)
Frying pan
Rule
Straight edge (36 inches long)
Large Spoon
Bucket (10-quart capacity)
Hammer
Wood Block (4x4 hard wood recommended)

Determining the In-place Dry Density

The calibrated steel ring is placed over the area to be tested and the base course material within the ring is carefully loosened with a pick and removed with the scoop. The material is placed in the bucket for weighing. As the material is removed, the ring is lowered to the full depth of the layer by striking the top of the wooden block with a hammer. After all material has been removed, the ring is removed from the base course layer and the thickness is carefully measured to the nearest one-sixteenth of an inch by placing a straight edge across the top of the hole and taking five or more measurements along opposing diameters (Refer to Diagram 3).

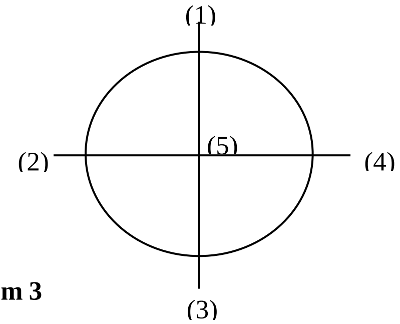


Diagram 3

From these measurements the average thickness of the layer is determined. Although the steel ring has an outside diameter of 18 inches, which theoretically would occupy a volume of 0.147 cubic feet per inch of depth, it has been found that its effective diameter is 18.3 inches, and it actually occupies a volume of 0.152 cubic feet per inch of depth. The volume in cubic feet occupied by the material is calculated by multiplying the average depth of the layer in inches by 0.152. Average depth of layer x 0.152 = cubic feet of base material. The wet density of the base course is calculated by dividing the weight of the material removed by its volume.

$$\text{Wet Density} = \frac{\text{Wet Wt. of Material in Pounds}}{\text{Volume of Material in Cubic Feet}}$$

The moisture content of the base material is determined by weighing out a minimum of 1,000 grams of the material and drying it out over the gas burner. Care must be exercised in drying the sample to avoid overheating. Overheating will result in an erroneous value of the moisture content. To prevent overheating, the aggregate mixture shall be dried over a low flame and shall be frequently stirred. The sample shall be removed from the flame immediately when it appears to be dry. The moisture content in percent of the dry material is calculated by the following formula:

$$\text{Moisture Content} = \frac{(\text{Wet Wt.} - \text{Dry Wt.})}{(\text{Dry Wt.})} \times 100$$

The dry density of the base course is calculated using the following formula:

$$\text{Dry Density} = \frac{(\quad \text{Wet Density} \quad)}{(100 + \text{Moisture Content})} \times 100$$

$$\text{Degree of Compaction \%} = \frac{(\text{Dry Density of Aggregate In-Place})}{(\text{Dry Density by Laboratory Test})} \times 100$$

Step-by-step Procedure for Performing Test 3

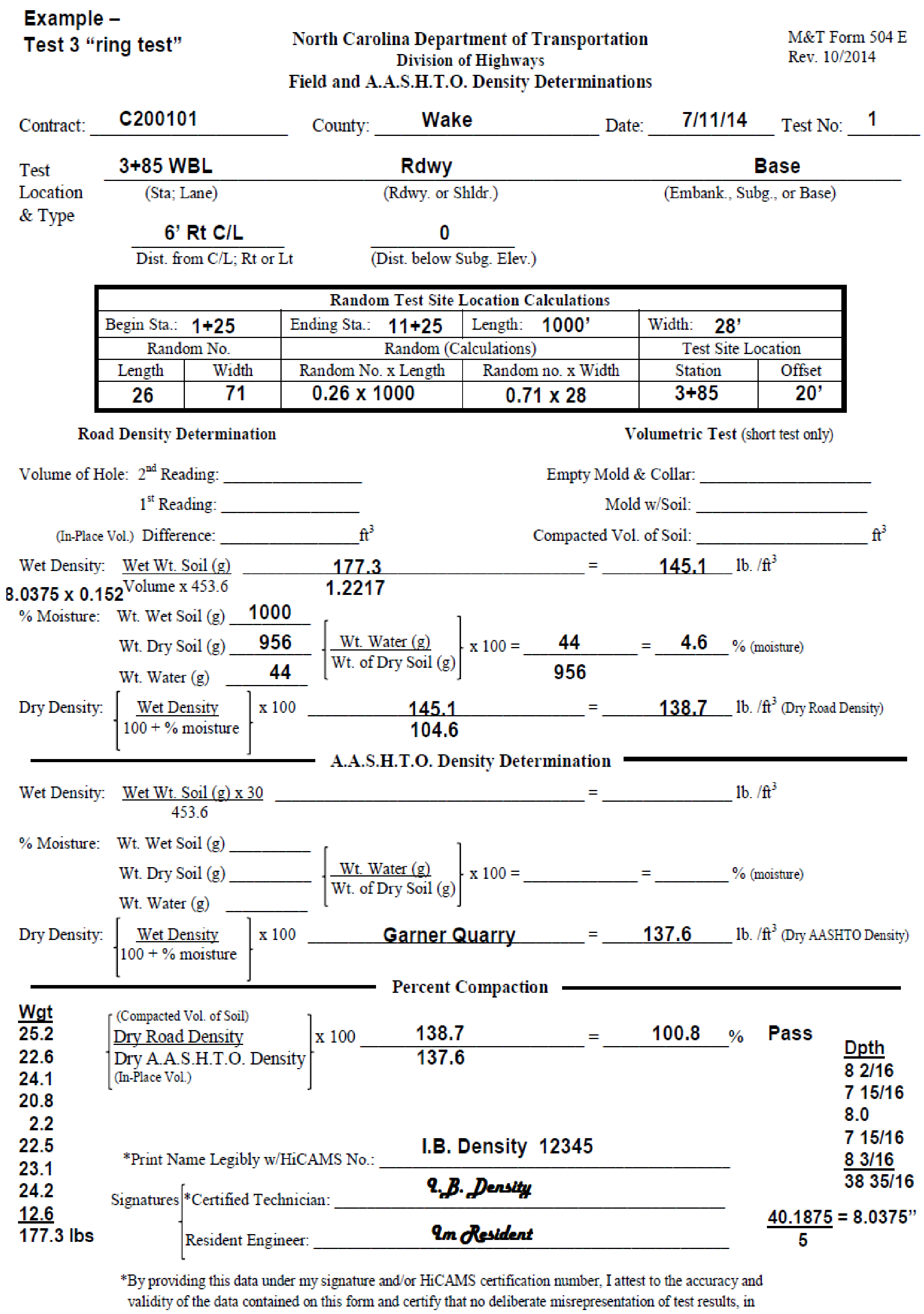
1. Level the scale.
2. Verify that the 2,000-gram weight reads as 2,000 grams on the scale, with a ±1 - gram tolerance.
3. Tare the bucket.
4. Place the sampling ring on the surface of the layer to be tested.
5. Using the pick loosen the material on the surface within the ring.
6. Remove the material and place in the bucket. Repeat 5-6 until bucket is 2/3^{rds} full. NOTE: Halfway through the layer, perform additional steps 6a to 6f for determining the in-place moisture content.

6a. Tare the weigh pan.
6b. Thoroughly mix the loose material in the ring.
6c. Obtain a 1,000-gram moisture sample. This is the sample for determining the in-place moisture content of the material.
6d. Dry the soil. When using a burner, be sure not to overheat the soil.
6e. Weigh the dry soil and record.
6f. Tare the bucket.

7. Weigh the material and record.
8. Dump the material on the ground (but do not discard!)
9. Lower the ring through the layer by striking the top of the wood block with the hammer.
10. Repeat steps 5 - 9 until the ring rests on the top of the next layer (the subgrade).
11. Remove the ring carefully.
12. Move to the side of the hole any loose material that has fallen during ring removal.
13. Take five measurements of the depth of the hole: one at the center of the hole and at four points equally spaced along the edge of the hole (that is, a measuring point is 90 degrees from an adjacent measuring point). All measurements will be to the nearest 16th of an inch. Calculate the average of the 5 readings – this will be the “depth” of the hole used for calculations.
14. Using the data recorded, follow the steps on M&T Form 504 for obtaining percent compaction.

Sources of Error for Test 3

1. Carelessness in measuring depth of density hole.
2. Forcing steel ring into base course.
3. Failure to mix material from hole before taking moisture sample.
4. Failure to place straight edge down to flat surface of base course when measuring depth of density hole.
5. Scales not level.



Example –
Test 3 "ring test"

North Carolina Department of Transportation
Division of Highways
Field and A.A.S.H.T.O. Density Determinations

M&T Form 504 E
Rev. 10/2014

Contract: C200101 County: Wake Date: 7/11/14 Test No: 1

Test Location & Type
3+85 WBL (Sta; Lane) Rdwy (Rdwy. or Shldr.) Base (Embank., Subg., or Base)
6' Rt C/L (Dist. from C/L; Rt or Lt) 0 (Dist. below Subg. Elev.)

Random Test Site Location Calculations					
Begin Sta.: 1+25		Ending Sta.: 11+25	Length: 1000'	Width: 28'	
Random No.		Random (Calculations)		Test Site Location	
Length	Width	Random No. x Length	Random no. x Width	Station	Offset
26	71	0.26 x 1000	0.71 x 28	3+85	20'

Road Density Determination

Volumetric Test (short test only)

Volume of Hole: 2nd Reading: ________
1st Reading: ________
(In-Place Vol.) Difference: ________ ft^3

Empty Mold & Collar: ________
Mold w/Soil: ________
Compacted Vol. of Soil: ________ ft^3

Wet Density: Wet Wt. Soil (g) / Volume x 453.6 — 177.3 / 1.2217 = 145.1 lb. $/ft^3$

8.0375 x 0.152

% Moisture: Wt. Wet Soil (g) 1000
Wt. Dry Soil (g) 956
Wt. Water (g) 44

[Wt. Water (g) / Wt. of Dry Soil (g)] x 100 = 44 / 956 = 4.6 % (moisture)

Dry Density: [Wet Density / 100 + % moisture] x 100 — 145.1 / 104.6 = 138.7 lb. $/ft^3$ (Dry Road Density)

A.A.S.H.T.O. Density Determination

Wet Density: Wet Wt. Soil (g) x 30 / 453.6 ________ = ________ lb. $/ft^3$

% Moisture: Wt. Wet Soil (g) ________
Wt. Dry Soil (g) ________
Wt. Water (g) ________

[Wt. Water (g) / Wt. of Dry Soil (g)] x 100 = ________ = ________ % (moisture)

Dry Density: [Wet Density / 100 + % moisture] x 100 Garner Quarry = 137.6 lb. $/ft^3$ (Dry AASHTO Density)

Percent Compaction

[(Compacted Vol. of Soil) Dry Road Density / Dry A.A.S.H.T.O. Density (In-Place Vol.)] x 100 138.7 / 137.6 = 100.8 % Pass

