VIRGINIA DEPARTMENT OF TRANSPORTATION
SOILS AND AGGREGATE COMPACTION
2023

FIRST DAY

Course Registration

Chapter 1: Characteristics of Soils and Their Relationship to the Compaction of Soils

Chapter 2: Construction and Testing of Embankment Material

Break for Lunch

Chapter 3: Construction and Testing of Subgrade Material

Chapter 4: Installation of Pipe and Testing of Pipe Backfill

SECOND DAY

Chapter 5: Establishing Target Values for Density and Moisture Content

Chapter 6: Field Moisture and Density Testing with the Nuclear Gauge

Break for Lunch

Chapter 6: Field Moisture and Density Testing (Continued)

THIRD DAY

Chapter 7: Correcting Density Test Results for Plus 4 Material

Break for Lunch

Chapter 8: Roller Patterns, Control Strips and Test Sections

Examination: Open book - 50 multiple choice (20 come from the 8 math problems)

Grading: Score must be 70% or better to pass

Certification: Students must successfully pass the written exam by November 30, 2023. The Proficiency exam must be completed by Dec. 12, 2023 in the following areas: One Point Proctor, Field Moisture Testing, Speedy Moisture Testing, Direct Transmission, Roller Pattern, Control Strip and Test Section.

Exam Results: Certifications can be found on VDOTU. Non-VDOT personnel can find their results at the following website: https://virtualcampus.vdot.virginia.gov/external

Create a new account if you have never taken a VDOT certification course. If you do not know your login and password, DO NOT create a new account, email VDOTUniversity@vdot.virginia.gov or call (804)328-3158 for login information and any questions.

Scheduling: To schedule your Soils and Aggregate Proficiency exam see our website @ www.ccwatraining.org/vdot. Select your date and location and register for your exam. For questions please contact the Community College Workforce Alliance at (804)523-2290.

VIRGINIA DEPARTMENT OF TRANSPORTATION

SOILS AND AGGREGATE COMPACTION

FIELD CERTIFICATION

STUDY GUIDE

2023

Prepared By: The Virginia Department of Transportation (VDOT), Materials Division

Note: The information included in this manual is generally compatible with current VDOT Road and Bridge Specifications; however, it should not be considered or used as a primary reference for VDOT specifications. In order to ensure you are referencing the right specifications, always consult the current or applicable VDOT Road and Bridge Specification Book.

VIRGINIA DEPARTMENT OF TRANSPORTATION
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2023

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CHARACTERISTICS OF SOILS AND THEIR RELATIONSHIP TO COMPACTION OF SOILS

LEARNING OUTCOMES

- Understand the general characteristics and classifications of soils
- Understand the relationship between laboratory test results and soil compaction
- Understand the relationship between soil moisture and construction density

INTRODUCTION

Soil is defined, in soil mechanics, as “a natural aggregate of mineral grains that can be separated by such gentle mechanical means as agitation in water”. Rock is defined as “a natural aggregate of mineral connected by strong and permanent forces”. Some of the material used in construction by the Department is “soil”. This could come from on- site sources (Regular Excavation), off-site sources (Borrow Excavation), crushed aggregate (Crusher Run, Dense Graded Aggregates for roadway base and subbase), or blended natural and crushed aggregates (Select Material).

Soils and aggregates can be classified into four broad groups based on the grain particle size. They are as follows:

TABLE 1.1
Classification of Soil and Aggregate Material

Soil Type	Grain Particle Size Description
Gravel	3” Sieve to the #10 Sieve
Sand	#10 Sieve to the #200 Sieve
Silt and Clay	Smaller than the #200 Sieve

Note: In general laboratory work, the silt and clay sized particles are labeled as “minus #200 material”. The percentage of silt and clay present in a soil sample can be determined by hydrometer analysis.

In nature, we generally find a mixture of these soils, such as sandy gravels, silty clays, clayey sands or any other combination of these materials.

Aggregates are classified into many mixtures based on particle size. In addition to using pit supplied aggregates (no manufacturing or crushing performed), VDOT uses processed blends of crushed stone and stone fines produced in a “pugmill” to make a graded aggregate mixture for pavement foundations or bases. Besides producing the correct percentage retained on the chosen sieves in the pugmill, cement and other additives can be added to the mixture to change the characteristics of the aggregate blend.

As defined above, soil is an earthen material overlaying the rock crust of the earth. The materials making up the loosely bound aggregate material we define as soil are mineral grains, organic material, water or moisture and gases or air. The mineral grains that make up most of the soil mixture are described by the following properties:

- Size – Described by particle or grain diameter or average dimension. Major divisions of the classification system using sizes as the criteria are gravel, sand, silt and clay. The very fine fraction of the soil, that is the silt and clay, have a wide variety of properties and determine a lot about the characteristics of the entire soil mixture.

- Shape – The shape of the grains larger than 0.06 inches is distinguishable with the naked eye. These grains constitute the very coarse to coarse fractions of the soil. The shapes can be round, angular, sub-angular or sub-round. Finer fractions of soils are indistinguishable to the eye and generally have a plate-like shape. Elongated grains and fibers are sometimes found in the fine fractions of soil.

- Surface Texture – Refers to the degree of fineness and uniformity of a soil. Texture is judged by the coarser grains and the sensation produced by rubbing the soil between the fingers. Smooth, gritty, or sharp are several terms used to describe texture of soils.

- Surface Forces – Soils with very fine particles and plate-like grains, electrical forces on the surfaces of the grains are the major influence as to the way these soils react with water.

- Consistency – Refers to the texture and firmness of a soil. Described by terms such as hard, stiff and soft, the lab test that describes consistency is the Atterberg Limits, which will be discussed later.

- Cohesion – The mutual attraction of particles due to molecular forces and the presence of moisture films. The cohesion of a soil varies with its moisture content. Cohesion is very high in clay, but of little importance in silt or sand.

- Sensitivity – A characteristic exhibited by clays, and describes the loss in strength of a clay material after it has been disturbed. That means that a clay material in a cut, that seems very strong, may lose a great deal of its strength after being cut and filled in another place. Other types of soils can be equally sensitive to other types of disturbance such as extreme changes in moisture or exposure to vibration.

- Moisture Content – This is a measurement of how much moisture a soil is holding in its void spaces. It has a great impact on the consistency of the soil, its density, and its compactability. The importance of understanding and controlling soil moisture cannot be overstated.

To simplify the identification process, properties of these soil blends, such as gradation and soil moisture indices, are used to classify these materials so we may easily identify which soils will provide the best service as a construction material and which materials will not. VDOT uses the Unified and AASHTO classification system for classifying soils but there are a lot of other methods available. Those include:

- Pedological Soil Classification System (used by geologists)
- Federal Aviation Agency Classification System
- U.S. Department of Agriculture

Each of the above mentioned classification systems uses a slight variation of the same premise to best define a soil for a particular purpose.

THE RELATIONSHIP OF LABORATORY TEST RESULTS TO COMPACTION OF SOILS

As part of preliminary engineering, the soil at a construction location is sampled and tested.

The final Soil Survey is done after the line for a project has been approved by the Location and Design Division. Soil Survey sampling is done by the District Materials Section's Geology crews. It consists of sampling the soil at specified points along a project.

For cut sections, 50 lb. samples of each material in the cut are taken. Since soil may be in many layers, it is likely that there will be more than one type of soil in any cut. To determine field moisture, samples weighing approximately 50 grams are taken each 5 feet down, especially when the soil is wet, or above optimum moisture content. Finding out the field moisture, or how wet the soil is in place, is very important in determining whether or not that soil can be used in one of the fill sections of the project.

When samples go to the lab, several tests are run. Each test gives information about the soil, and how it will behave under construction or loaded conditions. These tests are gradation, moisture content, optimum moisture/maximum density (also referred to as the laboratory proctor), Atterberg limits, CBR and soil classification. We will not be going over most of the testing procedures in any detail here, only what the results mean to you in the field, when you may be deciding how to handle a particular soil, or possibly having problems with it.

SOIL AND AGGREGATE GRADATION

Names and definite size limits have been developed for different particle sizes of soil. This naming and defining places all soil tests on a common ground for comparison. The amount of each size group contained in a soil is one of the major tools used in judging, analyzing and classifying a soil.

The amounts of each particle size group are determined in the laboratory by tests referred to as "mechanical analysis". The amounts of gravel and sand are determined by passing the material through a set of sieves with different size openings with the sieve having the largest opening placed at the top and progressively smaller openings of the sieves as you go down the nest (see Figure 1.1). The weight retained on each sieve is determined and expressed as a percentage of the total sample weight. These sieves and their openings are in a table on the next page. The term "gradation" refers to the distribution and the size of the grains--how the soil breaks down into relative amounts of each size particle. An analysis of a soil is generally broken down into two parts: 1) the "coarse" gradation, and 2) the "fine" gradation. The coarse gradation is determined by using sieves or screens with progressively smaller openings to separate grains, while the fine gradation is determined by a hydrometer analysis, which uses particles settling in water as its principle. In this section only the coarse gradation will be discussed.

TABLE 1.2
Nominal Openings for Select Sieve Sizes

		Type of Material	
Sieve Number	**Nominal Opening**	Unified	AASHTO
3 in. (75.0 mm)	3”	Gravel	Gravel
2 in. (50.0 mm)	2”		
1 in. (25.0 mm)	1”		
¾ in. (19.0 mm)	0.750		
½ in. (12.5 mm)	0.500		
3/8 in. (9.5 mm)	0.375		
¼ in. (6.3 mm)	0.250		
No. 4 (4.75 mm)	0.187		
No. 8 (2.36 mm)	0.0937	Sand	
No. 10 (2.0 mm)	0.0787		
No. 20 (850 µm)	0.0331		Sand
No. 40 (425 µm)	0.0165		
No. 60 (250 µm)	0.0098		
No. 80 (180 µm)	0.0070		
No. 100 (150 µm)	0.0059		
No. 200 (75 µm)	0.0029		
Less than No. 200 (75 µm)		Silt and Clay	Silt and Clay

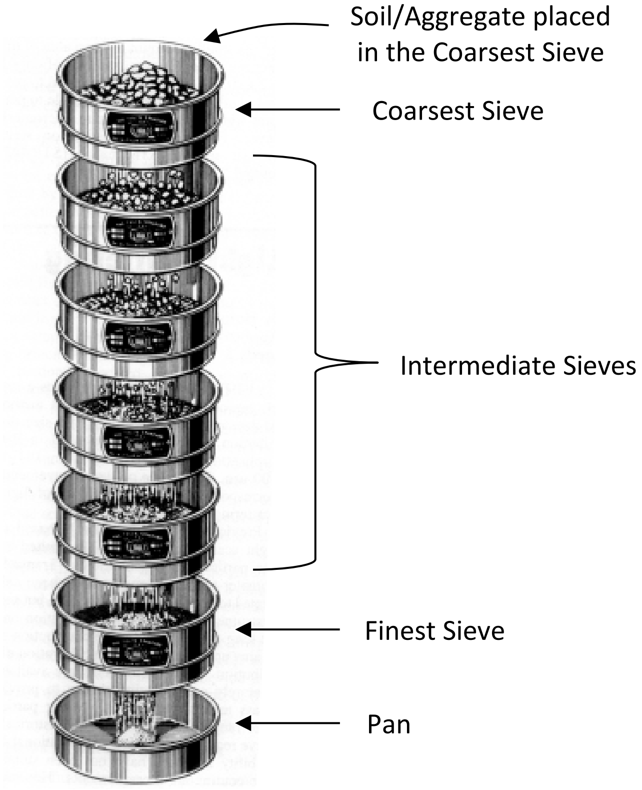


Figure 1.1: Illustration of a Sieve Analysis

Some materials are designed to be densely graded--that is: most of the voids are filled with particles. Open graded aggregates are sized so that they leave a lot of open space in between. Because of this, open graded aggregates are difficult to compact, and therefore, are generally not used as an aggregate base course, but are good as a drainage blanket or in underdrains.

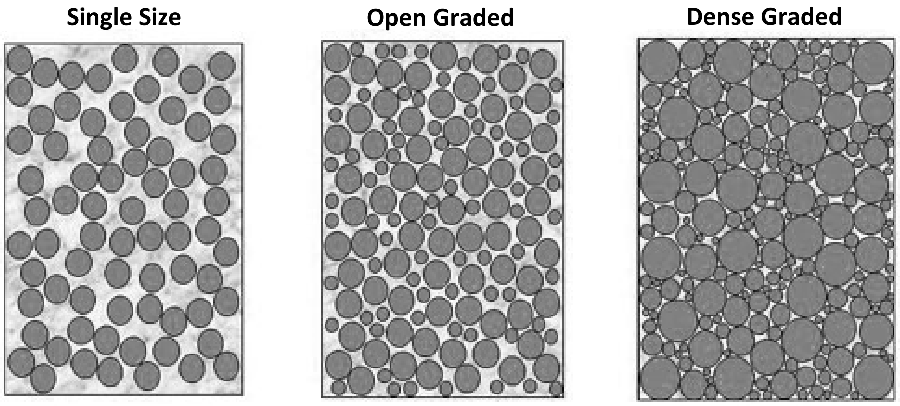


Figure 1.2: Comparison of Aggregate Grading

Most of the aggregates used in aggregate base courses are dense graded, since a dense gradation gives the material more strength to support a structure. There may be instances where a better quality material is needed to cap the subgrade to provide better support for the pavement but does not have to be of as high a quality as an aggregate base material. In this case, a select material (see Table II-6) would be used.