Wgt
25.2
22.6
24.1
20.8
2.2
22.5
23.1
24.2
12.6
177.3 lbs

Dpth
8 2/16
7 15/16
8.0
7 15/16
8 3/16
38 35/16

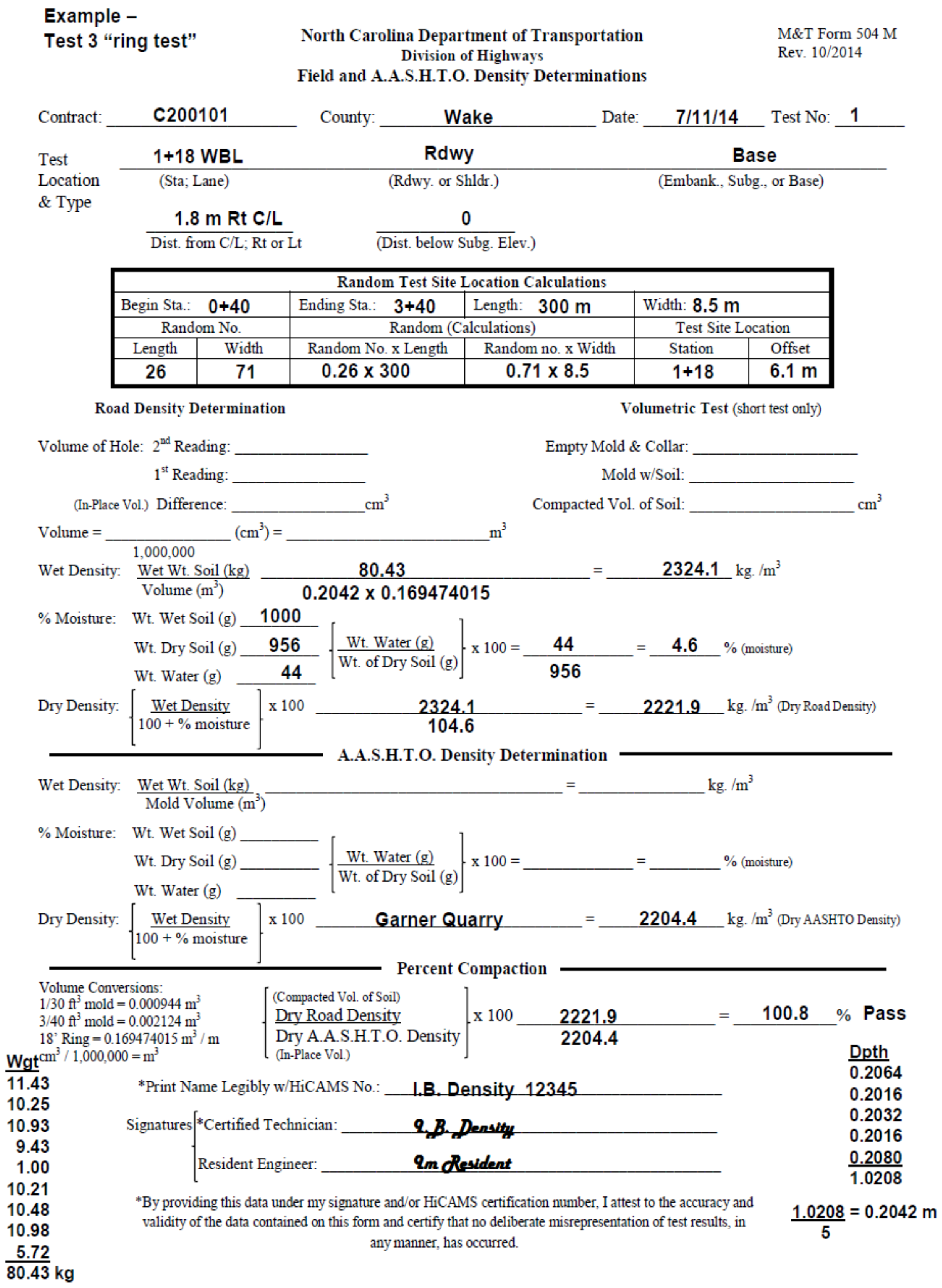
40.1875 / 5 = 8.0375"

*Print Name Legibly w/HiCAMS No.: I.B. Density 12345

Signatures
*Certified Technician: I. B. Density
Resident Engineer: Im Resident

*By providing this data under my signature and/or HiCAMS certification number, I attest to the accuracy and validity of the data contained on this form and certify that no deliberate misrepresentation of test results, in

Figure 9 Example of Test 3 "Ring Test" (English units)



Example –
Test 3 "ring test"

North Carolina Department of Transportation
Division of Highways
Field and A.A.S.H.T.O. Density Determinations

M&T Form 504 M
Rev. 10/2014

Contract: C200101 County: Wake Date: 7/11/14 Test No: 1

Test Location & Type: 1+18 WBL (Sta; Lane) Rdwy (Rdwy. or Shldr.) Base (Embank., Subg., or Base)

1.8 m Rt C/L (Dist. from C/L; Rt or Lt) 0 (Dist. below Subg. Elev.)

Random Test Site Location Calculations					
Begin Sta.: 0+40		Ending Sta.: 3+40	Length: 300 m	Width: 8.5 m	
Random No.		Random (Calculations)		Test Site Location	
Length	Width	Random No. x Length	Random no. x Width	Station	Offset
26	71	0.26 x 300	0.71 x 8.5	1+18	6.1 m

Road Density Determination

Volume of Hole: 2nd Reading: ________
1st Reading: ________
(In-Place Vol.) Difference: ________ cm^3
Volume = ________ (cm^3) / 1,000,000 = ________ m^3

Wet Density: Wet Wt. Soil (kg) / Volume (m^3) = 80.43 / 0.2042 x 0.169474015 = 2324.1 kg. $/m^3$

% Moisture: Wt. Wet Soil (g) 1000
Wt. Dry Soil (g) 956
Wt. Water (g) 44
[Wt. Water (g) / Wt. of Dry Soil (g)] x 100 = 44 / 956 = 4.6 % (moisture)

Dry Density: [Wet Density / 100 + % moisture] x 100 = 2324.1 / 104.6 = 2221.9 kg. $/m^3$ (Dry Road Density)

Volumetric Test (short test only)

Empty Mold & Collar: ________
Mold w/Soil: ________
Compacted Vol. of Soil: ________ cm^3

A.A.S.H.T.O. Density Determination

Wet Density: Wet Wt. Soil (kg) / Mold Volume (m^3) ________ = ________ kg. $/m^3$

% Moisture: Wt. Wet Soil (g) ________
Wt. Dry Soil (g) ________
Wt. Water (g) ________
[Wt. Water (g) / Wt. of Dry Soil (g)] x 100 = ________ = ________ % (moisture)

Dry Density: [Wet Density / 100 + % moisture] x 100 Garner Quarry = 2204.4 kg. $/m^3$ (Dry AASHTO Density)

Percent Compaction

Volume Conversions:
1/30 ft^3 mold = 0.000944 m^3
3/40 ft^3 mold = 0.002124 m^3
18" Ring = 0.169474015 m^3 / m
cm^3 / 1,000,000 = m^3

(Compacted Vol. of Soil) Dry Road Density / Dry A.A.S.H.T.O. Density (In-Place Vol.) x 100 = 2221.9 / 2204.4 = 100.8 % **Pass**

*Print Name Legibly w/HiCAMS No.: I.B. Density 12345

Signatures: *Certified Technician: I.B. Density
Resident Engineer: Im Resident

*By providing this data under my signature and/or HiCAMS certification number, I attest to the accuracy and validity of the data contained on this form and certify that no deliberate misrepresentation of test results, in any manner, has occurred.

Wgt
11.43
10.25
10.93
9.43
1.00
10.21
10.48
10.98
5.72
80.43 kg

Dpth
0.2064
0.2016
0.2032
0.2016
0.2080
1.0208

1.0208 / 5 = 0.2042 m

Figure 10 Example of Test 3 "Ring Test" (metric units)

Section 9 – Field Application of Test Methods

Except as noted elsewhere in this section, the “squeeze” test will be used to estimate the optimum moisture content of a soil. This method, if properly performed, can provide a value of optimum moisture content close to that obtained from a moisture-density curve performed on the same material. By using this method, a technician can rapidly determine if a Contractor is placing material at a moisture content that meets the requirements of the *Standard Specification* (Section 235; Page 2-23) which currently states:

> *Increase or decrease moisture content of the material before compacting to produce the maximum density that will provide a stable grade*

An important responsibility of the technician is to monitor the construction process to ensure compliance with this section of the Specifications. Since the optimum moisture content of a soil may change many times within any given area (due to changes in the soil type), to specify a definite range of moisture content would be difficult to enforce or document. The “squeeze” test on the other hand provides a rapid means of continually monitoring moisture content of the material as it is being placed. However, it must be performed properly, and if the technician has reason to question if the material is being placed at a moisture content outside the requirements of the Specifications, then he/she shall perform the necessary test or tests to support his/her estimate.

In the past, we have encountered a great deal of difficulty using the “squeeze” test for estimating optimum moisture. This difficulty may be due to a technician’s inability to perform the “squeeze” test properly but may also be due to the lack of a procedure to document the test and prove that the “squeeze” test results were reasonable. In order to aid the technician in checking results, the following procedure will be used:

1. One (1) out of every fifteen (15) tests will be a comparison test which will consist of performing Test 1 (long test) and a moisture-density curve.

2. For small projects which require less than 15 density tests a minimum of one Test 1 with a moisture-density curve must be performed.

3. Test 1-A will be permitted for the remainder of the tests.

4. In questionable situations, the technician should perform Test 1 and perform a moisture-density curve to assure that a reasonable accuracy in the “squeeze” test is being obtained.

5. The results of each comparison will be numbered and recorded in a field book or in a designated file in Sharepoint.

The above procedure will serve as a record of the technician's ability to estimate optimum moisture and as an aid to the technician in improving his/her ability to accurately estimate the optimum moisture content of a soil. The field book maintained by the technician shall be kept as shown in Table 3. A section for this information can be designated in the Project Density Diary or designated file in Sharepoint (refer to Section 11 in this manual).

Date	No.	Sta. Or Area Sample Obtained	Inspector	Test 1 Results: Estimated Optimum Moisture and Dry Density	Moisture-Density Curve: Optimum Moisture and Max. Dry Density

Table 3

It shall be the responsibility of the technician and the Resident Engineer to ensure the values obtained by this comparison are reasonably close. If the values obtained are not reasonably close, then the technician shall review his/her method of estimating optimum moisture by the "squeeze" test and make the necessary adjustments. If difficulty is encountered in obtaining reasonably close results, the technician shall notify the Resident Engineer who will request assistance from the Field Operation Section.

Provided a project meets certain requirements (described below), the Resident Engineer may, in lieu of the "One Point Proctor", use the following procedures:

1. Embankment areas constructed of borrow material - At the time samples of borrow material are submitted to the GeoMaterials Laboratory for approval, the Resident Engineer may request to develop moisture-density curves and use them in lieu of running the "One Point Proctor" (AASHTO portion of the long test). This approval by the GeoMaterials Laboratory would only be given if the material is reasonably uniform in composition. Upon approval by the GeoMaterials Laboratory, the Resident Engineer would develop moisture-density curves and use them as a basis for determining optimum moisture content and maximum dry density (target density). It shall be the responsibility of the Resident Engineer to ensure that enough check curves are performed to determine if the material has changed significantly. Each moisture-density curve shall be numbered consecutively, and the number shall be recorded on the density test report when it is used as the basis for the moisture determination.

2. Projects utilizing soil type base course material - The same procedures as outlined in number one above may be used.

3. Embankments constructed of excavated material of a uniform nature - If the Resident Engineer feels the material being excavated and placed in an embankment area is reasonably uniform, a moisture-density curve can be performed as described in number one above. The Resident Engineer must understand when following this

procedure that it is his/her responsibility to ensure that enough moisture-density curves are performed to determine that the material has not significantly changed.

If any of the above three procedures are followed, the AASHTO Determination shown on the bottom of the test report (M&T Form 504) will not be computed for each test that is performed, but the value obtained from the moisture-density curve will be used, and it shall be noted on the report. The use of Procedures 1, 2, or 3 described above will not eliminate the necessity for the technician to be able to perform the “squeeze” test properly. When utilizing this testing procedure, the technician will be required to perform and record the results of one Test 1 (long test) with a moisture-density curve for every fifteen (15) soil density tests (described in Section 9 of this manual).

Section 10 - Equipment

Maintenance and Care of Equipment

1. *Scales* - Scales should be kept in box when not in use to prevent damage and accumulation of dirt. Scales should also be kept out of rain and extremely dusty conditions. CHARGE THE SCALE BATTERY OVERNIGHT AT LEAST ONCE EVERY WEEK (whether the device is used or not). Do not use any chargers for charging the battery other than the one that was issued with the device.

2. *Volumeter* - The volumeter should be protected against breakage and freezing temperatures. When the volumeter is not to be used for an extended period of time, remove the balloon, drain the water, release pressure from set screw, and clean the device prior to placing it in storage. When a new volumeter is purchased, the base must be turned down 1/32 of an inch to fit inside the collar of the 1/30 cubic foot mold.

3. *Steel Density Rings* - The density rings should not be lowered into the base course by tapping with metal objects. The use of sledgehammers and other metal objects distorts the upper edge of the steel ring.

4. *Rammer* - Care should be exercised in compacting the top layer of soil in the mold to avoid striking the mold collar.

5. *Gas burners* should be handled with care to avoid denting or breaking the container or damaging the valves. Follow OSHA Regulations when operating, handling or transporting LP tanks and NEVER transport a gas burner while it is attached to the LP tank.

Checking Accuracy of Equipment

1. *Volumeter* - Accuracy may be checked by measuring the volume of a 1/30 cubic foot mold. The first reading should be taken on a flat surface and the second reading over the mold. This procedure should be performed three times and the measurements averaged to obtain the volume check (0.0333 +/- 0.003 cu. ft.).

2. *Scales* - Accuracy of scales may be checked by weighing objects of known weight. This may be done by weighing various combinations of the weights. (Example: 1,000-gram weights vs. 2 – 500-gram weights, 2,000-gram weights vs. 2 - 1,000-gram weights). The scale should be at a near-level position when in use.

3. *Rammer* - The rammer used in performing Test Method AASHTO T 99 should weigh 5.5 pounds (2,495 grams +/- 9 grams) and have a free fall of 12 inches (+/- 1/16 of an inch). The weight of the rammer may be checked by removing it from the sleeve and placing on a scale. The fall may be checked by placing the rammer at its maximum height in the sleeve and measuring the interior distance between the bottom of the rammer and the end of the sleeve.

Section 11 – Documentation Instructions at Project Level

Conventional density acceptance tests shall be performed by a technician with a valid Conventional Density Testing Certification issued by the Department. The standard report form entitled, "Field and AASHTO Density Determinations" (M&T Form 504), is used to record all density determinations. If properly equipped and trained the test data should be entered into the Sharepoint system. At the time the density test is performed, the technician shall fill out an original or enter the test data into Sharepoint. If test results are maintained in paper format a copy shall be retained by the Resident Engineer. If the test data/results are entered into Sharepoint and HiCAMS, copies of the density test reports are not to be sent to Materials and Tests. However, the reports must be sent to Materials and Tests for reviewing if requested by a Materials and Tests representative.

Each report is to be numbered consecutively according to the type of material (i.e. embankment, subgrade, pipe backfill, etc.) being tested. When a check test is necessary, it shall carry the number of the original test that failed, plus an alphabetical designation. An example of this system of numbering would be: First embankment density test would be No. 1. All subsequent embankment density tests would carry consecutively higher numbers (i.e. 2, 3, 4, 5, etc). If embankment density test No. 32 failed, and a check test was completed, the check test would be numbered 32A. If on the same project, the Contractor begins constructing the subgrade, the first density test performed on the subgrade would be number 1.

All reports, including those showing densities below those required by the Specifications, are to be submitted and entered into HiCAMs and Sharepoint. When a density test is completed, and it fails to meet the minimum requirements of the Specifications, there are two approaches that can be taken:

1. The Contractor is required to perform corrective action and then a check test is performed within five feet of the original test. In this case the corrective action taken by the Contractor will be described on the bottom of the test report made for the check test.
2. The Resident Engineer may consider the area in question as being acceptable without any additional work being required of the Contractor to bring the density to values required by the Specifications. In this situation the Resident Engineer will apply Section 105-3 of the *Standard Specifications* and place a statement at the bottom of the report describing why he/she considers the results as being acceptable. Once the comment is added, the Resident Engineer shall sign the test report.

There is sufficient information provided on the report form to plot the locations of the density tests. This may be desirable on larger, more complex projects, but is not required. However, the Resident Engineer shall ensure that the minimum testing frequency as stated in the "Minimum Sampling Guide" or listed in this manual (refer to Section 2) is obtained.

In addition to the required information shown on the report form, the technician shall note on the report those densities that are performed on pipe backfill and structure backfill. A sufficient number of these tests shall be performed to ensure that a Contractor's backfilling operations are acceptable.

If, while performing a density test, the technician encounters enough rock to prevent the accurate completion of Test 1, 1-A, and 2, then he/she shall fill out the report (M&T Form 504) by placing as much information as possible. The technician should also note on the bottom of the report that the density test(s) could not be run due to rock. This report would then be handled in the same manner as all other reports.

Upon completion of each density report, a summary of the results should be entered into the Project Density Logbook. An example of a typical Logbook is provided in Table 4 below. The Logbook serves as a quick reference guide for all density tests performed on a project and can be utilized to ensure enough tests are being performed, the number sequences are correct and if enough "long tests" with curves are being performed. Each type of material requiring a density test should be listed in a separate section. For example, separate sections would be created for a project with density test(s) in each of the following material classifications: Embankment, Pipe Backfill, Subgrade, Lime Stabilized Subgrade, Cement Stabilized Subgrade, etc. These sections will be prepared in the following manner:

Contract Number: __________________
Project Number: ___________________
Type of Material: __________________
County: __________________________

Test #	Sta.	C/L offset (Lt. or Rt.)	Dist. Below Subgrade	Material Type	Test Type	Date	% Comp.	Initials	Pass / Fail	Remarks

Table 4

HICAMS Data Entry

All density tests performed must be entered into the HiCAMS database. Since this database is utilized for project certification, results must be entered correctly to ensure accuracy when completing the final certification. Procedures for data entry into this system are beyond the scope of this manual. For assistance, consult the person in your office who has been trained in HiCAMS.

Section 12 – Instruction for Independent Assurance

Since all Independent Assurance (I.A.) density tests are comparative tests, it is imperative that I.A. density tests be performed as accurately as possible. Tests shall be performed in accordance with the procedures outlined in the test method applicable to the material. If there should be a deviation from the prescribed procedures, the results will not be accepted.

Confidence limits were established for each comparative test. If the difference is outside the Excellent/Good confidence limits, it will be considered as a Fair/Poor correlation and an investigation will be required in order to determine the reason(s) for the discrepancy. In addition, the following instructions shall apply to all I.A. density tests.

1. The M&T technician shall locate the project technician performing acceptance density tests and assess the project personnel's ability to perform the test.

2. The M&T Technician shall perform a comparative test within 5 feet of the acceptance test site.

3. Once the M&T technician has completed the test and has obtained results from the technician's acceptance test, he/she shall fill out the conventional density assessment form as explained below:

    A. When designating type of material the M&T technician shall use ABC, CTBC, Subgrade, Lime Stabilized Subgrade, Cement Stabilized Subgrade, Aggregate Stabilized Subgrade, or Embankment.

    B. For Conventional Density tests 1-A, the M&T technician shall record the percent compaction only; put a dash in all other spaces. For ABC, the M&T technician shall record the in-place Dry Density (lbs. / ft.^{3}) and percent compaction. For all other Conventional Density Tests, the M&T technician shall record all the required information.

4. On each visit to a project, the M&T technician shall complete a project report M&T Form 901, showing tests made and samples taken. This report shall be signed by the technician or the Resident Engineer and the M&T technician, and a copy shall be left with the technician or Resident Engineer for inclusion in the project files.

<u>Test Results Evaluation Procedure</u>

Once the test results and other pertinent information have been recorded on the correlation sheets, the difference between I.A. and acceptance test results will be computed by subtracting one from the other. The next step consists of looking in the Confidence Limits Table for the particular material being evaluated and comparing the difference with the established limits. The difference is then rated as Excellent, Good, Fair or Poor. If the difference is outside the Excellent/Good confidence limits, it will be considered as a Fair/Poor correlation and an investigation will be required in order to determine the reason(s) for the discrepancy.

Confidence Limits Table: Aggregate Base Course

Properties	Sign	Excellent Maximum Limit	Good Maximum Limit	Fair Maximum Limit
% - Compaction	+/-	2.4	3.1	3.9

Table 5

Confidence Limits Table: Subgrade and Embankment

Properties	Sign	Excellent Maximum Limit	Good Maximum Limit	Fair Maximum Limit
In-Place dry density (PCF)	+/-	3.2	4.1	5.0
Estimated Optimum Moisture Content (%)	+/-	1.6	2.1	2.5
AASHTO T-99 dry density (PCF)	+/-	1.9	2.4	2.9
Percent Compaction	+/-	2.4	3.1	3.8

Table 6

Section 13 – Responsibilities of Project Personnel in Conjunction with Independent Assurance Personnel

Materials Technicians are representatives of the Materials and Tests Unit whose duties and responsibilities are to take comparative samples of and perform comparative tests with project personnel on all projects. Each time a Materials Technician visits a project, they are required to fill out a report (M & T Form 901) and leave a copy with project personnel. There is a place on the report for either the Resident Engineer or the technician to sign. The signature of the project representative signifies that the project personnel know an I.A. sample has been taken, and the project personnel as an individual, accepts the results of the test as being reasonable.

Project personnel must furnish whatever information is necessary to the Materials Technician. For density testing this information would include: (1) Location and results of project acceptance tests. (2) Any other information, such as changes that would affect the results of the tests. This does not mean that project personnel are to direct the M&T technician as to where the samples and/or tests are to be performed. This determination is the responsibility of the M&T technician.