TABLE 1.3[1]
Design Range for Dense-Graded Aggregates

Amounts Finer Than Each Laboratory Sieve (Square Openings[2]) (% by Weight)

Size No.	2”	1”	3/8”	No. 10	No. 40	No. 200	ASTM D4791 Flat & Elongated 5:1
21A	100	94-100	63-72	32-41	14-24	6-12	30% max.
21B	100	85-95	50-69	20-36	9-19	4-7	30% max.
22	-----	100	62-78	39-56	23-32	8-12	30% max.

[1] Table II-9 in VDOT Road and Bridge Specifications
[2] In inches, except where otherwise indicated. Numbered sieves are those of the U.S. Standard Sieve Series

TABLE 1.4[3]
Design Range for Select Material

% Weight of Material Passing Each Sieve

Type	3”	2”	No. 10	No. 40	No. 200	ASTM D4791 Flat & Elongated 5:1
I	Min. 100	95-100	25-55	16-30	4-14	30% max.
II	Min. 100	Min. 100	-----	-----	Max. 25	30% max.
III[4]	-----	-----	-----	-----	Max. 20	30% max.

[3] Table II-6 in VDOT Road and Bridge Specifications
[4] A maximum of 25 percent of material retained on the No. 200 sieve will be allowed for Type III if the liquid limit is less than 25 and the plasticity index is less than 6

Particles passing the No. 200 Sieve are known as fines. A soil that contains a high percentage of fines is more affected by water than one with a low percentage of fines. Exactly how that soil will react with water can be predicted by the use of a test called the Atterberg Limits.

ATTERBERG LIMITS

Soil may exist in several states depending on its moisture content. At low moisture a soil will behave as a solid, with increasing moisture it becomes plastic and with excess moisture it flows like a liquid. The moisture content of the soil has a big effect on how well the soil will work as an embankment material or under a pavement.

The Atterberg Limits are determined by a laboratory test that will define the moisture limit consistency of fine grained soils. The test is done on the material that is finer than the openings of the No. 40 sieve.

Atterberg Limits are moisture content limits where a soil goes from one moisture state to another moisture state. In each moisture state a soil will generally react and perform differently in construction work. The effect of moisture on a soil's performance is more evident for soils with fines (minus No. 200) that have clay minerals. The greater the amount of clayey fines in the soil, the greater the effect. A material which does not have clayey fines, such as a clean sand or an aggregate which has fines resulting from crushing (stone dust), would not exhibit the same problems as a material with clayey fines. The following figure illustrates the different moisture states and the limits of each state.

Figure 1.3: Illustration of Atterberg Limits' Relationship to Water Content

The amount of water in a soil is defined as the water content, and is expressed in percentage of the dry weight of the soil:

$$W(\%) = \frac{\text{Weight of Water}}{\text{Weight of Solids}} = \frac{W_w}{W_s} \times 100$$

On a test report, the Atterberg Limits are expressed as a number, not a percent. Even so, they do represent moisture content. The Atterberg limits are the liquid limit, the plastic limit, and the shrinkage limit. The liquid limit is defined as the moisture content at which the soil changes from a plastic state to a liquid state. The plastic limit is defined as the moisture content at which the soil changes from a semi-solid state to a plastic state. The shrinkage limit is defined as the moisture content at which the soil changes from a solid state to a semi-solid state.

Not all soils have a plastic limit. Many sands, for instance, have no moisture content at which they are plastic. A material with no plastic state is called "non-plastic" and this will be noted on the test report you receive as "NP". The numerical difference between the liquid limit (LL) and the plastic limit (PL) is the plasticity index (PI = LL – PL). The plasticity index (PI) is therefore the moisture content range over which the soil will behave in a plastic state.

The difference between the Shrinkage Limit and the Plastic Limit is the SHRINKAGE INDEX. In this range of water contents, as the material loses water it will lose volume. This is not a good characteristic of a construction material as it will be too dry to properly compact.

If a soil is 100 percent saturated, that is, all the voids are full of water, AND has high moisture content, this is an indication that the void space is large and the soil is loosely compacted. If, on the other hand the soil is 100 percent saturated and has LOW moisture content, this indicates that the void space is small, and it is compact.

In the field, the Atterberg limits can be used as a guide as to how much a soil is likely to settle or consolidate under load. Find the field moisture content and compare it to the Atterberg Limits--if the Field Moisture is near the Liquid Limit, a lot of settlement is likely. The opposite is true if the field moisture is near or below the plastic limit.

On the next page are the specification requirements for Atterberg Limits for Select Material Type 1. They are based on a statistical quality acceptance program, which will not be covered here. The values on the table should give you an idea what range of Atterberg Limits values are typical for the material.

TABLE 1.5[5]
Atterberg Limits: Select Material Type I

No. Tests	Max. Liquid Limit	Max. Plasticity Index
1	25.0	6.0
2	23.9	5.4
3	23.2	5.1
4	23.2	5.0
8	22.4	4.7

[5] Table II-8 in VDOT Road and Bridge Specifications

TABLE 1.6
Atterberg Limits: Select Material Types II & III

Type	Max. Liquid Limit	Max. Plasticity Index
II	30.0	9.0
III	30.0	9.0

TABLE 1.7[6]
Atterberg Limits: Select Material Types II & III

	Max. Liquid Limit	Max. Plasticity Index	
No. Tests	**Subbase and Aggregate Base Type I and II**	**Subbase Size No. 21A, 21B, and Aggregate Base Type II**	**Aggregate Base Type I and Subbase Size No. 19.0**
1	25.0	6.0	3.0
2	23.9	5.4	2.4
3	23.2	5.1	2.1
4	23.0	5.0	2.0
8	22.4	4.7	1.7

[6] Table II-11 in VDOT Road and Bridge Specifications

Using the Atterberg Limits and the results from the sieve analysis, the soil can now be classified.

CLASSIFICATION

Soil classification systems are based on the properties of the soil grains themselves instead of the intact material as found in nature. Although the behavior of soil during and after construction primarily depends on the properties of the intact soil, valuable information concerning the general characteristics of a soil can be inferred from its proper classification according to one of the standard systems available to the practitioners. As mentioned earlier, VDOT uses both AASHTO and the Unified Soil Classification System (USCS) depending on the specific use in its design and construction operations. AASHTO classification is mostly used for the highway and pavement whereas Unified Soil Classification System is widely used for foundation. Both of these classifications are based on gradation analysis (grain size distribution) and consistency as determined by Atterberg Limits.

Unified Soil Classification System

Unified soil classification system divides soils into two broad groups depending on percent materials passing the No. 200 sieve. When 50% or more passes the No. 200 sieve, the soil is considered as fine-grained whereas soil with more than 50% retained on the No. 200 sieve is classified as coarse grained. These large groups are further subdivided into smaller groups.

Coarse-grained soils are divided into two groups based on 50% particles on the No. 4 sieve: Gravel and Sand with symbols of G and S, respectively. Again, the gravels and sands are each subdivided into four groups:

1) Well-graded and fairly clean material (symbol W);
2) Well-graded with excellent clay binder (symbol C);
3) Poorly-graded but fairly clean material (symbol P);
4) Coarse materials containing fines but does not show binding effect like clay (symbol M);

Fine-grained soils are divided into three groups: 1) Silt (inorganic silt and fine sand), 2) Clay (inorganic) and 3) Organic Soils (silts and clays) with symbols M, C, and O, respectively. Each of these groups is again subdivided into two groups according to its Atterberg Limits, as shown in Figure 1.2: soils with low compressibility (symbol

L) and soils with high compressibility (symbol H).

Highly organic soils are classified as peat (symbol Pt) on the basis of visual classification. These are usually fibrous organic matter such as peat and swamp soils of very high compressibility with a dark brown to black color and an organic odor.

Table 1.8 summarizes unified soil classification system for proper identification of dual group symbols in a laboratory.

TABLE 1.8
Unified Soil Classification System

Major Division		**Group Symbol**	**Laboratory Classification Criteria**		**Soil Description**
			% Passing No. 200 (75 µm) Sieve	**Supplementary Requirements**	
Coarse-grained (over 50% by weight retained on the NO. 200 (75 µm) sieve	Gravelly Soils (over half of the coarse fraction retained on the No. 4 Sieve	GW	0 to 5	C_u is > 4	Well-graded gravels, sandy gravels
		GP	0 to 5	C_c between 1 and 3; not meeting above gradation requirements for GW	Gap-graded or uniform gravels, sandy gravels
		GM	12 or more	P.I. < 4 or below A-line	Silty gravels, silty sandy gravels
		GC	12 or more	P.I. > 7 or above A-line	Clayey gravels, clayey sandy gravels
	Sandy Soils (over half of the coarse fraction passing the #4 Sieve	SW	0 to 5	C_u is > 4	Well-graded gravelly sands
		SP	0 to 5	C_c between 1 and 3; not meeting above gradation requirements for SW	Gap-graded or uniform sands, gravelly sands
		SM	12 or more	P.I. < 4 or below A-line	Silty sands, silty gravelly sands
		SC	12 or more	P.I. > 7 or above A-line	Clayey gravels, clayey sandy gravels
Fine-grained (over 50% by weight retained on the No. 200 (75 µm) sieve	Low Compressibility (L.L. < 50)	ML	Plasticity Chart (See Figure 1.3)		Silty, very fine sands, or clayey fine sands, micaceous silts
		CL	Plasticity Chart (See Figure 1.3)		Low plasticity clays, sandy or silty clays
		OL	Plasticity Chart (See Figure 1.3)		Organic silts and clays of low plasticity
	High Compressibility (L.L. > 50)	MH	Plasticity Chart (See Figure 1.3)		Micaceous silts, diatomaceous silts, volcanic ash
		CH	Plasticity Chart (See Figure 1.3)		Highly plastic clays and sandy clays
		OH	Plasticity Chart (See Figure 1.3)		Organic silts and clays of high plasticity
Soils with fibrous organic matter		Pt	Fibrous organic matter; will char, bur or glow		Peat, sandy peat, and clayey peat

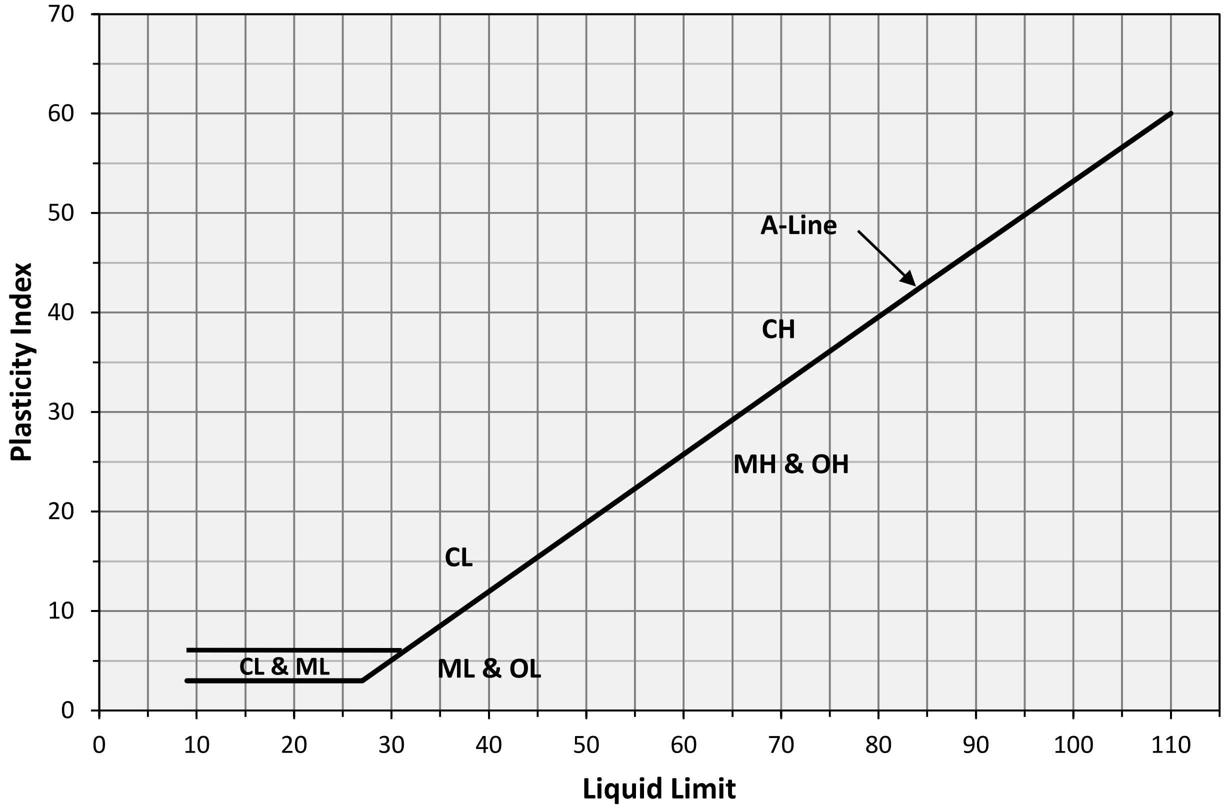


Figure 1.3: Unified Liquid and Plasticity Index Ranges for Silt-Clay Materials

AASHTO Classification

AASHTO classification system also uses two broad categories of soils: granular material (less than 35% passing the No. 200 sieve) and silt-clay material (more than 35% passing the No. 200 sieve). The classification (further grouping) procedure based on gradation analysis and Atterberg Limits is given in Table 1-4. The inorganic soils are classified into seven groups corresponding to A-1 to A-3 for granular materials and A-4 through A-7 for silt-clay materials. These groups are further subdivided into a total of 12 sub-groups based on gradation and Atterberg Limits. Similar to USCS, highly organic soils are grouped in one classification as A-8. Any soil containing fine-grained materials is further rated with a Group Index (a number calculated from materials passing the No. 200 sieve, liquid limit and plasticity index). The higher the Group Index, the less suitable the soil as subgrade material. If this number is near 20 or more, then the subgrade support is usually considered poor because of the presence of a high percentage of fines with moisture sensitivity.

TABLE 1.9
AASHTO Classification of Soils and Soil-Aggregate Mixtures

General Classification	**Granular Materials (35% or less passing the No. 200 (75 µm) Sieve**							**Silt-Clay Materials More than 35% passing the No. 200 (75 µm) Sieve**			
Group Classification	A-1		A-3	A-2				A-4	A-5	A-6	A-7
	A-1-a	A-1-b		A-2-4	A-2-5	A-2-6	A-2-7				
Sieve Analysis (% Passing)											
No. 10 (2.00 mm)	50 mx	----	----	----	----	----	----	----	----	----	----
NO. 40 (0.425 mm)	30 mx	50 mx	51 mx	----	----	----	----	----	----	----	----
No. 200 (0.075 mm)	15 mx	25 mx	10 mx	35 mx	35 mx	35 mx	35 mx	36 mn	36 mn	36 mn	36 mn
Characteristics of fraction passing No. 40 (0.425 mm) Sieve											
Liquid Limit	----	----	----	40 mx	41 mn	40 mx	41 mn	40 mx	41 mn	40 mx	41 mn
Plasticity Index	6 mx	6 mx	N.P.	10 mx	10 mx	11 mn	11 mn	10 mx	10 mx	11 mn	11 mn
Usual types of significant constituent materials	Stone fragments gravel and sand		Fine sand	Silty and clayey gravel and sand				Silty soils		Clayey soils	
General rating as subgrade	Excellent to Good							Fair to Poor			

Note: Plasticity index of A-7-5 subgroup is equal to or less than L.L. minus 30. Plasticity index of A-7-6 subgroup is greater than L.L. minus 30. See Figure 1.4 below.

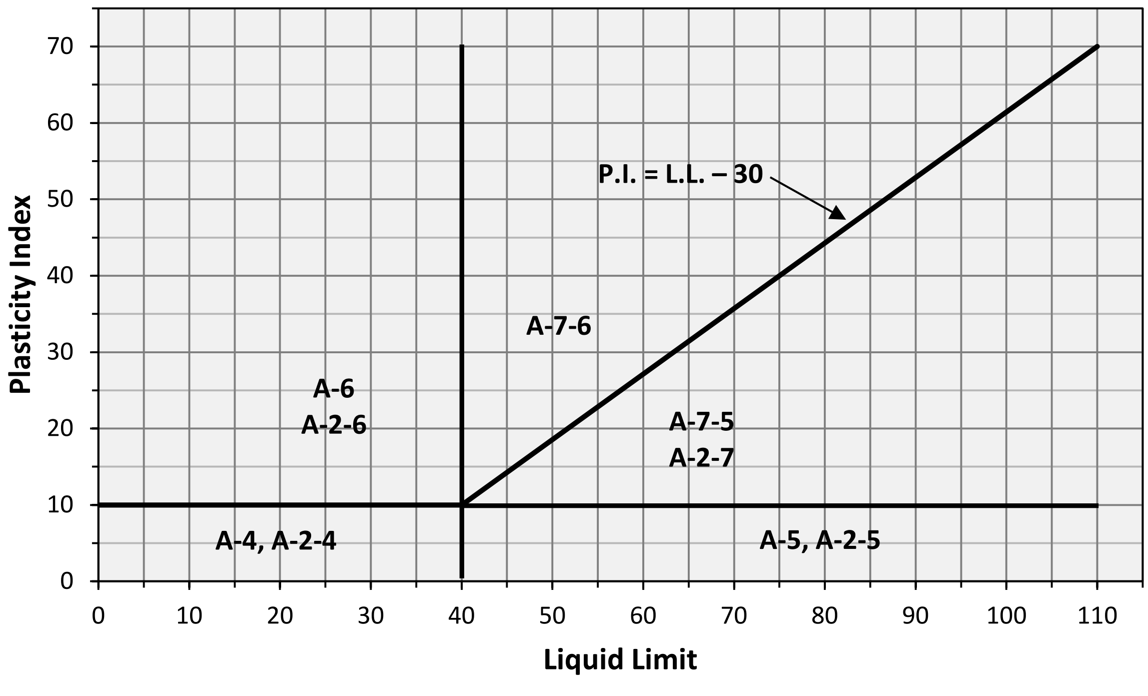


Figure 1.4: AASHTO Liquid and Plasticity Index Ranges for Silt-Clay Materials

At this point we have seen how two laboratory tests, gradation or sieve analysis and the Atterberg Limits, can be used along with the Classification table to get a general idea of how the particular soil will behave. When you have a lab report for a soil on your project, the classification will have already been done.

The next characteristic of soil we will examine gives the relationship of soil moisture and density achieved by compaction. As soil is compacted in the field, the void content gets smaller. That is, the compaction equipment makes the soil denser by pushing all the particles closer together. Although having too much water in a soil will prevent proper compaction, there needs to be some water in the soil to get good compaction. The water not only adds a little density, but lubricates the soil particles so that they can move during compaction to the tightest arrangement possible.

SOIL MOISTURE RELATIONSHIP

To illustrate the states that soils can be found in nature, the following schematic diagram of soil is used. The components of a soil mass are shown by the mineral grains of solids, the water or moisture, and the air or gases. Weight of a mass of soil is only due to the weight of the solids and the water in the soil, while volume is due to the solids, water and air. The voids between the solids of a mass of soil are filled with water and/or air as shown below. These relationships are illustrated below:

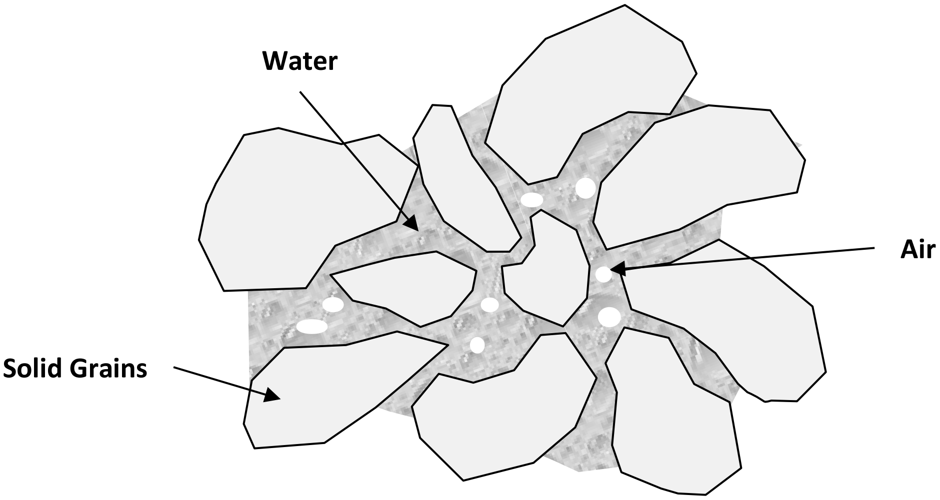


Figure 1.5: Nature State of Soil

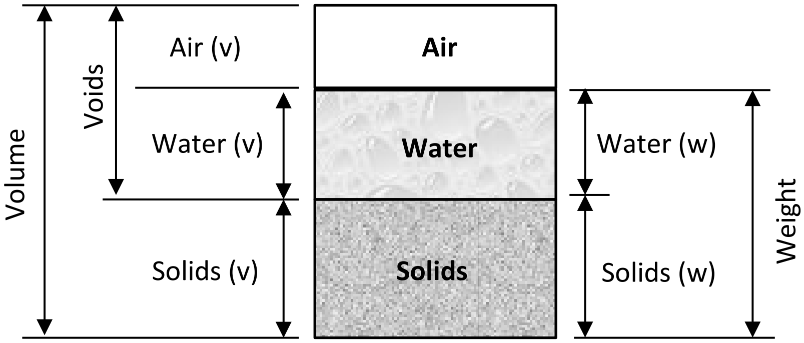


Figure 1.6: Wet Soil Weight and Volume Relationships (Phase Diagram)

The volume of the voids is filled with air and water. The total weight is due to the weight of the solids and water. This is the most common state found in construction. The compaction tests run by the inspector is this same comparison of weight and volume.

HOW DO WE RELATE SOIL MOISTURE RELATIONSHIPS TO CONSTRUCTION DENSITY

What is Density?

Density is the ratio of the mass of an object to its volume (pounds per cubic feet, lb/ft^3)

Density of soil or aggregate:

- Maximum Theoretical Density (lab or field)
  - AASHTO T99 & T180
  - VTM 1
- Field Density Testing
  - Nuclear Gauge
  - Sand Cone

Compaction of a material in construction is measured by comparing its field unit weight or field density with its maximum dry density. The density of a soil is defined as the weight of the soil in one unit of volume, or pounds per cubic foot.

$$\text{Compaction (\%)} = \frac{\text{Field Dry Density}}{\text{Max. Theoretical Density}} \times 100$$

Now that general characteristics of soil have been addressed, the next section will cover characteristics as determined by tests, and what this tells you about how a soil will respond to compactive efforts.

Laboratory Proctor

In order to know how well the contractor is compacting the soil in question, we must know how dense the soil would become under the best possible conditions. The lab test used to determine this is the Proctor. (The “Standard Proctor” Density Test is the most commonly used. There is also a “Modified Proctor” Density Test, but it will not be discussed here).

The test consists of making a soil mold of compacted soil at different moisture contents. The object is to find the optimum moisture content, which is the moisture content at which the soil compacts best, and the maximum density, which is the density achieved at optimum moisture.

On the curve below (Figure 1.7), you can see that as water is added, the density of the soil in the mold increases until the optimum moisture content is reached. Where the water content is low (W1), there is too little water to "lubricate" the soil particles. The friction of the dry soil particles will be enough to retard compaction. As water is added, the soil is lubricated and the compactive effort becomes more efficient. After this, the density decreases (W4) because water starts replacing soil in the mold (water is lighter than soil).

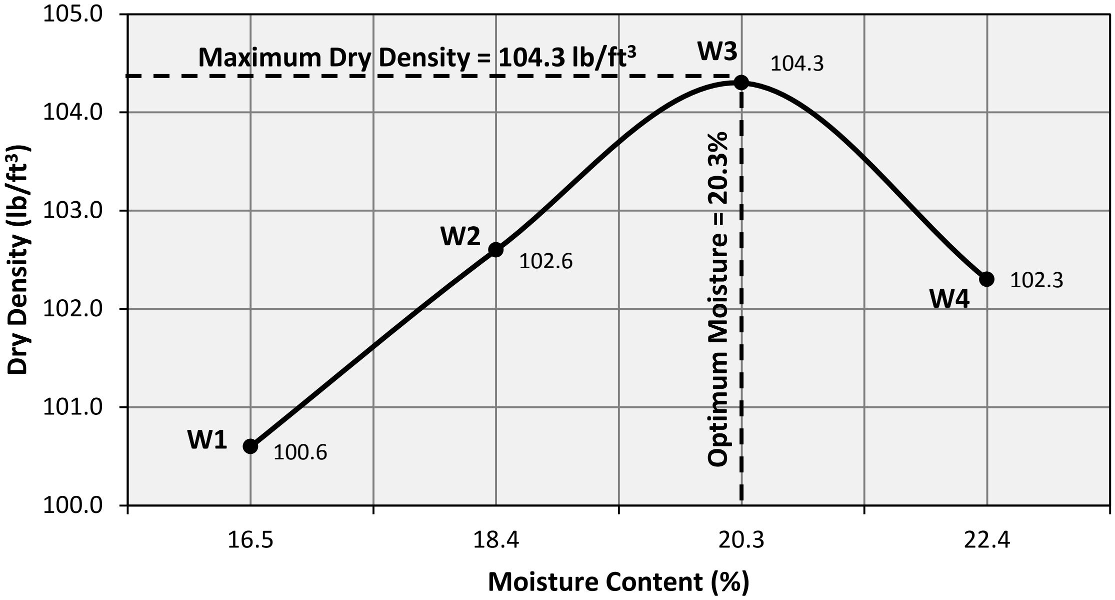


Figure 1.7: Example Moisture-Density Curve

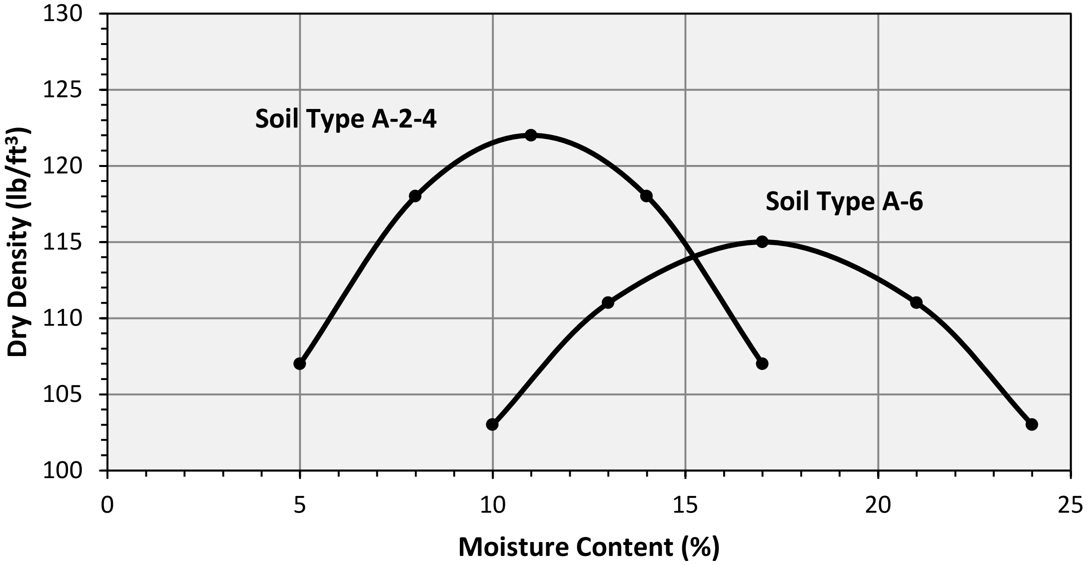


Figure 1.8: Example Moisture-Density Curve Comparing Different Soil Types

The soil designated A-2-4 (silty sand) will reach a higher maximum dry density than the A-6 (clayey soil). These are the soils represented on the moisture density curves above. The A-2-4 is a soil with less fines (35 percent max) and the moisture density curve is relatively steep on both sides of the optimum moisture content. The A-6 is a soil with more fines (36 percent minimum) and the moisture density curve is relatively flat on both sides of the optimum moisture content. Therefore, the moisture control during compaction in the field will require stricter control for the A-2-4 silty sand (steep curve) than the A-6 clayey soil.