Upon receipt of a copy of a Materials Technician test report, project personnel should attach it to the related project acceptance test and place both tests in the project files. It is the responsibility of the Resident Engineer to furnish this information to the M&T representative.

Section 14 – Determining Random Test Site Locations

In order to prevent biased testing random numbers are used to calculate test sites. Use the table of random numbers provided in Appendix B - Random Numbers to calculate test locations. Determination of test sites is completed in two dimensions by locating a station (length) and a pull (or offset) distance from the edge (width). Refer to the following steps for an example of calculating test site in a fill area or embankment.

Plan View (Embankment)

For this example, the fill area is 150 feet wide from toe of slope to toe of slope and begins at station 10+50 and ends at station 20+30. The total length of the fill area is 980 feet (2030 – 1050 = 980 feet). Refer to the following steps to randomly determine a test site within the embankment.

1. Refer to random number tables in Appendix B of this manual to determine random number multipliers. In this example the random numbers are:
   8121
2. Calculate the random length location by using the first two digits and placing a decimal in front of the number. The formula is as follows:
   Random Number x Length of Fill Area
   For this example: **0.81 x 980 feet = 793.8 or 794 feet**
3. Calculate the random width (offset) location by using the last two digits and placing a decimal in front of the number. The formula is as follows:
   Random Number x Width of Fill Area
   For this example: **0.21 x 150 feet = 31.5 or 32 feet**
4. Add 794 feet to 10+50 to determine the station of the test site
   For this example: **1050 + 794 = 1844 or Station 18+44**
5. Determine offset distance (can pull from right or left of embankment but must be consistent)
6. Reference offset distance from the Center Line (recorded on M&T 504 Form).
7. Record random number and calculations used for determining test site on the density report form (M&T 504).
8. Repeat this procedure for each density test performed

Section 15 – Ethics / Falsification

Ethics has the following definitions when referenced in a dictionary:

1. A principle of right or good behavior
2. A system of moral principles or values
3. The study of general nature of morals and the specific moral choices an individual makes in relating to others
4. The rules or standards of conduct governing the members of a profession

In order to the maintain trust of the general public, the Department has implemented an Ethics Policy and the latest version is as follows:

North Carolina Department of Transportation

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ETHICS POLICY

~~~~~~

Preamble

The holding of a public office by appointment or employment is a public trust. Independence and impartiality of public officials and employees of the Department of Transportation are essential to maintain the confidence of our citizens.

The members of the Board of Transportation, officers and employees of the North Carolina Department of Transportation have a duty to the people of North Carolina to uphold the public trust, prevent the occurrence of conflicts of interest, and endeavor at all times to use their position for the public benefit.

To this end, members of the board, officers, and employees of the Department of Transportation shall ensure that an atmosphere of ethical behavior is promoted and maintained at all times.

Introduction

The major transportation functions of the North Carolina Department of Transportation (NCDOT) include highways, public transportation, motor vehicles, railways, bicycles, pedestrian facilities, aeronautics and ferries. The NCDOT is statutorily responsible for providing the necessary planning, construction, maintenance, and operation of an integrated statewide transportation system for the economical and safe transportation of people and goods as provided for by law, including the registration of transportation vehicles and driver’s license. It is in the public interest to establish policies on ethical conduct which set forth a code of behavior to be followed by employees of the NCDOT that is consistent with federal and state laws, as well as related Department policies. These policies on ethical behavior are intended to guide the actions of all employees of NCDOT.

Employees of the NCDOT are expected to maintain and exercise the highest ethical standards of conduct in the performance of their duties and responsibilities, and as a condition of employment shall abide by this policy. Employees of the NCDOT are expected to conduct themselves in a manner that prevents all forms of impropriety, to

include but not limited to, placement of self-interest above public interest, partiality, prejudice, favoritism and undue influence.
This policy applies to all employees of the NCDOT and shall be brought to the attention of each employee during orientation and through annual training by Human Resources. Failure to comply with this policy will be grounds for disciplinary action up to and including dismissal.

Definitions

1. Conflict of interest -

A conflict of interest arises when an employee's private interest, usually of a personal, financial or economic nature, conflicts or creates the appearance of a conflict with the employee's public duties and responsibilities.

2. Gift -

A gift is anything of value given without compensation.

3. Favor -

A favor is any opportunity, service, accommodation, use of facility, or other benefit made available for less than fair market or normal value given in exchange for being influenced in the discharge of one's duties and responsibilities.

4. Employee -

Employee for the purposes of this policy shall mean both State officer and employee holding an office or employment with the North Carolina Department of Transportation.

5. Family -

Family for the purposes of this policy includes spouse, you and your spouse's children, parents, in-laws, step-parents, step-child, step-sibling, grandchildren, brother, sister, uncle, aunt, first cousin, also any dependent person living in the same household.

I. Conflict of Interest

No employee shall have any interest, financial or otherwise, direct or indirect, or engage in any business, transaction or activity that is in conflict or could appear to be in conflict with the proper discharge of his or her duties. An appearance of a conflict of interest exists when a reasonable person would conclude from the circumstances that the employee's ability to protect the public interest, or perform public duties, is compromised by personal interest. Examples of conflict of interest are as follows:

A. Misuse of Official Position

No employee shall use or attempt to use his or her position with the NCDOT to secure unwarranted privileges or advantages for himself, herself or others.

B. Contracts and Purchasing Order Agreements

No employee authorized to draft, negotiate, administer, accept or approve any contract, subcontract or purchase order agreement on behalf of the State, or any member of his/her family, shall have, directly or indirectly, any financial interest in such contract, subcontract or purchase order agreement.
In an effort to avoid the appearance of impropriety while conducting the public's business, employees will be restricted from accepting any employment or engaging in any relationship following their

employment with NCDOT with any business entity in connection with any contract, subcontract or purchase order agreement that they participated in any of the following activities:

1. Drafting the contract, subcontract or purchasing order agreement;
2. Defining the scope of the contract, subcontract or purchasing order agreement;
3. Selection of the business entity for services;
4. Negotiation of the cost of the contract, subcontract or purchasing order agreement, including calculation of man-hours, fees or extent of services;
5. Administration of the contract or purchase order agreement.

This section is not intended to prohibit employment with a business entity if the employment is on work other than the specific contract, subcontract or purchase order agreement with which they were involved. An exception to this section of the policy may be granted when recommended by the Secretary of Transportation and approved by the Board of Transportation.

C. Real/Personal Property

No employee or member of his/her family shall use an employee's position to profit from, directly or indirectly, an interest in real or personal property.

D. Business Opportunities

No employee or member of his/her immediate family shall accept any business or professional opportunity when such person knows, or reasonably should know, that the opportunity is being afforded to them with the intent to influence the performance of the employee's official duties.

E. Outside Employment and Activities

In accordance with NCDOT Secondary Employment policy, the employment responsibilities to the State are primary for any employee working full-time and and other employment in which that person chooses to engage is secondary. An employee shall have the approval from the division, branch or unit manager before engaging in any secondary employment.

No employee shall accept employment or render services for any private or public interest when that employment or service is in conflict with the discharge of his or her official duties or when that employment may tend to impair his or her objectivity or independence of judgment in the performance of such duties or induce them to disclose confidential or any information gained through their State duties.

F. Use of Information

No employee shall, directly or indirectly, use, disclose, or allow the use of official information which was obtained through or in connection with his or her official duties and which has not been made available to the general public for the purpose of furthering the private interest or personal profit of any business entity or person, including the employee.

II. Gifts and Favors

No employee shall knowingly, directly or indirectly, ask, accept, demand, exact, solicit, seek, assign, receive, or agree to receive anything of value for the employee or for another person, in return for being influenced in the discharge of the employee's duties and responsibilities.

No employee shall solicit for a charitable purpose a gift from a subordinate employee, except as provided in NC General Statute, Section 138A-32 (b).

No employee shall solicit or accept, directly or indirectly, on behalf of himself or herself or family member, any gift or favor from a contractor, subcontractor, vendor, supplier, lobbyist or any other individual or other business entity that:

1. Has or is seeking to obtain contractual or other business or financial relations with the Department;
2. Conducts operations or activities that are regulated by the Department;
3. Have interests that may be substantially affected by the performance or non-performance of the employee's official duties.

Exceptions to this section, gifts and favors, are noted in NC General Statute, Section 138A-32 (e).

Any such gift or favor received from a contractor, subcontractor, supplier, lobbyist or any other individual or other business entity must be reported and remitted immediately through the appropriate chain of command to the Secretary of Transportation.

III. Consultation

Employees are urged to consult with the Division of Human Resources, Classification, Compensation & Policy Unit staff when an ethical question arises under this policy.

IV. Distribution and Training of Ethics Policy

A copy of this policy will be presented to all new employees at the time of employment and posted in a conspicuous place throughout the Department and made available on the NCDOT web site.

Training shall be provided by Human Resources every other year.

V. Enforcement and Compliance

This policy will be enforced by the Secretary of Transportation. Failure to comply with the above policy will be grounds for disciplinary action up to and including dismissal from employment with the NCDOT. Conflicts of interest or unethical behavior that defrauds the Department, vendor, contractor, subcontractor, or supplier may also be violations of criminal law and may result in criminal prosecution.

VI. Disclosures

Any employee who identifies a conflict of interest shall disclose the same promptly in writing through appropriate management channels to the Secretary of Transportation.

Falsification

North Carolina State Law G.S. Chapter 136 Roads and Highways
13.2 Falsifying highway inspection reports

(a) Any person who knowingly falsifies any inspection report or test report required by the Department of Transportation in connection with the construction of highways shall be guilty of a Class H Felony.
(b) Any person who directs a subordinate under his direct or indirect supervision to falsify an inspection report or test report required by the Department of Transportation in connection with the construction of highways shall be guilty of a Class H Felony.

Punishment for a Class H Felony can result in up to 10 years in jail, up to $10,000.00 in fines or both.

Federal Law Title 18-Crimes and Criminal Procedure
Part I – Crimes