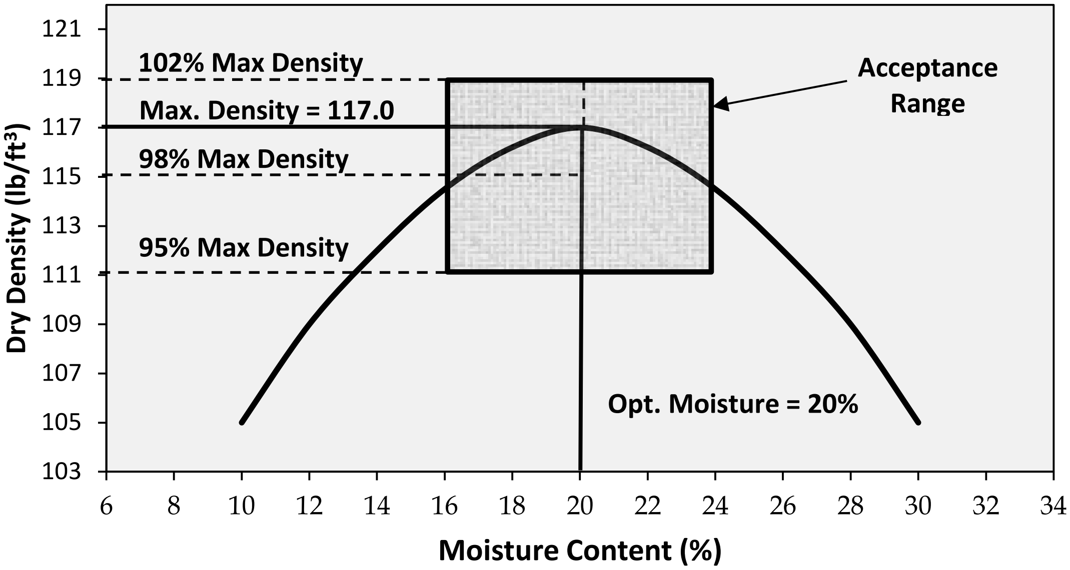


Figure 1.9: Acceptance Range for Moisture and Density

Figure 1.9 above will help you see the relationship between the optimum moisture/maximum density and the Specifications. This curve has VDOT Specification acceptance ranges blocked in. It is presented in this form to make it clear how the specification relates to the proctor, and what the areas on the curve mean. If you are working on a compaction and the values from the densities being run start falling out of the passing range, seeing where they fall on a graph like this may indicate to you where the problem is (for example, too much or too little moisture in the soil).

If, during construction, the density results either change suddenly, or simply don't make sense to you, these suggestions may help you determine what's happening:

1) Check your math, and the test itself.
2) When using the nuclear method, check closely the area around the pin for either rocks or voids of some sort. Also, make sure the Standard Counts for that day are within the expected ranges (Moisture and Density).

Once you have checked these things, other reasons for unexpectedly changing densities are:

- Temperature – if you are working in very cold temperatures, a drop in temperature can cause a reduction in maximum dry density, especially in clayey soils. (Soil shall not be placed or compacted at temperatures below freezing).
- Lift thickness – if for reasons of uneven subgrade, uneven application of material, or constructing a grade, the lift being compacted is uneven across its section, this can cause unevenness (change) in density/compaction.
- When excavated material consists predominantly of soil, embankment shall be placed in successive uniform layers not more than 8 inches in thickness before compaction over the entire roadbed area. Each layer shall be compacted at optimum moisture, within a tolerance of plus or minus 20 percent of optimum, to a density of at least 95 percent as compared to the theoretical maximum density.
- More compactive effort – either a change in the number of rollers, or a change in the haul route so the fill is being compacted additionally by the haul trucks.
- Moisture control – a change in the moisture of the material, this is especially likely on dry, hot and windy days.
- Change in the material – this is the most common reason for density results to either change quickly or stop making sense. ALWAYS be aware of the type of material being compacted and alert to changes. The possibility that you have run into soil that is not represented by a lab report that you have does exist.

CHAPTER 1 – STUDY QUESTIONS

1) True or False. The voids in a saturated soil are partly filled with water and partly filled with air.

2) VDOT uses _____________________ Classification Systems to classify soils.

3) _________________ refers to the texture and firmness of a soil.

4) Silt and clay are made up of particles that are smaller than the _________________ sieve.

5) The _________________ is the distribution of various particle sizes within the material.

6) _________________ means that the particles in a mixture are sized so that they fill most of the voids; there is very little space in between soil or stone particles.

7) The moisture content at which a soil begins to behave like a liquid is called the __________________.

8) The behavior of a material where the material deforms under load and does not go back to its original shape is called _________________.

9) The moisture content at which a soil can be compacted to its maximum dry density with the least amount of compactive effort is called the _________________.

10) True or False. A soil that contains a high percentage of fines is more affected by water than one with a low percentage of fines.

11) True of False. Open graded aggregates are used in a pavement to give the structure more strength.

2

CONSTRUCTION AND ACCEPTANCE TESTING OF EMBANKMENT MATERIAL

LEARNING OUTCOMES

- Understand the principles of foundation and embankment construction
- Understand the testing procedures and requirements for embankment material
- Understand the testing frequencies for embankment and structural fill material

INTRODUCTION

Building a roadway is like building any other structure. You must begin with a firm foundation to end up with a quality job. Many structural problems associated with our roads can be traced back to an improper foundation.

Overall performance of a pavement structure ultimately depends upon the proper construction of the following three elements:

- Foundation
- Subgrade
- Embankment

FOUNDATION CONSTRUCTION

To prepare for construction of an embankment:

- Establish erosion controls
- Clear and grub
- Start with a firm foundation

Before excavation and filling begin, we must ensure that a firm foundation is provided on which to build the embankment. During embankment construction, following proper methods and construction practices ensure we produce a structurally competent element to support our roadway as well as its own weight. Additionally, after our embankment is finished, we must provide a firm foundation for our pavement structure. The foundation in this case is the subgrade, which is the top of the shaped earthwork.

Often, the pavement structure itself is more closely scrutinized and more heavily monitored than the three elements outlined above. However, the best materials and construction will not make up for lack of quality of foundation, embankment and subgrade.

Competent testing and monitoring during construction is a key factor in achieving a quality product and should be of primary concern to the Construction Inspection team. This chapter is intended to give the student a working knowledge of the construction of embankments and subgrade including specifications, documentation, and standard methods and practices.

WORK PLATFORM CONSTRUCTION FOR SOFT/YIELDING AREAS

Two techniques used to construct work platforms are bridging lifts and geosynthetic fabric. Figure 2.1 illustrates common practice for "bridging" over swampy areas to construct a "work platform" for the remainder of the embankment. The thickness of the "bridging" layer should be such that it is capable of supporting hauling equipment while subsequent layers are being placed. An alternative method of creating a work platform is the use of geosynthetics to separate and reinforce the bridge layer placed on the swampy/soft area or later reinterpretation. In addition, plans and specifications need to define the responsibilities of both department and contractor.

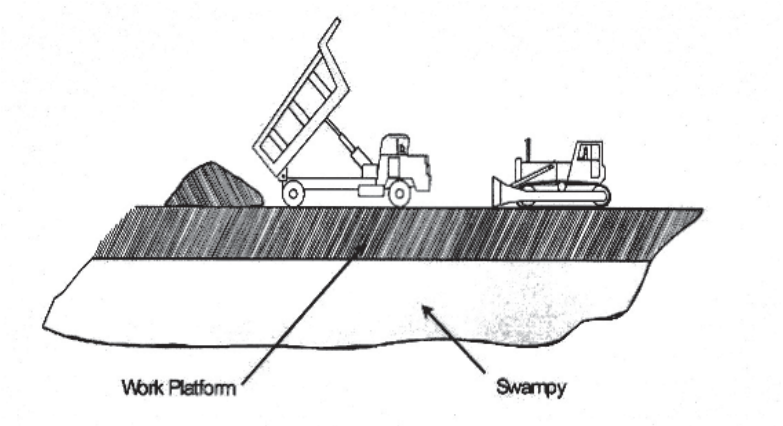


Figure 2.1: Illustration of Bridging Lifts

The nose, or leading edge, of the embankment should be maintained in a wedge shape to facilitate mud displacement in a manner that will prevent its being trapped in the embankment. The front slope of the wedge should be maintained at a slope ratio steeper than 2H:1V. Compaction equipment should not be used on this platform layer. To reduce the thickness of the work platform and possibly its impact on the swampy area by mud displacement, a geosynthetic can be placed on the swamp prior to the placement of the material that will be used to construct the work platform. Again compaction equipment should not be used on this material. Regardless of how the work platform is constructed any subsequent layer should be compacted as required in the specifications.

Special situations may arise such as the presence of underground tanks, existing foundations and slabs located within the construction limits. These structures must be removed and disposed of in a location approved by the Engineer. In lieu of removal, foundations and slabs located 3 feet or more below the proposed subgrade may be broken into pieces not more than half a foot in any dimension and reoriented to break the shear plane and allow for drainage. Tanks may be filled with flowable fill.

EROSION AND SILTATION CONTROL

Erosion and siltation controls must be installed prior to beginning any land disturbance. Silt fence, filter barrier, baled straw, check dams, or brush barriers are needed to protect surrounding land and waterways from the effects of erosion and siltation. The most commonly used erosion and siltation control devices are temporary silt fences and fabric silt barriers.

Baled straw silt barriers may be substituted for silt fence with the approval of the Engineer in non-critical areas, such as pavement locations where filter barriers cannot be installed as shown on the plans or required by the specifications, locations where the runoff velocity is low, and locations where the Engineer determines that streams and other water beds will not be affected. Silt sediment basins are required if rain runoff from a watershed area of 3 acres or more flows across a disturbed area.

Erosion and siltation control devices and measures shall be maintained in a functional condition at all times. The Contractor shall have on the project site an employee certified in Erosion and Sediment Control and designated as the RLD (Responsible Land Disturber). The RLD certification it is to be obtained from the Department of Environmental Quality. The RLD shall inspect temporary and permanent erosion and siltation control measures for proper installation and deficiencies immediately after each rainfall, at least daily during periods of prolonged rainfall, and weekly when no rainfall occurs. Deficiencies shall be immediately corrected. The Contractor shall make a daily review of the location of silt fences and filter barriers to ensure that they are properly located for effectiveness. Where deficiencies exist, corrections shall be made immediately as approved or directed by the Engineer. The absence of the RLD will result in suspension of any land disturbing activity.

CLEARING AND GRUBBING

Clearing is defined as the removal of trees, brush, debris, and other large items, while grubbing is the removal of stumps, roots, and topsoil. Clearing and grubbing should not apply to vegetation and objects that are designated to be preserved, protected, or removed in accordance with the requirements of other provisions of the specifications. Grubbing of rootmat and stumps shall be confined to the area where excavation shall be performed within 15 days following grubbing.

When and Where to Clear and Grub

Clearing and grubbing is required in these areas:

- All cut sections
- Fill sections less than 5 feet in depth and directly beneath the pavement and shoulders
- Any borrow excavation sites

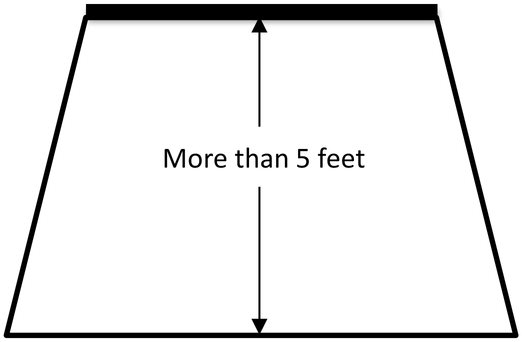


Figure 2.2: Stumps, Roots, Topsoil, and other materials must be left in place

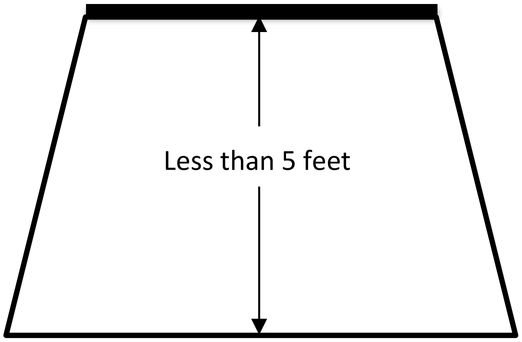


Figure 2.3: Stumps, Roots, Topsoil, and other materials must be removed

Clearing is required in all areas within the construction limits or designated on the plans. The Contractor may clear and grub to accommodate construction equipment within the right of way up to 5 feet beyond the construction limits at his own expense, if approved by the Engineer. Erosion and siltation control devices shall be installed by the Contractor prior to beginning grubbing operations.

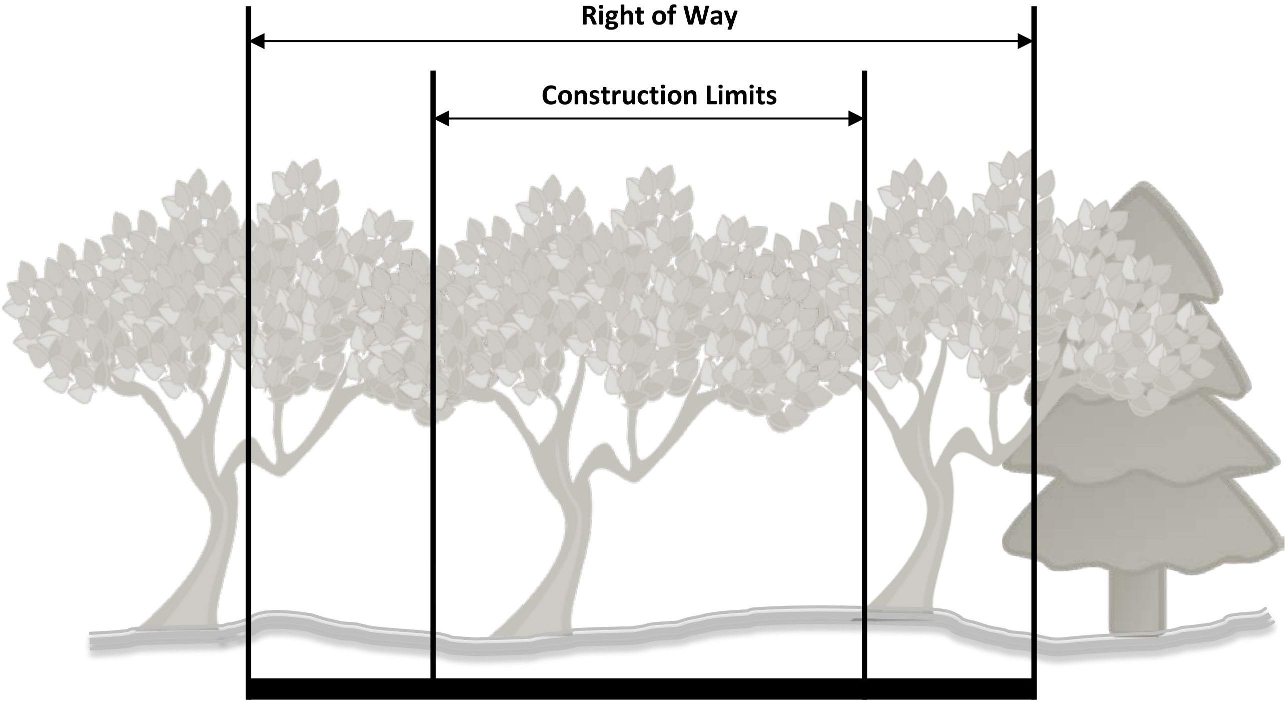


Figure 2.4: Illustration of Standard Right of Way and Construction Limits

The surface area of earth material exposed by grubbing, stripping topsoil, or excavating shall be limited to that necessary to perform the next operation within a given area. Grubbing of root mat and stumps shall be confined to the area over which excavation is to be performed within 15 days following grubbing.

Any stumps left in place must be no more than 6” above original ground, or low water level. Branches of trees that overhang the roadway or reduce sight distance and that are less than 20 feet above the elevation of the finished grade shall be trimmed using approved tree surgery practices.

Vegetation, structures, or other items outside the construction limits shall not be damaged. Trees and shrubs in ungraded areas shall not be cut without the approval of the Engineer.

Clearing and grubbing is done in the designated areas of the fill section to ensure that organic matter is not a factor in the structural integrity of the embankment foundation. The surface area directly beneath the pavement and shoulders, on which embankments of less than 5 feet in depth are to be constructed, shall be grubbed. Areas that will support compaction equipment shall be scarified and compacted to a depth of 6” to the same degree as the material to be placed thereon

When the material to be excavated makes the use of explosives necessary, the Contractor needs to notify each property and utility owner having a building, structure, or other installation above or below ground in proximity to the site of the work where they intend to use explosives. The specifications detail the Contractor’s responsibility and necessary actions to be taken.

Where rock or boulders are encountered, the Contractor needs to excavate and backfill by specified methods of undercutting rock.

Disposal of Removed Material

Combustible cleared and grubbed material shall be disposed of in accordance with the following:

- Used in Erosion Control Systems
- Buried as directed by the Engineer
- Burned if allowed by local ordinance

When specified on the plans or where directed by the Engineer, material less than 3 inches in diameter shall be used to form brush silt barriers when located within 500 feet of the source of such material. Material shall be placed approximately 5 feet beyond the toe of fill in a strip approximately 10 feet wide to form a continuous barrier on the downhill side of fills. Where selective clearing has been done, material shall be piled, for stability, against trees in the proper location. On the uphill side of fills, brush shall be stacked against fills at approximately 100 foot intervals in piles approximately 5 feet high and 10 feet wide. Any such material not needed to form silt barriers shall be processed into chips having a thickness of not more than
1/3 inch and an area of not more than 6 square inches and may be stockpiled out of sight of any public highway for use as mulch.

Stumps and material less than 3 inches in diameter that are not needed to form silt barriers and that are not processed into wood chips shall be buried where designated on the plans and permitted by the Engineer, placed in disposal or borrow pits, or disposed of by burning in accordance with the requirements of Section 107.16(b)2.

Trees, limbs, and other timber having a diameter of 3 inches and greater shall be disposed of as saw logs, pulpwood, firewood, or other usable material; however, treated timber shall not be disposed of as firewood. Not more than 3 feet of trunk shall be left attached to grubbed stumps.

When specified that trees or other timber is to be reserved for the property owner, such material shall be cut in the lengths specified and piled where designated, either within the limits of the right of way or not more than 100 feet from the right-of-way line. When not reserved for the property owner, such material shall become the property of the Contractor. Any consideration of marketable use of this material should be cleared with the Engineer.

GRADING METHODS AND PRACTICES

The following are some of the methods and practices used to protect the work, however the department reserves the right to require the contractor to use other temporary measures not discussed here or in the specifications to protect erosion or siltation conditions.

Grade to Drain

- Crown Surface
- Roll Surface
- Direct Water
- Install Slope Drains
- Install Side Ditches.

Unless precautions are taken, rainfall can be a hindrance during construction. The top of earthwork shall be shaped to permit runoff of rainwater. Temporary earth berms should be constructed and compacted along the top edges of embankments to intercept run off water. Temporary slope drains should be included to intercept and transport the runoff water to prevent damage to the earth slopes by erosion. These drains may be of flexible or rigid material. The contractor can also lessen the impact of erosion by maintaining the specifications suggested schedule for seeding slopes.

The practices outlined above will help the contractor get back to work sooner than if they had not been followed, but they are not a cure-all for wet weather. After a rain the surface of the embankment or subgrade in cut sections should be checked for acceptable moisture content. When the moisture in the upper part of the embankment or subgrade is too wet, measures must be taken to ensure that otherwise acceptable material is not placed on top of wet material. Methods for handling adverse moisture conditions will be discussed in a later section.

If drainage structures are involved in the work, the construction of check dams and silt settlement boxes should be one of the initial items of work accomplished.

EMBANKMENT CONSTRUCTION

An embankment is defines as a structure of soil, soil aggregate, soil-like materials, or broken rock between the existing ground and the subgrade.

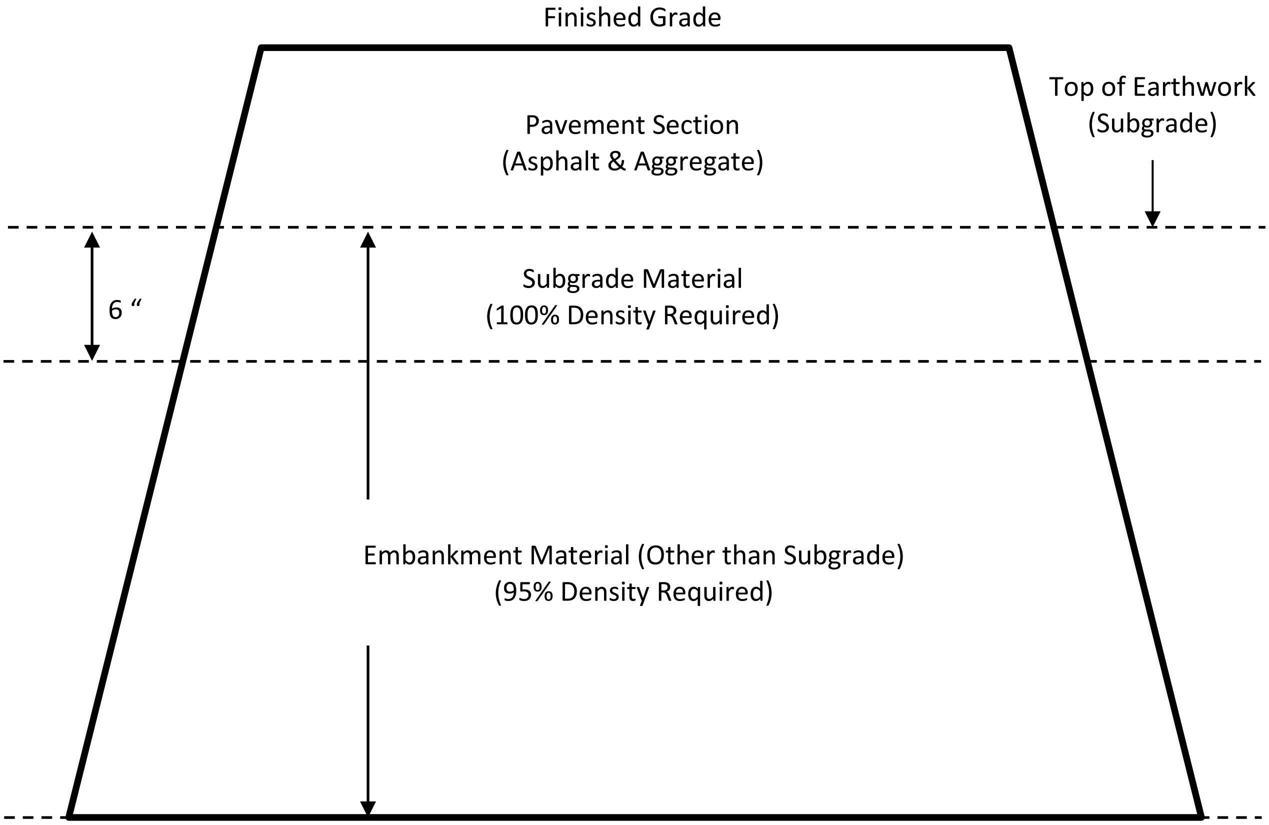


Figure 2.5: Typical Embankment Section

After necessary clearing and grubbing and once a firm foundation is obtained, embankment construction can begin. Failure to do this can result in compaction problems throughout its construction. As discussed before, the surface area directly beneath the pavement and shoulders on which embankments of less than 5 feet in depth are to be constructed shall be denuded of vegetation. Areas that will support compaction equipment shall be scarified and compacted to a depth of 6 inches to the same degree as the material to be placed thereon.

Soil that is not required to be removed should be thoroughly disked before constructing the embankment. Areas that contain material unsuitable as a foundation for an embankment should be undercut to a firm foundation material and backfilled as directed by the Engineer. Unsuitable material is defined as a material found to be undesirable for use in construction due to its poor load carrying capability, excessive moisture (exceeds allowable moisture content allowed by specifications), organic content, extreme plasticity, or other reasons.

Cisterns, septic tanks and other structures have to be filled with broken foundation masonry or rock placed in uniform layers and thoroughly compacted. Wells have to be closed in accordance with Department Policy.

Requirements of Embankment Materials

- Must be approved material (meet AASHTO M57)
- Must not contain muck
- Must not contain frozen material
- Must not contain roots
- Must not contain sod
- Must not contain other deleterious material

Types of Embankment Fills

- Regular excavation
- Borrow excavation
- Commercial sources
- Specialized materials
    - Light weight fill
        - Aggregate
        - Flowable fill
        - Cellular concrete fill/foam concrete fill
        - Tires
    - Fly ash
    - Slag

PLACEMENT OF LAYERS

As shown in Fig. 2.6, the first lifts of embankment material should be placed in low areas. Successive layers should be continuously manipulated to provide uniform layers approximately parallel to the finished grade. As material is brought in and spread, large roots and other objectionable materials must be removed and disposed of in an approved manner.

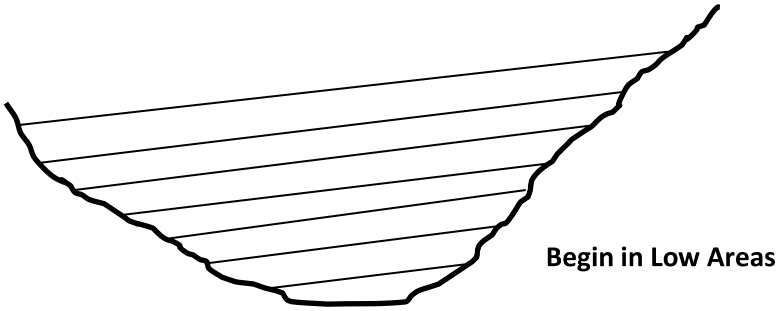


Figure 2.6: Illustration of Layer Placement

Lift Placement

- Uniform Layers
    - Lift Thickness
    - Moisture
    - Compactive Effort
- Parallel to Finished Grade

Because of the large amount of soil in an embankment, it is not feasible to blend it so that the entire embankment is homogeneous. We can, however, take steps to ensure we get uniformity.