Chapter 47 – Fraud and False Statements
Section 1020. Highway Projects

Whoever, being an officer, agent, or employee of the United States, or of any State or Territory, or whoever, whether a person, association, firm, or corporation, knowingly makes any false statement, false representation, or false report as to the character, quality, quantity, or cost of the material used or to be used, or the quantity of the work performed or to be performed, or the costs thereof in connection with the submission of plans, maps, specifications, contracts, or costs of construction of any highway or related project submitted for approval to the Secretary of Transportation; or Whoever knowingly makes any false statement, false representation, false report, or false claim with respect to furnished or to be furnished, in connection with the construction of any highway or related project approved by the Secretary of Transportation; or

Whoever knowingly makes any false statement or false representation as to a material fact in any statement, certificate, or report submitted pursuant to the provisions of the Federal-Aid Road Act approved July 11, 1916 (39 Stat. 355), as amended and supplemented,
Shall by fined under this title $10,000.00 or imprisoned not more than five years, or both.

Falsification of Records is defined as the changing or misrepresentation of Data or Tests. Falsification also includes the destruction of alteration of records.

Section 16 - Conclusion

There may be instances where difficulties will be encountered that the project personnel may need assistance in solving. If this occurs, the Resident Engineer should contact the Technical Trainer in their area and request assistance. If, in the event the results obtained by the Materials Technician and project acceptance samples/tests are not in reasonably close agreement, the two groups of individuals performing the testing must meet and try to determine why the difference exists. If they are unable to arrive at a solution, the Field Services Engineer shall be notified, and whatever steps are necessary to arrive at a solution will be taken. Below is a chart that provides the general ranges of optimum moisture and maximum dry density for the major soil types. This chart is general and there may be individual soils that, while having the same general characteristics, may fall outside the values given in the chart. This chart is furnished for information purposes only and is not to be used in any other manner.

AASHTO Classification	Visual Description	Maximum Dry Weight (lb/ft^3)	OMC Range
A-1	Granular Materials	115-142	7-15
A-2	Granular Materials/Soils	110-135	9-18
A-3	Fine Sand and Sand	110-115	9-15
A-4	Sandy Silts and Silts	95-130	10-20
A-5	Elastic Silty Clay	85-100	20-35
A-6	Silt-Clay	95-120	10-30
A-7-5	Elastic Silty Clay	85-100	20-35
A-7-6	Clay	90-115	15-30

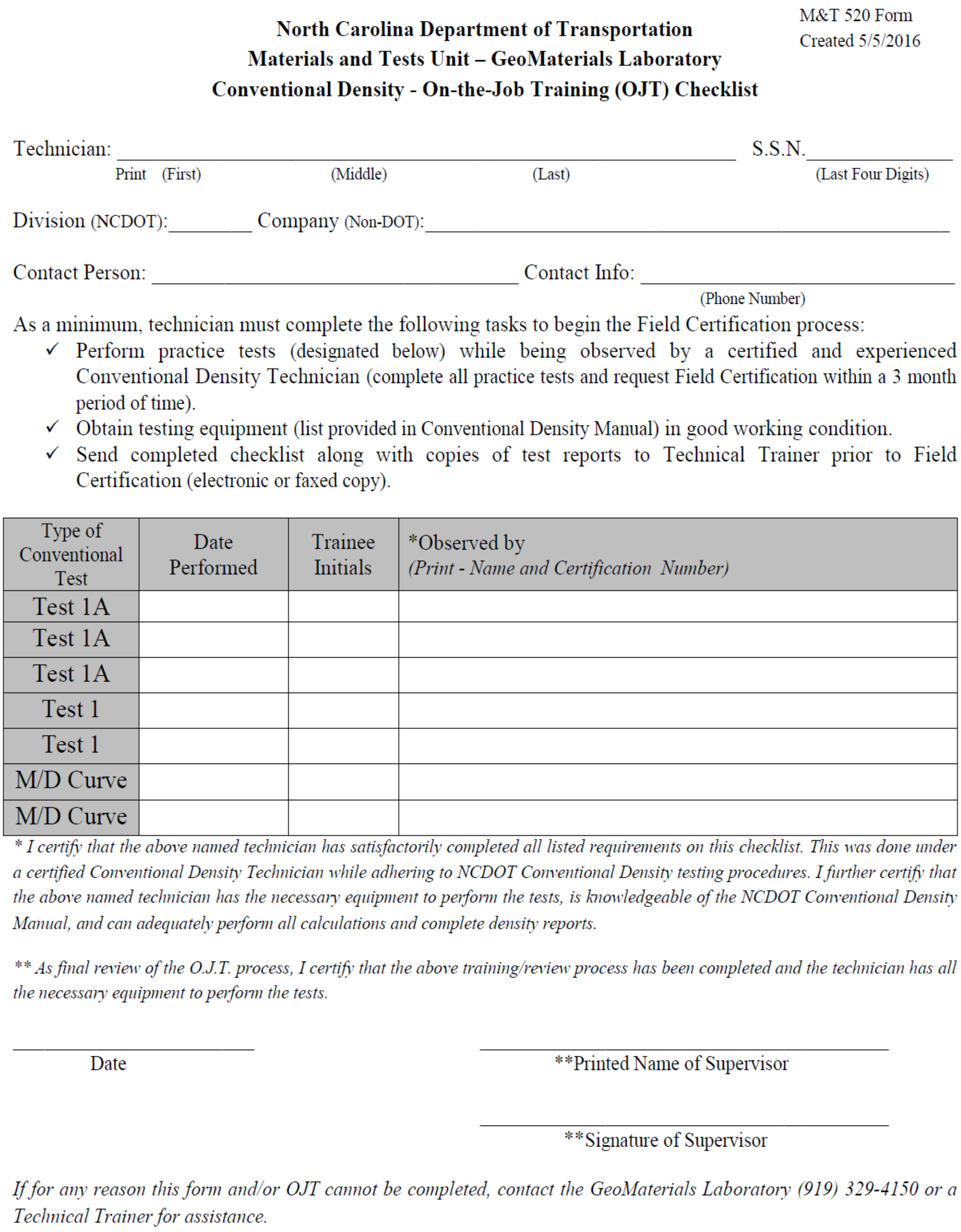
Table 7

Appendix A – Certification Process

A "Pending" certification status will be granted to individuals completing the Conventional Density class the first time. In order to complete the certification process and obtain an "Active" status, the individual must complete the following:

- Successfully complete the Conventional Density course with passing exam
- Complete OJT requirements
    - Perform practice tests to become familiar with equipment and proper procedures
    - As a minimum perform: 3 – Test 1A, 2 - Test 1 and 2 M/D Curves
    - Tests must be documented on OJT Form (M&T Form 520) and signed off by certified technician
    - Supervisor or Final Review Technician must sign off confirming completion
- Supervisor should contact the local Technical Trainer to schedule a *Field Certification*
    - Completed OJT Form and test report forms must be submitted to the Technical Trainer for review
- Technician must have the necessary equipment (in good working condition) to perform tests
- Technical Trainer will observe the individual perform tests
- Depending on the individual's abilities and performance, one of the following will occur
    - Trainer determines the individual has the minimum competency to perform the tests, and grants an "Active" certification
    - Trainer determines the individual does not have the minimum competency and may perform additional training or request the individual perform additional practice
        - Another appointment may be required to complete the Field Certification process
- Trainer will grant an assessment rating of either satisfactory or unsatisfactory depending on individual's abilities and performance
    - If an unsatisfactory rating is granted, another assessment will be required within 10 days

For individuals completing the Conventional Density class to re-new their certification, the Technical Trainer will review the individual's test history and assessment results. Based on the data, the Trainer will grant either "Active" or "Pending" status. If "Pending" status is granted the individual will be required to complete the Field Certification process including the OJT requirement. A copy of the OJT (M&T 520 Form) is provided on the following page.



M&T 520 Form
Created 5/5/2016

North Carolina Department of Transportation
Materials and Tests Unit – GeoMaterials Laboratory
Conventional Density - On-the-Job Training (OJT) Checklist

Technician: ____ S.S.N.__________
Print (First) (Middle) (Last) (Last Four Digits)

Division (NCDOT):________ Company (Non-DOT):____________________________________

Contact Person: ___________________________ Contact Info: ______________________
(Phone Number)

As a minimum, technician must complete the following tasks to begin the Field Certification process:

- ✓ Perform practice tests (designated below) while being observed by a certified and experienced Conventional Density Technician (complete all practice tests and request Field Certification within a 3 month period of time).
- ✓ Obtain testing equipment (list provided in Conventional Density Manual) in good working condition.
- ✓ Send completed checklist along with copies of test reports to Technical Trainer prior to Field Certification (electronic or faxed copy).

Type of Conventional Test	Date Performed	Trainee Initials	*Observed by *(Print - Name and Certification Number)*
Test 1A			
Test 1A			
Test 1A			
Test 1			
Test 1			
M/D Curve			
M/D Curve			

** I certify that the above named technician has satisfactorily completed all listed requirements on this checklist. This was done under a certified Conventional Density Technician while adhering to NCDOT Conventional Density testing procedures. I further certify that the above named technician has the necessary equipment to perform the tests, is knowledgeable of the NCDOT Conventional Density Manual, and can adequately perform all calculations and complete density reports.*

*** As final review of the O.J.T. process, I certify that the above training/review process has been completed and the technician has all the necessary equipment to perform the tests.*

______________________ ______________________________
Date **Printed Name of Supervisor

____
**Signature of Supervisor

If for any reason this form and/or OJT cannot be completed, contact the GeoMaterials Laboratory (919) 329-4150 or a Technical Trainer for assistance.

Appendix B – Random Numbers

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	0	1	2	3	4	5	6	7	8	9
1	8121	3695	7367	7390	8568	9550	3107	3589	8240	3059
2	4185	5885	0699	3204	5610	3896	1692	2695	3354	9693
3	7423	7796	3747	8271	6052	8188	7913	4975	2525	3610
4	9153	3997	4351	5758	1611	0736	9949	9995	0791	5927
5	1617	6057	8761	8397	9092	0148	6552	7139	1588	0437
6	8760	3170	1224	4708	0815	7609	6584	4617	7047	6426
7	3588	2066	9567	9292	0174	4935	8792	5666	4876	7563
8	8103	5156	3440	4230	5757	5140	6858	5421	1223	8256
9	8871	2553	7202	1987	6385	6288	0497	0593	6161	1683
10	2558	2199	3805	9831	2606	0624	2742	6778	8157	3922
11	1647	1685	0752	8003	8052	2455	7920	1365	4418	6671
12	3135	8556	7712	6194	0847	4364	8858	2267	9994	4963
13	1724	3556	1740	5269	4034	9277	5271	2460	6228	9373
14	2328	3165	8382	7037	2065	4960	8404	6799	5599	9198
15	1350	8343	8993	2840	3880	6539	5501	9722	8424	2622
16	7427	7379	3549	1647	4225	0282	9025	2254	3500	7996
17	7022	0294	6714	9525	0941	3820	4074	8394	2468	9783
18	8582	9671	1036	5445	2233	6034	4240	2131	8345	7991
19	1345	4065	8880	5665	0032	7527	0726	8775	4522	2962
20	3849	0739	2216	6402	3115	4240	6081	2627	2578	9722
21	2250	7900	4486	2135	5081	2413	3685	5667	7988	4918
22	1078	4157	4885	8291	3507	0345	5105	9547	0599	5050
23	6836	1367	4019	5421	6796	1270	9592	0791	5013	5774
24	0978	2451	6865	3278	1912	7451	1343	8765	4038	9477
25	7835	8049	9898	8251	1842	7846	9007	9482	6945	6260
26	4356	9453	8545	5332	0915	6979	2074	2311	9361	8185
27	9158	3851	2403	5209	3580	1300	6650	3150	9335	5735
28	4316	7272	4590	6287	6553	9722	0058	0401	3953	8653
29	5549	7531	1942	3645	5393	0629	6401	3296	0927	2436
30	6446	5760	6850	8674	5189	9503	9662	6626	6170	8798
31	5533	5470	4593	4133	3524	9750	6566	4050	3014	9224
32	7379	0162	5237	1777	9430	2462	3288	5292	3377	8172
33	1664	5435	8368	3431	0291	8455	0159	9895	5849	5898
34	5630	6913	4948	7774	3575	0962	3186	9191	9381	0363
35	6847	7886	3963	8404	0751	0896	2633	9154	3847	5726
36	0950	4958	0297	1385	1083	8430	7831	4219	7010	1479
37	1363	4546	0731	3425	7256	0680	1903	7998	6275	1711
38	1184	2079	7299	9090	3535	3001	2088	1327	7482	8025
39	0736	5980	7034	6469	8688	6732	0461	5775	1210	7049
40	2673	8834	8132	0201	3634	0894	0819	6503	2522	6862
41	9059	7950	3589	1176	0131	8472	6691	6129	3032	5897
42	1605	7970	6152	4179	3269	1914	1468	9593	0850	2435
43	6865	3708	4096	0209	0469	7307	3216	3367	7560	9979
44	2379	2554	9753	2693	4604	8478	7480	7997	0441	8842
45	9821	7026	1331	3689	6738	8468	4876	5971	3939	2112
46	2140	9626	9884	3633	7163	5128	1821	9941	8127	5608
47	5432	6779	6373	6790	0845	7405	1457	6813	2481	6026
48	3460	8006	3670	6930	0523	5017	6487	1702	9237	1591
49	5265	7029	8790	6612	1052	8625	7070	3711	9177	8296
50	4271	3777	0048	6319	8807	0362	4318	9076	3108	2183

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	0	1	2	3	4	5	6	7	8	9
51	4724	4526	5407	2546	8332	4853	4422	1499	4129	5573
52	1277	8872	2569	9657	2544	8421	8617	8572	8662	1449
53	7992	6889	3350	1842	3408	8162	9357	5693	8528	4256
54	1908	4882	1892	0335	0131	9624	1024	5572	0089	4228
55	9525	7954	0657	9898	1340	9036	8409	3500	3784	6469
56	6089	6132	9614	6758	0288	0108	8623	8408	3360	3024
57	4909	2362	5297	3386	8329	8149	0845	6834	8831	4806
58	7386	1628	1494	8937	7838	8812	2994	6349	7933	8200
59	7320	7019	8328	7948	3274	5229	5753	0248	2559	0390
60	9763	0440	7154	0970	1852	3077	1522	3851	9877	6720
61	7820	1467	9175	7889	7498	3613	5527	7392	8590	1015