When soil is being hauled to the project from an excavated area (regular excavation or borrow site), it should be dumped on the lift of embankment currently being constructed and worked into place for compaction. This practice not only blends the soil better but also achieves a better bond between the two layers. Figs. 2.7 & 2.8 show the incorrect and the correct method respectively.

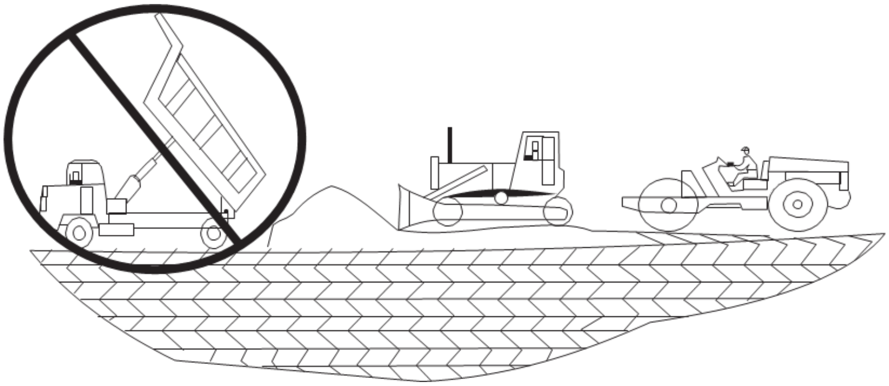


Figure 2.7: Illustration of Incorrect Layer Placement

This method would lead to non-uniform lift thickness, poor mixing of soil/aggregate, and non-uniform compactive effort.

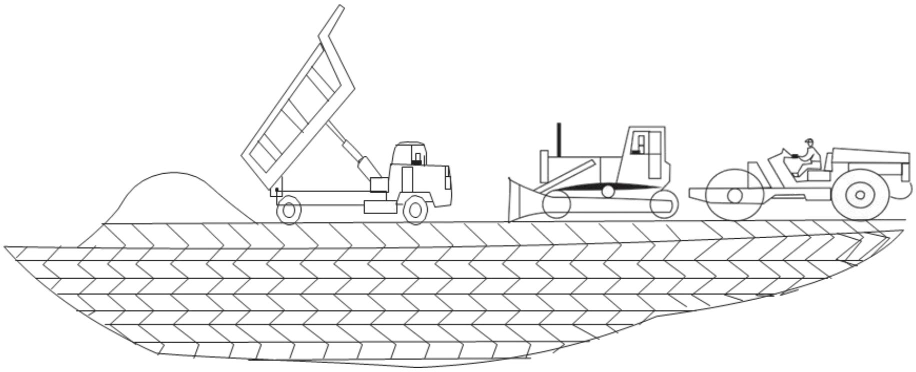


Figure 2.8: Illustration of Correct Layer Placement

This method promotes uniform layer thickness, improved mixing of soil and/or aggregate in layer, and promotes uniform compactive effort.

Monitoring Lift Thickness

The compaction of soils is influenced by how they are manipulated. Uniform layer or lift thickness is essential in achieving proper compaction. Typical lift thickness for soils in an embankment is eight inches loose, six inches compacted. When lift thickness is increased the actual compaction will decrease for a given compactive effort. As construction progresses, continuous leveling and manipulation of the surface of the fill will help keep the material mixed and the lift thickness uniform. Continual observation in the field is necessary to construct quality embankments. This cannot be overemphasized. Constant maintenance and monitoring of the fill surface helps ensure consistent layer thickness. Lift thickness can be measured as the new lift is placed. Checking the elevation at the top of each lift also ensures that proper lift thickness is maintained.

Monitoring lift thickness is a simple procedure when done as a new lift is being placed. Find the leading edge of the new loose lift. Lay a straight edge such as a leveling rod or shovel handle on top of the loose material so that it extends beyond the edge and over the previous compacted lift. Use a rule to measure from the bottom of the straightedge to the top of the previous compacted lift. This provides a good field check of lift thickness.

ROCK FILLS

When the excavated material consists predominately of rock fragments of such size that the material cannot be placed in layers of the thickness prescribed without crushing, pulverizing, or further breaking down the pieces resulting from excavation methods, such material may be placed in the embankment in layers not exceeding the thickness of the average size of the larger rocks. Rock not over 4 ft. in its greatest dimension may be placed in an embankment to within 10 ft. of the top of the earth work. The remainder of the embankment to within 2 ft. of the top of the subgrade shall not contain rock more than 2 ft. in its greatest dimension. Each layer shall be constructed so that all rock voids are filled with rock spall, rock fines and earth.

Rock shall be placed, manipulated, and compacted in uniform layers. Figures 2.9 and 2.10 show the proper method of spreading rock fill. Rock shall not be end dumped over the edge of the previous layer but dumped on top of the previous layer and worked into place. This reduces segregation of the larger rocks.

Figure 2.9

Figure 2.10

The 2 ft. of the embankment immediately below the subgrade shall be composed of material placed in layers of not more than 8 inches before compaction and compacted as specified herein for embankments. Rock more than 3 inches in its greatest dimension shall not be placed within 12 inches of the subgrade in any embankment. Lift thickness and rock size depend on where you are relative to the top of the subgrade. This is illustrated in Figure 2.11.

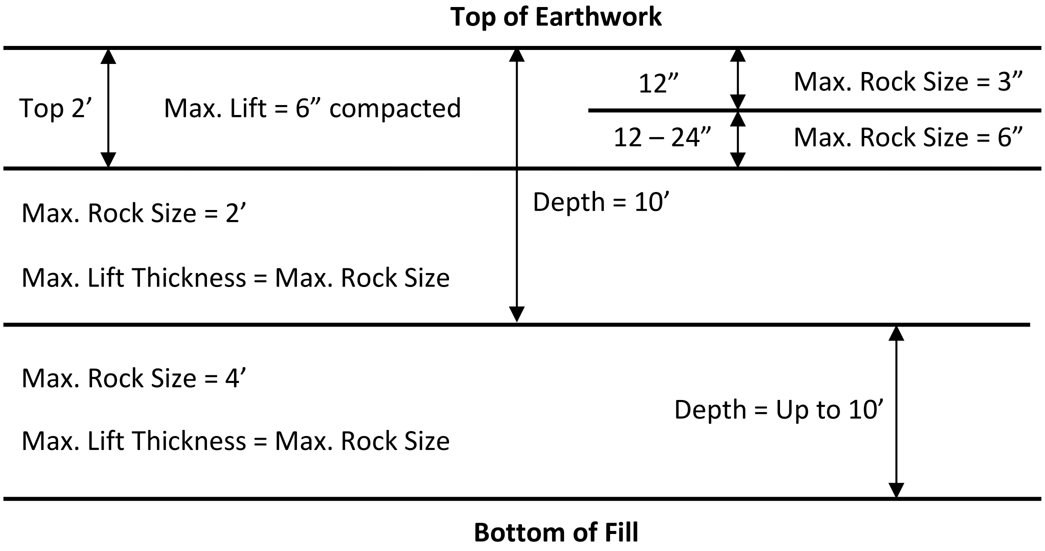


Figure 2.11: Requires for Rock Size and Lift Thickness

The best material is to be reserved for finishing and dressing the surface of the embankment. Attention to where and how rock is placed in an embankment is critical to achieving a dense and a stable structure.

Moisture shall be added for the purpose of controlling dust. The amount of rock present in an embankment that will preclude conducting density tests should remain flexible and should be at the discretion of the project inspector. It should be understood that if it is possible to conduct a test, then a test should be run.

SLOPE CONSTRUCTION

Special attention during construction is of the utmost importance. Poor construction can result in costs in maintenance and repairs that are greater than the initial costs. Major factors affecting slopes are the intrusion of water and the slope too steep for the soil type.

The problem of water intrusion can be minimized by following sound construction practices. Methods for grading to drain as outlined on page 8 can help keep surface runoff from eroding slopes. If the embankment is adequately crowned to promote drainage and good compaction is achieved along the outer edges of the slope and on the slope face itself, intrusion of water into the slope can be minimized. If the soil along the slope face is loose, it will provide a good area for grass seed to germinate, but as soon as a heavy rain hits the area heavy erosion and undercutting of the slope takes place which can lead to more serious problems if not properly repaired. If a grass bed is established, the zone of grass roots becomes saturated and there is nothing stable for the roots to establish anchorage. If this mass becomes laden with enough water, the grass and soil within the root mat slides down-slope, exposing the soil which can then become further saturated.

The effects of weather falling directly on the slope can be minimized by properly compacting the face of the slope and seeding the slope as soon as practicable. Section 302 of the Specifications details the requirements for incremental seeding to make sure large areas of slopes are not exposed to the elements for extended time periods. To make sure of this, seeding operations are to be initiated within 48 hours after reaching the appropriate grading increment for seeding, or upon suspension of grading operations for an anticipated duration of greater than 15 days, or upon completion of grading operations for a specific area.

Incremental seeding of slopes to prevent sloughing of soil on 5 feet or less slopes are applied in one action. On slopes 5 to 20 feet tall, seeding should be applied in 2 actions. On slopes greater than 20 feet tall, seeding should be applied in 3 actions. On slopes greater than 75 feet, seeding should be applied in 25 foot increments.

Problems associated with slopes being too steep for the soil are more difficult to handle. Flattening slopes may require purchasing costly additional right-of-way. However, building it “right the first time” is better than going back and rebuilding.

BENCHING

Construction of Embankments on Existing Embankments or Hillsides

To ensure stability of the new embankment, we must provide for a foundation and a suitable bond:

- The foundation is called a bench
- The bond is formed by continuously manipulating the old and new fills
- Benching can be used for new construction and for repairs of failed slopes

Special care is needed when widening existing fills or constructing fills on hillsides to assure stability. Simply constructing the new embankment directly on top of the existing one is unacceptable. In addition to compaction, two conditions must be met to ensure the new embankment is secured to the existing slope. The existing slope must be benched to provide a foundation for the new embankment. Benches are a series of horizontal cuts beginning at the intersection with original ground and continuing at each vertical intersection with the previous cut. Secondly, the existing slope or hillside is to be continuously blended with the fill material to provide a bond between the old and new material. The following figures illustrate the concept of benching.

If the existing slope or hillside is steeper than 4:1 but not steeper than 1 1/2:1, the minimum bench width is 6 feet. If the existing slope or hillside is steeper than 1 1/2:1 but not steeper than 1/2:1, the minimum bench width is 4 feet.