62	3167	2673	5391	5861	0901	4319	8630	9741	5844	7179
63	1701	9045	6529	3580	5265	5790	0414	1969	6780	7105
64	9024	2687	9310	8705	6172	4296	4610	4770	9415	5817
65	6613	4140	2942	2429	9435	8638	8063	1782	6352	7470
66	8449	3176	2217	2969	9996	0447	0516	7859	4525	9581
67	2557	8074	1255	0774	0337	0577	1722	9844	2828	1217
68	9599	1141	1301	9528	2589	1320	7096	1065	3956	6446
69	1992	3807	2096	2780	3358	2803	1457	3717	7601	3117
70	9415	4611	2177	6089	5341	5515	5414	6149	9383	6722
71	6277	6742	2609	2270	6942	1263	8254	1222	7007	7702
72	6330	0455	9317	8445	4361	5738	5322	4667	1433	1937
73	3087	5719	9831	9429	4720	7923	3490	3870	4504	4822
74	1623	3781	9202	2754	1574	3176	3289	3261	9601	8993
75	3456	3994	6498	8484	2594	2955	4836	9337	1417	6546
76	4065	3370	8734	2929	4353	0030	8154	6112	8268	3625
77	3117	5586	3840	7581	0440	7342	1148	2381	9102	6323
78	5770	4381	6456	4863	6505	2027	3656	4672	4027	5691
79	3540	0884	0684	7373	7772	2173	5824	6140	5151	2873
80	1383	6130	0608	0641	1401	3446	0809	6275	4667	6200
81	1694	1598	9773	1641	7271	9571	0956	3317	0638	1462
82	2261	1353	1201	0736	8451	0263	0675	6441	5095	5745
83	0879	8102	3441	9589	6066	6034	2895	0705	8152	1118
84	0267	1101	5030	2776	4676	9728	9698	0278	3653	5743
85	2050	0889	3674	9318	0837	2335	5784	4499	8971	3147
86	6512	9995	8944	5634	7796	4263	9758	6645	1275	1092
87	7778	2306	9643	1905	5315	3015	3158	7265	0190	2208
88	8201	5616	9194	1858	9491	0217	4368	7537	5073	4929
89	2415	0561	8289	2994	7341	4908	1498	8806	9611	5683
90	1938	6471	6108	5497	8081	5295	2897	5618	7229	3668
91	8780	5691	2190	8789	2697	8130	1357	4497	4674	6903
92	8632	5993	7960	0241	5771	9741	9251	3265	6100	6505
93	8636	2303	8091	0273	2265	1886	6465	5330	3707	6802
94	2814	8569	7178	0352	7279	8659	3164	3247	3857	9803
95	7407	7803	7879	1235	4695	8607	5468	3632	5282	4763
96	6352	6868	2150	6844	7191	4442	1561	8629	8724	7650
97	3135	5350	8557	9532	7192	5708	2930	8740	2747	5827
98	6418	0736	8251	5329	6641	8120	8985	3926	6810	0857
99	2070	3609	9184	7250	1270	8171	3581	7679	8326	3488
100	6862	4480	5051	5262	8832	6762	0369	2089	6209	1998

	0	1	2	3	4	5	6	7	8	9
101	2899	1397	0235	0319	5904	0003	8088	1905	7733	8060
102	7825	5409	9375	8387	7821	4044	2004	3784	4062	1510
103	2554	7423	3644	2702	5572	1547	4754	7605	0586	7517
104	9202	0022	0512	9403	4981	0887	8136	3810	2234	0531
105	6587	4132	4073	1627	0845	7391	5286	9327	8620	8679
106	2936	3705	1683	6125	9589	4711	5039	2451	1535	1785
107	0866	5059	3535	4076	3550	7915	3887	4104	9853	0749
108	2291	1818	2466	7884	2218	2089	8594	4615	9316	4174
109	4657	3232	4034	2133	7406	5246	3377	8644	3751	7402
110	4684	1278	1045	7780	1042	3752	8510	4452	6530	4322
111	5150	0521	7345	5987	0250	0216	3283	6590	0612	5895
112	6216	0290	0287	1327	1261	6902	7833	6256	1022	6096
113	0299	4050	7214	6390	7254	0100	1926	6506	1355	0648
114	8268	5594	6620	4371	2606	9710	1366	9945	2715	7083
115	2147	1822	7118	9840	2088	9800	0022	8955	2936	9209
116	1993	1361	4090	4753	7990	2339	6809	2638	2294	4783
117	0888	8380	5567	0165	5333	9343	6287	0128	7050	9734
118	8392	0864	4284	1869	4291	8100	3582	2437	0650	8812
119	3474	8099	3307	8070	2799	5794	5904	4804	5860	4604
120	9301	9691	6256	6788	5190	8793	7480	2763	0468	1625
121	1853	7462	9459	9440	9875	7335	7369	8559	0987	9817
122	8015	2527	0764	8683	6457	3355	0294	1177	7623	3952
123	9671	5790	1460	9181	3987	6303	0321	3132	0770	7984
124	3144	7732	9614	3003	7232	0436	1470	5735	3160	5356
125	8246	3283	0251	6136	8041	3041	4981	2605	7530	0581
126	9410	9785	5355	5616	9907	9222	5300	3212	1632	0273
127	2616	5706	2815	1768	8394	0528	5177	1961	7451	0067
128	8657	8901	0217	5872	8963	8326	0714	8769	9706	0651
129	6101	0251	5333	5253	7051	5492	5837	9508	8029	2154
130	8736	4493	5116	1812	9457	9663	8396	0350	9900	7197
131	2240	8483	1383	3288	5045	6135	3773	0869	3415	8494
132	7945	5971	1429	9426	6198	2241	1371	6798	9069	0059
133	0107	7447	9726	0740	2626	8312	1683	6095	3929	4847
134	2686	3354	9387	1732	9036	2679	4551	0372	5562	1932
135	5762	2898	0169	9265	1804	8196	4461	3044	8148	3440
136	2362	0927	2213	1456	5872	7563	7873	8148	7408	9834
137	0943	2552	3463	5792	1722	5702	0579	2125	3553	7613
138	0968	5505	7917	7812	3297	0996	9626	3931	4954	8197
139	7411	6269	7709	2010	5424	7489	4087	1861	7894	2424
140	1229	9675	5555	1766	3242	2756	8831	1411	6424	6419
141	5477	7684	5707	6457	4473	4401	1814	1203	8406	1503
142	2924	2030	0232	0669	2015	2321	0028	3343	0103	9635
143	6147	3463	9393	6931	7262	0635	0100	2920	6879	9018
144	5397	1006	1167	8094	7679	9271	9529	2107	0380	2781
145	4924	4787	8326	3602	4829	8769	7156	3560	0245	0460
146	8302	2334	7454	2980	6858	8002	9723	6961	4359	2603
147	8116	1613	9955	7589	6207	6364	1470	4641	3399	4119
148	7772	0518	6668	6220	6073	5577	1132	4089	6615	7817
149	3005	6141	3449	7778	9822	2978	6583	6365	4640	9828
150	0515	2611	5698	1784	1272	6277	1186	6157	6562	0114

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	0	1	2	3	4	5	6	7	8	9
151	3801	9094	3984	9662	7013	4675	3305	9477	6052	6463
152	5112	8493	3522	9082	1259	9393	1363	8384	9077	7256
153	6661	7321	5734	2238	7349	4913	2483	8800	2084	5533
154	9440	7478	8781	8877	0784	0963	6873	1825	1932	5033
155	5575	9490	3125	9746	8568	4724	1302	3744	5244	2820
156	5284	0256	6717	4189	4073	4327	3656	5039	4245	6650
157	9402	0218	7307	4515	6334	8394	3425	6806	3673	5666
158	3906	6392	1065	1416	8697	0728	7785	5091	3460	7425
159	2766	6735	3663	1802	1945	0226	2890	9448	7061	6863
160	0941	1822	4303	2196	5075	6276	2804	6772	7075	9958
161	9641	5726	2258	5528	1576	9655	1350	9548	4420	1533
162	8979	7285	9994	3207	6047	2331	8674	6722	4125	0510
163	1714	8090	1709	6994	1431	2278	2794	2976	6309	2646
164	4473	4405	2564	4567	3264	2473	8196	0385	5586	9738
165	5375	7532	1932	4760	9993	9806	9774	0254	5170	5947
166	4603	9646	8579	9149	1790	4482	1995	3069	0243	2391
167	8730	2372	0050	5351	0881	0813	7665	3128	1342	1692
168	2327	6572	9247	8958	3354	2747	5210	1817	6554	7970
169	8861	7298	6073	4138	6858	1097	2735	4934	3751	3858
170	6806	8850	7228	1330	8635	5597	1984	6638	0457	6876
171	8652	8362	1567	4844	5784	2737	9932	1684	8423	2794
172	6088	8885	2404	3769	3819	1362	7183	4445	7179	8671
173	1815	6022	9460	7823	8611	4410	7561	2609	0254	4294
174	3473	8945	0964	8240	6844	0396	3358	8447	7657	9587
175	4161	4157	7503	9125	8884	3890	8211	8391	2024	0696
176	3023	6708	3570	8685	3584	8230	4494	8788	1539	1088
177	5655	0644	5188	3485	6691	2698	5291	9690	3617	5423
178	8740	9861	2845	2286	6512	5913	4321	5439	4228	7904
179	1434	3335	3009	1410	9929	3214	2694	0530	6950	8837
180	1737	5691	9354	6787	2523	6040	3340	3542	1793	8388
181	0161	8195	9583	6276	0864	3568	4505	2997	2970	6221
182	9370	2850	5188	0492	0391	3796	2465	6420	2489	6883
183	3775	2928	8101	1313	6547	3748	3816	9558	0907	8016
184	6584	0790	2139	0854	2152	1231	4360	5694	8259	7658
185	4667	7582	2206	8373	2859	7140	3121	9352	6677	2725
186	6455	5130	1084	2872	4378	3176	7364	1393	1209	4810
187	0060	5586	6029	8412	9000	6808	0742	6397	4092	1542
188	6850	8675	7744	0269	2198	8756	1343	6312	8701	6551
189	2517	8132	4397	7633	4431	8702	8616	3250	0689	3254
190	1036	5789	6891	3343	0728	2997	0805	5021	4329	1727
191	9404	1396	6110	1404	4309	0810	5538	8437	6531	6233
192	7108	3253	6374	5536	6072	1705	0244	4504	4154	6666
193	0998	2139	0131	0188	1107	9274	3802	4429	7715	4470
194	1886	4751	0727	3940	8296	4045	8515	5907	8092	4462
195	0410	0317	6966	2726	0128	4489	9773	6389	8605	3374
196	5696	2690	8968	1055	1258	7378	0854	5822	9896	3157
197	4121	7845	1399	1548	5388	9814	5393	2307	2361	0736
198	2653	7554	3951	3033	4620	7119	9086	6337	5045	1744
199	9176	7228	0312	9807	0250	2529	3850	6094	3210	8576
200	7889	9222	3120	4810	8011	6547	0712	4644	2915	1757

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201	0160	2080	4447	0987	8028	0893	8971	4711	3498	3214
202	5154	3661	9389	4489	7934	9303	5863	3013	5960	5528
203	5870	7150	9710	7592	9833	8508	3822	2767	7342	6994
204	3100	6300	8049	4190	3168	3921	3590	0225	2444	8492
205	5721	0309	6235	4420	9760	7120	5067	3677	5445	0166
206	3352	3597	3545	8929	7566	0659	8025	7646	9962	3558
207	6012	7380	8185	6058	4767	5729	4316	9275	0165	7284
208	3073	6406	9675	6618	8058	4886	0622	1399	1322	1086
209	8960	3547	7335	4895	8266	8777	8528	6159	6862	4045
210	9122	3189	1137	8510	4541	6840	2240	3387	7152	0303
211	1459	3953	3028	1387	5810	0653	3473	3428	9380	2324
212	1746	0560	8354	7708	2285	0271	3940	5701	3009	2806
213	0002	5212	7917	1803	3365	8926	5320	2260	1558	3065
214	7182	3788	0033	3700	7801	5444	4538	1490	2168	6773
215	4667	3429	8106	3438	0475	2585	2001	5522	0656	3263
216	0497	1847	8938	3034	9088	0171	0268	2200	8611	1604
217	0507	6271	7963	5876	9848	6195	7756	7009	2988	7755
218	7712	8211	3476	8087	9668	8525	1300	4946	7825	5942
219	8367	6320	8873	1714	2606	5061	7947	5577	2369	9865
220	4797	4636	8743	7654	8582	4404	1427	3184	4330	0629
221	2723	7808	4212	2829	5409	5536	4273	8463	3195	4760
222	0735	1290	5356	2656	0184	7098	3047	3119	3717	9146
223	2403	5596	2312	9495	7795	4340	5345	9760	0604	6924
224	3159	9707	2005	5170	5385	2547	2543	6824	1799	8770
225	1520	1715	5788	6617	4883	4298	5045	8441	7470	4036
226	7108	6343	3412	2468	9933	5243	6088	7536	4596	3891
227	0791	8526	5671	7048	9002	0659	0712	4177	1228	1953
228	1780	9336	7203	4396	8396	4545	1135	4896	5366	0708
229	5516	3683	9549	4366	9107	4131	0201	2591	8025	9653
230	4461	4751	8082	6812	2137	6132	3883	6558	4226	8948
231	9626	8918	2457	8185	7717	5394	6638	2502	5582	1122
232	6756	7753	9709	1035	2772	7304	3299	6694	7537	6602
233	5407	0516	5724	7163	4100	5175	9404	1533	5711	8976
234	2672	7284	8051	4037	8002	1559	8356	6394	7363	7046
235	3992	8742	2106	8239	9159	3264	7613	9875	7878	7387
236	0941	1041	5118	2023	0290	2367	8715	9205	1938	5930
237	6365	6705	4441	2372	1088	2556	2213	0804	4489	7373
238	0058	8038	0108	2366	7422	3279	4601	9582	5242	6909
239	3417	7647	7349	7279	6742	3162	5055	0446	7634	3001
240	3909	5035	8407	3799	8675	1271	1819	6555	1005	6819
241	2772	9332	6565	2386	1611	2155	9020	3950	7153	5833
242	1877	7002	4835	9720	4422	1244	7862	4014	9350	1454
243	5350	9156	7710	3431	5303	5049	4557	2826	3733	2119
244	4392	1336	0343	1648	8757	7994	8513	1310	5117	0218
245	0620	6016	8767	1768	3029	5651	1550	9273	5604	0129
246	0385	6746	3438	2298	5509	6194	7003	5151	3174	8353
247	5154	0200	3042	9369	0554	9107	5780	9933	5404	1179
248	0892	7126	7857	8375	0529	3641	3036	2352	0648	6838
249	3004	0224	9766	8811	4449	0446	0423	4018	5293	5149
250	2137	9259	7064	9222	0414	6276	1801	6341	3821	2858

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251	8738	0126	5574	8727	9689	5310	8428	8939	3604	5463
252	8286	7025	0656	8101	3620	4040	6008	5988	4441	7366
253	5196	2398	3488	9799	5889	4995	9320	5810	2571	5018
254	8629	9583	2781	3710	3393	8053	2582	9954	7504	3172
255	1491	9040	7888	3142	0234	4314	6470	0272	6718	7455
256	6885	0882	3539	4555	9705	2851	0905	3691	3599	1263
257	2744	1556	6438	8433	1455	0961	2163	3205	6737	2458