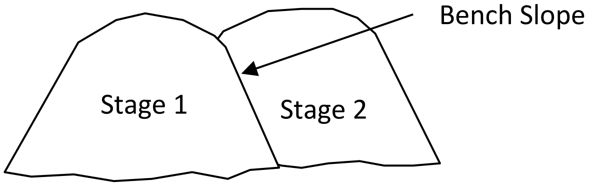


Figure 2.12: Benching ½ Width at a Time

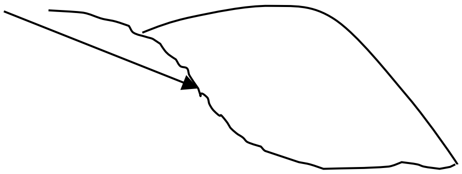


Figure 2.13: Benching Against Hillside

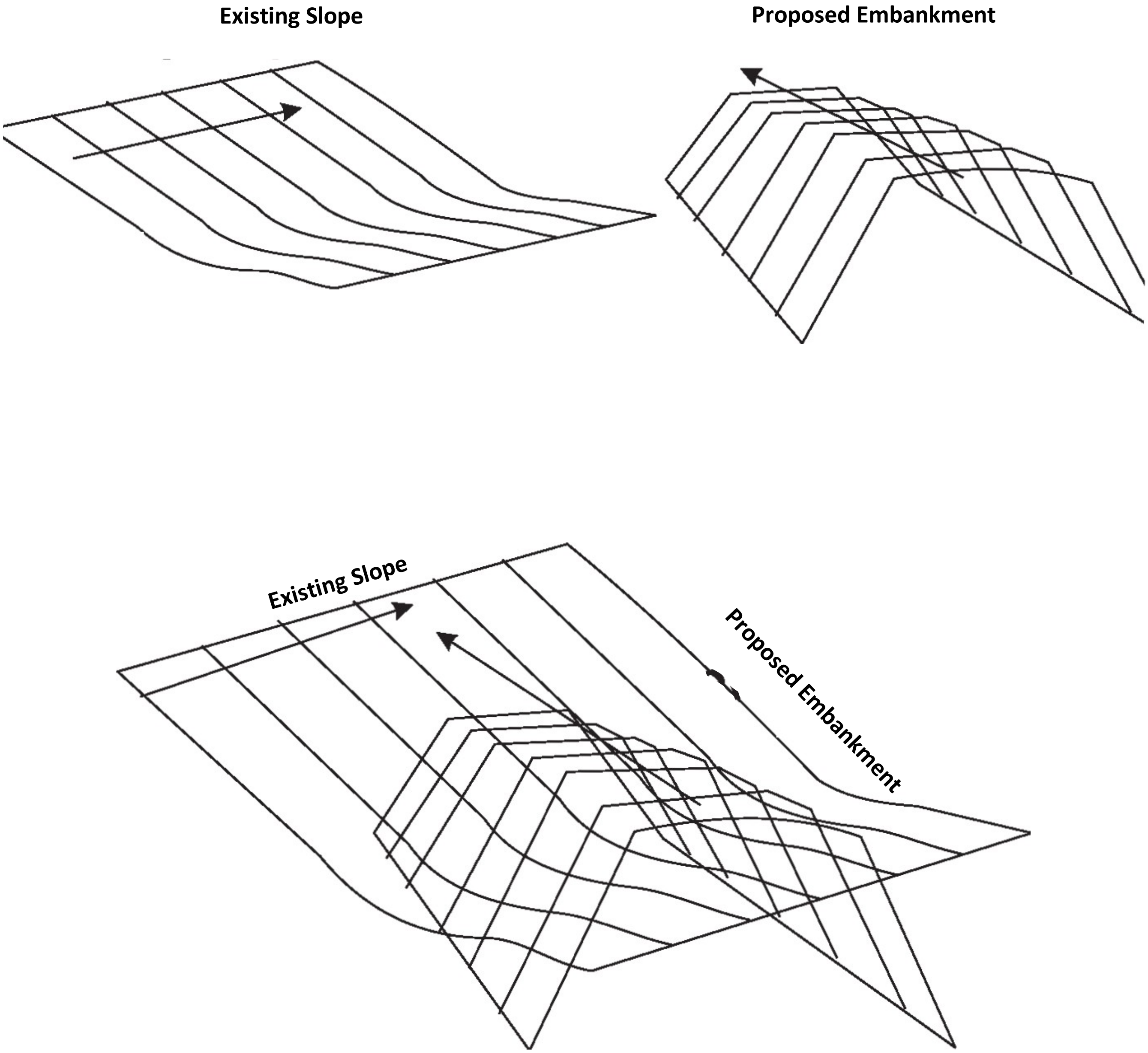


Figure 2.14: Benching Against an Existing Slope

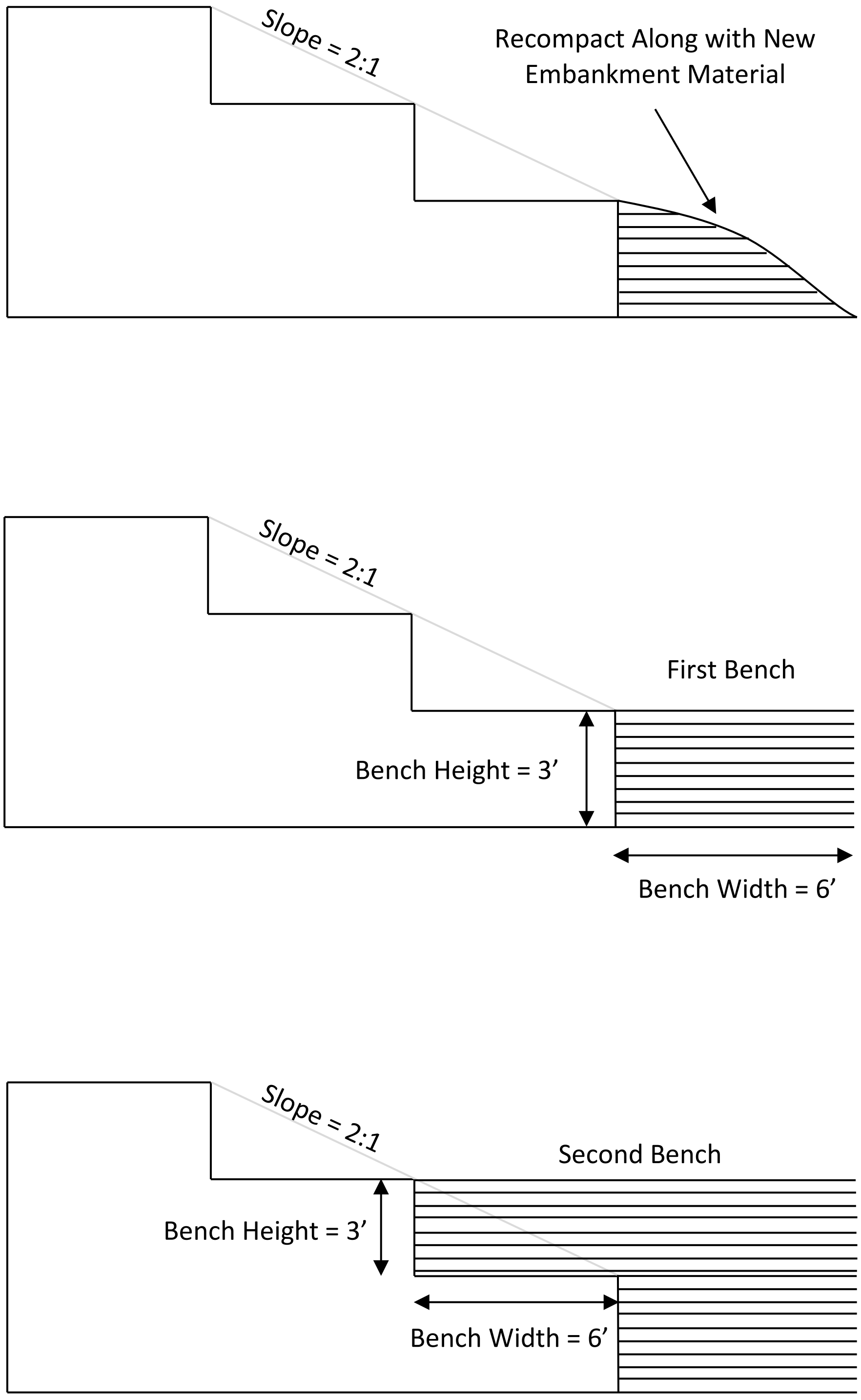


Figure 2.15: Proper Methods and Requirements for Benching

INTRODUCTION TO FIELD TESTING

Density Testing

Moisture Density Relationships

Every soil has a moisture content, known as optimum moisture, at which that soil can be compacted to its maximum density. Compacting the soil at optimum moisture and controlling the moisture content is critical to achieving adequate compaction. Too little moisture will require excessive compactive effort to obtain the desired density. If there is too much moisture, the maximum density cannot be reached until the excess water is released, regardless of how much the soil is rolled. The effect of moisture increases with decreasing particle size of the soil. That is, clays and silts (small particle size) are much more affected by the amount of water present than sands and gravels. Never underestimate the importance of moisture.

Proctor Test

The multipoint proctor test is run in the laboratory in accordance with VTM-1. A one-point proctor test, which is run at the project site, is run in accordance with VTM-12. Moisture/density curves made from the Proctor test are a good guide for the field control of moisture. Additional testing may be needed if unusual or unexpected soil is encountered.

Field Density Testing

Field density determinations will be performed with a portable nuclear field density testing device in accordance with VTM-10/AASHTO T310, or by other approved methods. Nuclear testing is the most widely used method. It involves the use of low level ionizing radiation to determine the total actual density of the tested material in units of pounds per cubic foot (pcf) and moisture in percentage of dry weight (%). When a nuclear device is used, density determinations for embankment material will be related to the density of the same material tested in accordance with the requirements of VTM-1 or VTM-12 and a control strip will not be required. Details of the test methods will be discussed in a later section.

Density Specifications for Embankment Material

- Minimum 95% of maximum theoretical density as determined by VTM-1 or VTM-12.
- Should not exceed 102% of maximum theoretical density

Moisture Tests

Oven/Pan Drying

This is the “old” method of testing for moisture, but it is very accurate. It employs the use of a set of scales, a pan, and a heat source (oven, gas stove or electric hotplate) for “cooking” the moisture out of the soil. Once the weight of the pan has been subtracted from the total weight, the basic moisture formula is used to calculate moisture content:

Formula for calculating moisture content:

$$W_{\%} = \frac{(W_{wet} - W_{dry})}{(W_{dry} - W_{con})} \times 100$$

Where:

$W_{\%}$ = Percent Moisture

W_{wet} = Weight of Wet Aggregate and Container (g or lb)

W_{dry} = Weight of Dry Aggregate and Container (g or lb)

W_{con} = Weight of the Container (g or lb)

“Speedy” Moisture Tester

This is the most widely used method for checking moisture, besides perhaps the nuclear gauge. The appeal is just as the name implies. It is quick and easy to perform. Correlations with oven dry moisture tests make the “speedy” very reliable. The “speedy” is used to obtain the moisture content for Proctor tests and conventional density testing. But because of its ease and quickness the “speedy” can help the inspector in other ways as well.

The Inspector should perform frequent moisture checks to be sure that the soil has the correct moisture content. It is recommended that the “Speedy” Moisture Tester be used for expediency in conducting these tests. When determining the moisture content for heavy clays, the “Speedy” test may be conducted by using the half sample method, or the field stove method may be used.

The Inspector should perform frequent moisture checks to be sure that the soil has the correct moisture content. It is recommended that the “Speedy” Moisture Tester be used for ex- pediency in conducting these tests. When determining the moisture content for heavy clays, the “Speedy” test may be conducted by using the half sample method, or the field stove method may be used.

The figure below shows the relationship between moisture content and dry density for a soil compacted with the same compactive effort at varying moisture contents.

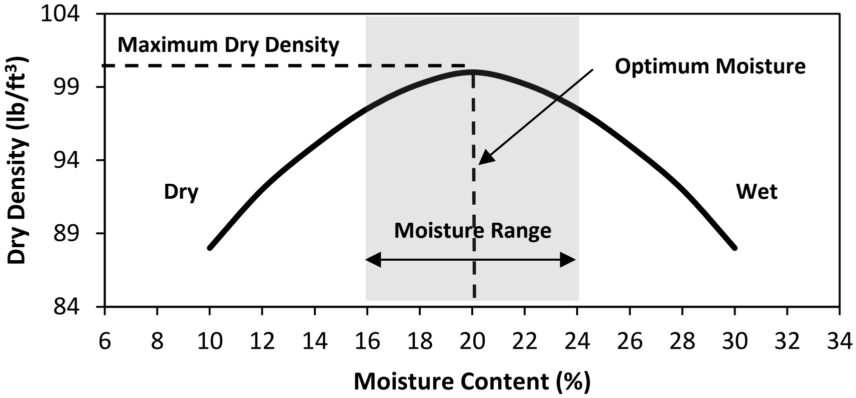


Figure 2.16: Moisture-Density Relationship

Moisture Specifications

For both the subgrade and embankment, the specifications require that each lift be compacted at optimum moisture, with a tolerance of ± 20% of that optimum moisture content. This specification and the range for a passing test is illustrated in Figure 2.16. If moisture is not within these specified tolerances, then the lift must be aerated or water added as the case may be. The moisture content for aggregate is ± 2 percentage points of the optimum moisture content. The moisture content for cement treated aggregate is also + 2 percentage points of the optimum content. The following examples illustrate how these specifications are applied.

Moisture Specifications:

- Soils + 20% of optimum moisture
- Aggregates + 2 percentage points of optimum moisture
- Cement Treated Aggregate optimum moisture + 2 percentage points of optimum moisture

Moisture Limits Example – Soils:

1) Given: OMC = 15%
2) Find Range (± 20%): 15% x 0.20 = 3%
3) Upper Limit: 15% + 3% = 18%
4) Lower Limit: 15% - 3% = 12%
5) Acceptable Moisture Range: 12% to 18%

Moisture Limits Example – Aggregates:

1) Given: OMC = 8%
2) Find Range (± 2 percentage points)
3) Upper Limit: 8% + 2% = 10%
4) Lower Limit: 8% - 2% = 6%
5) Acceptable Moisture Range: 6% to 10%

Moisture Limits Example – Cement Treated Aggregates:

1) Given: OMC = 5%
2) Find Range (+ 2 percentage points)
3) Upper Limit: 5% + 2.0% = 7%
4) Acceptable Moisture Range: 5% to 7%

Controlling Moisture

Not only is the distribution of soils particles important, but the distribution of moisture within the soil also influences it’s compactability. Moisture is necessary for filling all pockets in soil and for lubrication of the soil particles. If the moisture is not evenly dispersed, even though the compactive effort and average moisture may be acceptable, the density results will not be satisfactory. When additional moisture is required, better moisture control is generally obtained when added at the excavation. Decisions regarding where and how moisture will be added is the responsibility of the contractor.

To ensure proper moisture:

- Monitor material behavior
- Watch equipment
- Take plenty of tests

If the moisture content of the soil is too high, pumping can occur. When loaded, the material deforms, and as the load is removed the material springs back to its original position. The con- struction equipment looks like it is riding on a wave as it travels over the fill. In this condition the strength of the soil is substantially reduced. One solution is simply to let it dry out. If the pumping section is located in an undercut, additional drainage solutions may be needed. If the water content is not reduced by some means, and the possibility of drainage problems recurring is not eliminated, repeated loadings will create internal shear failure in the embankment. When pumping occurs, construction should not continue until a permanent solution to the drainage problems is found.

If moisture is too high:

- Wait
- Scarify
- Remove and replace
- Chemical treatment
- Geosynthetic bridging

If moisture is too low:

- Add water
- Thoroughly mix

MOISTURE AND DENSITY TESTING RATES

The minimum rates of acceptance testing for all the materials in this course are presented in Appendix A. The minimum rates for materials covered in this section of the manual are presented below. These rates are minimums! They should be treated as minimums.

The following figures illustrate the minimum rate of moisture and density testing required for acceptance.

Embankment Soils

There is a standard volumetric rate of one test for every 2,500 yd^3 of fill regardless of the length of fill. In addition, there are two testing rates depending on the length of the fill section:

1) Fill areas that are less than 500 feet
2) Fill areas from 500 to 2,000 feet

For fill areas that are less than 500 feet, one field density test for each 2,500 yd^3 from the bottom to the top of the fill, plus one field density test for every other 6” lift starting with the second lift.