258	7151	4750	6095	5337	0351	0195	3534	3551	9057	9258
259	0932	2673	3303	1271	0693	6085	5436	5071	8613	7754
260	3787	3647	2774	1479	0705	5762	9109	7973	0234	1627
261	5432	0890	5955	6306	0808	0595	5370	7828	9060	0900
262	4411	8675	9501	0470	3187	6746	9460	5219	6861	0252
263	2517	0941	1742	0320	1066	1632	3340	1779	1953	0403
264	9893	3022	3122	4194	2431	6441	1150	2419	0993	2814
265	4458	0712	8286	9156	0144	0853	2889	0752	2071	1967
266	2555	7714	6454	8424	2953	4083	5523	2402	5565	4877
267	9216	9051	0503	0948	3618	4645	9480	2773	3263	5260
268	8339	0418	0138	0621	7659	7614	7447	2702	8050	4418
269	0578	4867	2949	3278	9353	0528	6996	4985	7466	0562
270	1549	1857	8046	0828	6272	0429	3418	9482	6414	9865
271	6080	1044	7694	6380	2586	6890	0180	4510	5746	1061
272	5713	8882	2767	5543	4617	2028	7467	4201	4546	1038
273	1852	8853	3535	1588	3713	2645	5695	5920	3976	9559
274	9983	4276	6356	1430	6712	1960	0864	8141	1250	9109
275	2769	3262	9067	0222	5427	2138	0284	1652	8306	2801
276	0402	1540	1261	9724	7973	6497	1002	8296	8932	0561
277	2905	4816	1993	4133	0624	3722	7657	7018	5478	4947
278	8015	1002	2080	6152	6669	8702	9072	5154	5566	1960
279	8121	6009	2869	1354	3365	5494	4981	4995	9980	2596
280	5677	4328	8722	7179	6546	8694	9106	8683	4810	8793
281	5711	1090	2359	4469	9969	4643	0883	2827	0760	9017
282	8322	0249	3762	9962	7734	1456	9845	5780	3579	1940
283	2428	0148	6214	3472	8179	9928	7228	7385	4670	0145
284	4788	3796	8751	5801	7445	6592	6390	6925	3650	6391
285	1433	8831	7715	4040	9742	3589	3711	7050	4629	4769
286	4915	0972	1814	3753	3967	3774	4364	9655	7802	3470
287	5797	4758	0360	5646	8279	0078	9379	2050	5316	3735
288	1165	0540	1930	5730	2238	1212	5065	8288	1810	9952
289	1080	9746	9275	7872	2134	5756	6437	2613	8853	1388
290	9206	4169	5360	5897	8004	1263	1236	5349	0249	9954
291	7819	2316	2825	7552	2271	9595	5164	3306	5171	0588
292	8685	7689	9104	0477	0014	9977	0217	6092	8398	1493
293	5851	0869	0133	3025	9018	1154	4884	4605	8822	1712
294	8435	4257	7097	0086	4301	5930	4664	8767	0234	3160
295	1855	9220	1119	1450	2328	4328	3201	9835	0840	4623
296	4076	7372	7956	0744	0372	0902	4705	4243	3484	4177
297	2822	6671	0417	4235	8325	3187	8026	6820	6841	4386
298	2496	2711	2495	6289	7810	1554	3918	2795	3482	4791
299	5622	8509	4646	7790	3264	8837	7194	4731	6819	2442
300	4008	4838	2492	0135	9561	4802	1081	0023	2238	6158

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301	7971	9600	7771	8772	8435	2027	5803	0033	8970	4155
302	8916	5699	0591	8719	4498	2609	0459	7647	0320	1406
303	6942	5255	4686	8671	0435	8762	6161	7763	0228	9421
304	2294	8229	7456	2523	9850	4054	0943	5591	2951	4550
305	1645	0141	6784	7107	7772	4759	0825	7146	0683	6241
306	0949	7024	9174	7412	2993	5904	4995	5453	7312	1372
307	3293	0519	4628	7255	5641	3126	5726	2759	8034	7946
308	6061	4830	5023	1703	9558	2275	9429	2446	3771	1867
309	8269	1953	1720	7596	7750	4879	9931	6103	0351	7966
310	3898	6464	1927	8613	1479	7301	5411	3028	9727	2956
311	1216	5466	2732	1629	7795	3961	0034	0275	8634	7286
312	1932	4667	6220	3122	8644	2691	3519	4722	8363	9069
313	6282	3202	1882	6210	3919	5503	3479	0715	1592	4739
314	9945	4743	0529	0479	5508	4757	2391	6105	7648	8866
315	4640	1838	4422	5173	2505	3431	0148	7781	4495	9296
316	7556	2059	5748	6791	6495	1305	6639	4561	2675	4285
317	9486	8085	6798	4929	7497	8939	1496	1278	4137	3868
318	4833	2442	3674	6391	2363	9950	9302	1287	3896	1341
319	2327	4580	3942	0111	9792	6565	9369	6582	6979	4906
320	8863	7379	8320	4208	2733	7322	6314	4918	2082	6269
321	9973	0331	0667	3872	2031	8732	6123	8979	9625	1717
322	3339	0207	1905	5488	0284	6400	1988	6052	4194	5108
323	8389	2826	7292	3980	3218	4038	8662	3648	2386	9707
324	3180	7799	3047	5571	3707	2169	3793	4893	9386	5076
325	8191	0589	5106	7833	7842	8730	6251	0164	8707	7143
326	5253	0006	4530	8929	7185	0777	5710	9929	4266	3976
327	6528	8627	8978	7845	0664	6075	8496	3007	3578	0054
328	7664	6718	2538	9486	5703	7120	8521	3092	5061	6758
329	2582	6415	0185	1376	1930	0611	5333	0381	0880	5173
330	1136	9939	4940	4262	4442	0616	1642	3711	6661	5900
331	7513	7500	7655	4979	0730	8292	4986	7596	3652	8795
332	3446	3239	5826	8234	9200	1745	5635	7985	9250	5137
333	5455	3963	9270	7772	2076	6947	1196	3554	4870	9012
334	5924	9407	5714	2668	3667	6455	3736	8000	0996	6479
335	2062	0663	9732	7210	7176	0600	2711	8263	8836	0248
336	6634	8562	4390	9896	5874	8468	5407	2706	5132	3233
337	5243	5667	4099	1093	8198	0419	3648	5472	3009	6040
338	9597	7559	7021	5907	2099	4749	8298	9985	4888	0488
339	7760	2517	3740	1071	9069	0307	5007	6464	8696	7642
340	8368	7543	9761	8222	6295	1429	8476	0702	5817	2201
341	2369	6985	1520	0657	5866	0305	8556	2679	4856	4545
342	1448	7833	1185	7564	2764	3037	4394	4471	3569	8648
343	2818	8346	2583	1128	2617	3164	5323	8621	7900	5153
344	9695	5029	4842	1958	0011	1191	8417	3693	0577	8155
345	9332	6231	6059	4504	5868	0919	8981	0255	5019	0132
346	9973	3782	2950	5578	6946	5306	0573	7584	4650	0914
347	1079	9960	5463	8782	3807	5847	1143	4970	9450	6702
348	1996	2975	2548	8115	5636	6783	2446	2212	8888	6953
349	6143	3506	0304	7631	5600	5362	5023	4429	7326	4962
350	1881	1015	7634	1233	0344	7387	0618	5230	6089	1658

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351	2474	2846	2138	5148	5456	1827	9249	8511	0456	6711
352	4891	7097	6509	4975	1459	6666	6905	3446	6806	4006
353	0681	8014	6654	3268	2308	4404	8269	3880	1971	2340
354	8057	0244	6347	7837	9492	2710	8695	0157	8189	3298
355	6464	4582	6471	4256	9834	8259	5265	3994	9955	1857
356	8676	0217	6172	6026	2868	1308	4572	1540	8804	3022
357	7846	3762	1800	9549	8226	8940	8827	0862	1348	9595
358	5626	3873	6843	8420	6150	6098	1083	3060	4812	6298
359	9845	0138	1001	8645	0162	5240	6390	2301	7392	6690
360	9353	3771	5724	1013	5155	5456	1138	8420	1786	6626
361	6935	8841	1406	5737	8874	6992	5836	6368	0409	8243
362	0104	7282	8203	1156	6698	0060	2171	2400	7803	3631
363	5035	3811	5070	6267	6210	1465	2385	3399	1286	7238
364	9862	2735	5941	1736	3534	0971	5609	3581	2044	7319
365	0225	7328	1950	1095	8808	4012	6196	9592	7294	9312
366	7538	7869	0825	5632	6534	5707	5876	6540	4431	1354
367	9848	3955	0524	8485	0471	7074	5687	3348	9644	6513
368	8352	2284	5922	1596	4777	0526	4480	5497	5321	6962
369	6165	0280	8626	6560	6573	8171	2403	1660	8348	0153
370	0434	1242	8901	0752	4918	6366	8283	9303	5193	9159
371	4811	9244	4548	0196	2696	3400	2953	4985	3480	8546
372	0577	9457	2264	3497	2752	5823	5782	3961	8965	7713
373	1290	5220	7325	4913	0769	6142	2579	9710	1406	1196
374	8753	2693	7801	8681	2428	9102	6276	7679	1295	5501
375	1837	0731	4801	8869	2053	3620	4074	8615	5519	8346
376	3445	2093	5420	9643	7743	9290	3672	3090	7199	5490
377	6756	9995	9813	8272	4085	7116	6738	5947	1378	0111
378	2686	1974	4635	5511	0123	8896	2424	4066	7619	7305
379	9794	0151	2672	8724	6101	8873	5479	3676	3860	3475
380	4695	4339	2138	8908	7220	5788	1324	9837	8447	2175
381	1747	7440	8716	6254	0012	6060	5348	7185	5750	4662
382	1886	5166	7379	5530	8367	9896	2266	4165	8824	9835
383	1349	0670	0860	9406	8648	5621	8679	2194	3603	5648
384	2797	2535	1992	1905	0009	0033	4927	6876	0742	2964
385	3128	0069	2354	2819	4161	7102	2964	0416	2039	2529
386	1412	8649	0922	3149	3872	7622	9557	8675	0588	0191
387	2729	8481	1359	6697	3619	1353	7129	9649	1809	2201
388	2314	4349	4646	6545	3947	1674	4343	2835	2779	7938
389	4132	8683	4436	5899	0690	6158	6727	6992	4698	2044
390	4446	9426	3046	9184	0839	1683	1638	0381	9034	7293
391	6528	3645	6113	5319	4499	3842	2293	7107	7186	1688
392	3669	1878	2310	3170	1473	5727	8861	7295	1091	9753
393	9248	4854	1800	4241	6937	1053	4814	1170	0575	2612
394	1911	3848	4153	9481	1670	5639	2993	7943	3589	4976
395	6284	3306	7926	7823	0740	0951	6620	7050	8092	8800
396	7668	5957	9100	2999	9574	2412	7182	4656	9566	7086
397	0474	0478	5909	3983	2785	6208	5172	4475	0281	4669
398	8195	1115	3544	1547	4574	2611	7372	6316	9498	2554
399	1147	4374	0906	7740	7090	4901	7056	9893	7207	7998
400	4852	8998	8520	1484	9872	7766	3586	4545	4610	4880

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401	5903	2815	5600	3726	1747	2955	1887	2011	7023	2262
402	3919	7784	5844	9245	3032	0608	9045	6136	6952	8731
403	9503	3716	3501	0070	8298	1316	4132	4493	1861	0291
404	1086	1533	8345	5845	8600	4197	5063	1374	4890	9987
405	5996	8476	1614	5369	4138	6956	4761	7831	6253	5064
406	8436	0235	4916	7933	9734	4990	8029	6291	6313	7833
407	9786	0111	7147	9737	5904	9592	1918	3297	6639	8205
408	3818	9483	1180	3180	1560	9700	2598	6046	0978	9764
409	2080	2054	4466	3751	7813	0263	1414	4956	3837	4371
410	4294	3586	6006	3516	8383	9750	7403	8479	6064	6365
411	5412	0398	8619	7465	0449	3417	3759	1558	2947	8310
412	6177	7183	9247	4137	5425	4237	8035	4045	0093	2706
413	3381	3433	5711	5851	2136	0809	9689	4387	7166	6189
414	7027	2221	3889	9224	0597	3938	0041	6989	3954	3096
415	1136	3027	1515	2864	6250	5302	9795	5258	7223	8749
416	6343	3439	1807	0720	2440	2421	1456	2590	4164	9753
417	2124	6593	1687	9250	2937	5882	8580	3502	1821	7647
418	9325	4010	7456	2642	0180	9342	1220	9180	4981	4833
419	2340	2698	8789	1934	9747	7965	4748	4876	7761	3657
420	8104	0685	7177	4315	9974	4043	5756	2395	4274	7237
421	0853	8104	7012	6149	7514	7766	3877	7970	3408	8541
422	4592	1909	8828	0411	1621	2734	3756	0381	0688	7771
423	9309	2879	5269	0957	6308	0144	6880	7062	9329	5785
424	1421	6802	5710	3728	7241	8441	0393	4421	0624	1559
425	7599	8835	2748	5413	1506	5048	6173	0059	5326	4605
426	1801	9449	0797	3895	8311	0289	4797	1398	8431	1286
427	3294	9090	8380	5944	6006	1522	2214	0292	6575	3530
428	3445	2270	3259	7507	4084	7868	5625	1212	8575	3991
429	1022	0982	6854	1429	3931	6639	9170	1290	8998	8304
430	1019	2949	3740	2736	0035	9443	2872	5922	9422	4088
431	3259	0725	4998	6694	2155	6976	0381	6600	2252	2088
432	9556	6103	8231	6413	4297	2694	2367	9508	3610	4606
433	2916	3812	8645	8275	7166	8914	4340	8743	8870	1759
434	1634	3824	5008	4400	7670	7111	0210	6252	6571	4695
435	9727	1073	8076	9090	9802	9161	1969	4320	8970	4953
436	8288	1981	1202	5977	4534	1534	0361	8131	9021	1074
437	1991	0425	1232	0507	9400	3951	1574	6427	4018	0565
438	6855	9445	8507	2710	7031	3891	4395	4966	6465	0254
439	3829	3090	2294	5862	8456	0838	4262	2207	9315	1708
440	0687	0834	7690	5627	8793	9704	8979	3715	7620	1140
441	1192	6075	3222	8556	6901	0933	4516	0926	4335	4495
442	0828	8628	5557	4267	8715	4172	0999	3878	2273	7895
443	8506	4635	9763	3061	1415	1827	2584	3268	0820	6347
444	3664	7739	5915	6699	1254	5051	2199	9780	8256	9094
445	5207	0281	3380	4663	3723	3713	6068	7919	4572	3562
446	4758	3038	9066	6631	2989	0399	5011	3155	4363	5134
447	2948	2150	5274	2619	0872	4823	3397	9551	3514	0578
448	2916	6211	7975	3521	0002	8336	3572	4460	8194	4152
449	4074	8791	1711	9092	1662	1968	5890	8876	7886	8459
450	5522	0630	9099	9412	1987	2213	0365	0857	7059	5607

References

ASTM Manual, D-3665 Standard Practice for Random Sampling of Construction Materials, Volume 04.03.