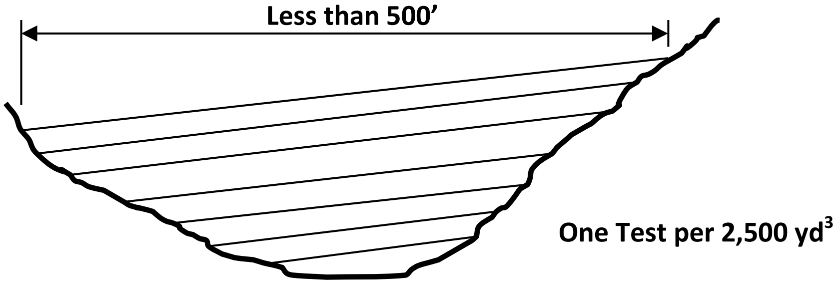


Figure 2.17: Typical Fill Section Less than 500’

For fill areas from 500 to 2,000 feet, one field density test for each 2,500 yd^3 from the bottom to the top of the fill, plus two field density tests for every 6” lift within the top 5’ of fill.

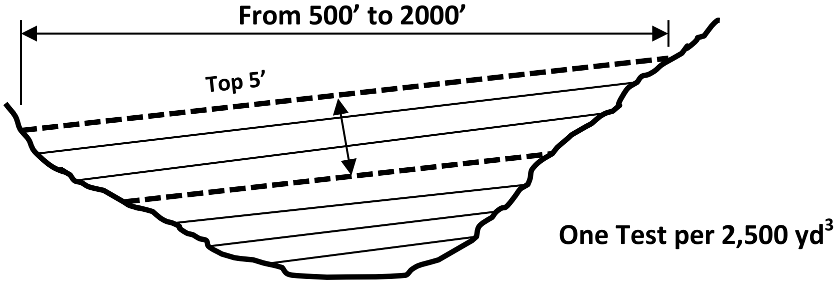


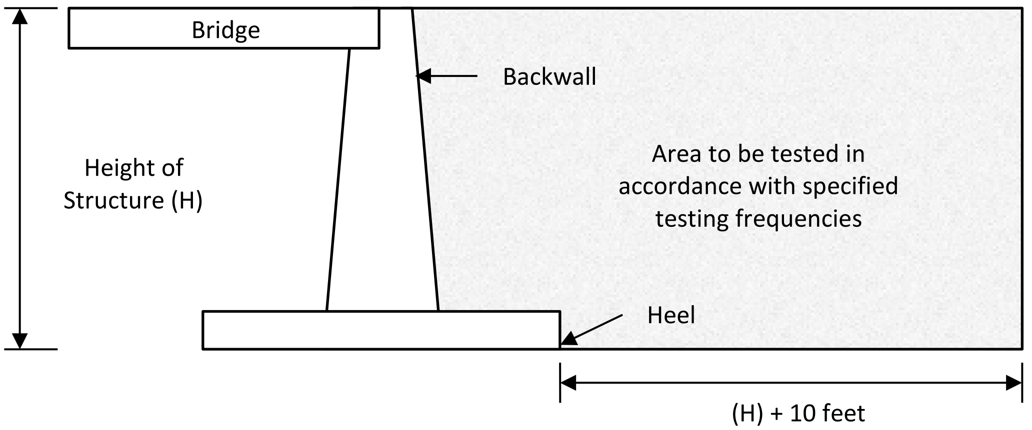
Figure 2.18: Typical Fill Section from 500’ to 2000’

Abutments, Gravity and Cantilever Retaining Walls

The testing frequencies for backfill behind Abutments, Gravity and Cantilever Retaining Walls are as follows:

A minimum of two tests shall be performed for every other lift, up to 100 linear feet behind the backwall, at a distance from the heel to no farther than a length equal to the height of the structure plus 10 feet.

Testing Frequencies and Locations for Bridge Abutments



Frequency of Testing = Two Field Density Tests on Every Other Lift

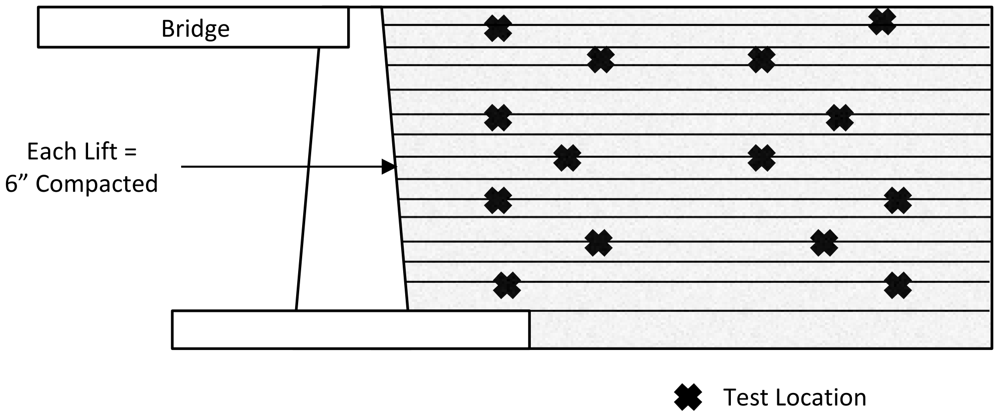
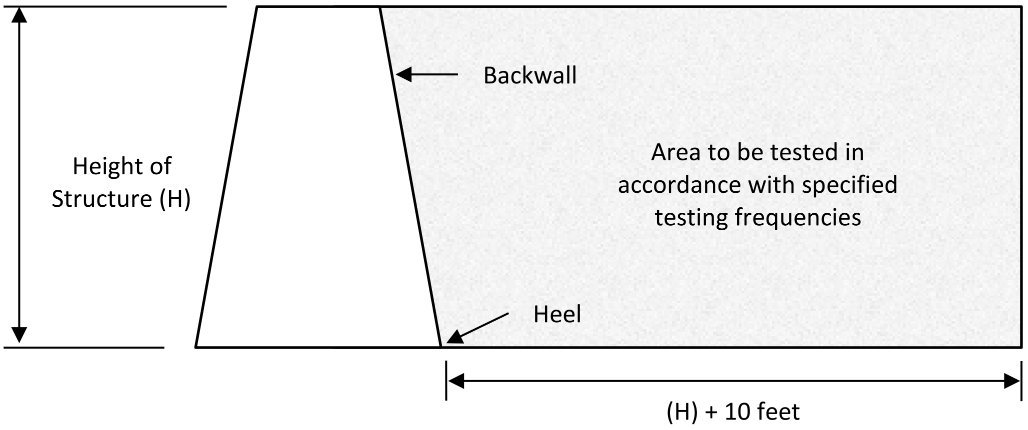


Figure 2.19: Testing Frequencies and Locations for Bridge Abutments

Testing Frequencies and Locations for Gravity Retaining Walls



Frequency of Testing = Two Field Density Tests on Every Other Lift

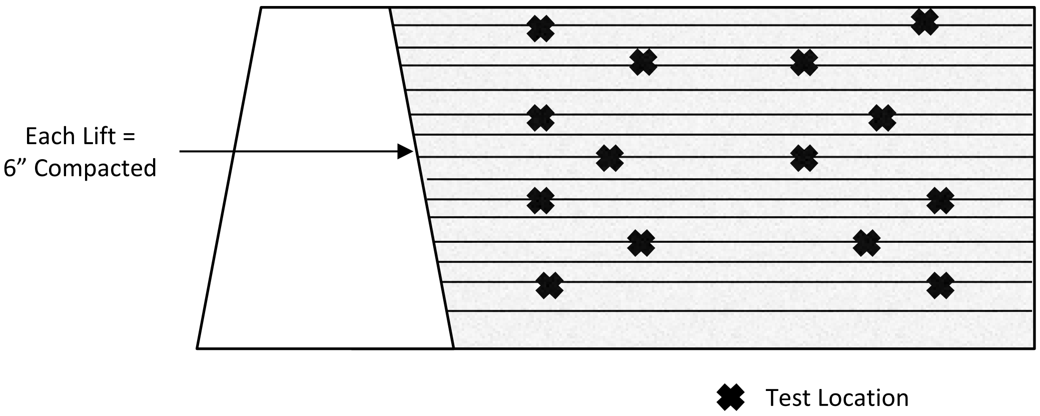


Figure 2.20: Testing Frequencies and Locations for Gravity Retaining Walls

Testing Frequencies for Mechanically Stabilized Earth (MSE) Walls

Less than 100 linear feet, a minimum of one test every other lift. The testing will be performed at a minimum distance of 3 feet away from the backface of the wall, to within 3 feet of the back edge of the zone of the select fill area. Stagger the tests throughout the length of the wall to obtain uniform coverage. Testing will begin after the first two lifts of select fill have been placed and compacted.

For walls of more than 100 linear feet, a minimum of two tests shall be taken on every other lift, not to exceed 200 linear feet.

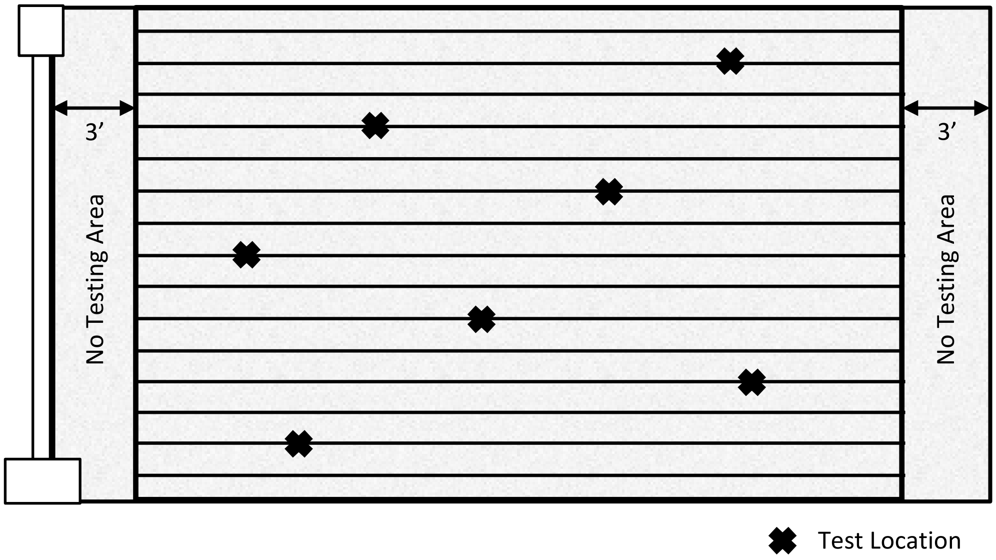


Figure 2.21: Testing Frequencies and Locations for MSE Walls (less than 100')

For structures/walls with an anchor system, compaction is not as critical as for MSE walls.

UNSUITABLE MATERIALS

VDOT accepts a wide variety of materials for use in embankments. The only soils that will not be accepted are topsoil, rootmat, any soil containing organic matter, saturated or highly plastic soils. Saturated or highly plastic soils have little load bearing capacity and would pump and rut significantly if placed in an embankment or if it were left as part of the subgrade. Saturated and highly plastic soils, as well as those high in organics, should be undercut to a firm foundation and backfilled with a better quality soil to improve bearing capacity and drainage.

Unsuitable material may be encountered either in the cut section or the embankment foundation (bottom of the fill). Specific treatments will be discussed later. However, material which is designated on the plans as unsuitable may be found to be suitable during construction because the moisture content may have changed since it was initially tested. If it is in a cut section, then such material may be used in embankments in lieu of borrow. If such material is at the embankment foundation, but designated to be removed, then it should be left and the inspector should notify the Project Engineer for an on-site review of the material.

The unsuitable materials do have one useful purpose in that they can be placed on the outside slope of embankments to make the overall slope angle flatter, thereby improving the stability of the slope. In order to avoid adversely affecting the drainage of the pavement, unsuitable materials cannot be placed within 6 feet of the top of the embankment.

This material shall not be placed in a structural area of the embankment. The structural area of the embankment shall be constructed with the slope ratio shown on the plans.

CHAPTER 2 – STUDY QUESTIONS

1) True or False. Clearing and Grubbing is required in fill sections less than 5 feet in depth, in borrow areas before excavation can begin, and in all cut sections.

2) In fill sections where stumps may be left in place, they must be no more than __________ high.

3) ________________ means to crown surface of embankment, roll surface of embankment smooth, direct water to appropriate erosion and siltation controls.

4) The first lift of embankment material placed in swampy areas is called ________________.

5) How should layers of embankment material be placed?

6) Please answer the following questions:

   a. For a fill with a height of 8 feet, a length of 1500 feet, and a volume of 61,200 cubic yards what is the minimum number of density tests required?

   b. For a fill with a height of 8 feet, a length of 400 feet, and a volume of 61,200 cubic yards what is the minimum number of density tests required?

   c. For a fill with a height of 10 feet, a length of 2200 feet, and a volume of 80,000 cubic yards what is the minimum number of density tests required?

7) Material is being placed 15 feet below the proposed subgrade in a rock fill. The maximum nominal size of the rocks is 3 feet. The maximum lift thickness in this case is _______________.

8) True or False. In building an embankment on a hillside, benching provides a place to test.

9) Is frozen embankment material acceptable to use in embankments?

10) Is 108 % compaction acceptable for embankment?

11) True or False. For subgrade and embankment, the specifications require that each lift be compacted at optimum moisture content with a tolerance of ±40%.

12) True or False. Embankment is a structure of soil, soil aggregate, soil-like materials, or broken rock between the existing ground and the subgrade.

13) ________________ is the minimum bench width for a slope steeper than 4:1 and less steep than 1½:1?

14) What is the density testing rate for fill areas less than 500 feet long?

15) What is the density testing rate for fill areas between 500 feet and 2000 feet?

16) What is the maximum distance from the heel of an abutment/gravity or cantilever retaining wall that is to be tested by the specified rates for walls if the structure is 12 feet high?

17) Material having a moisture content of more than 30% above optimum cannot be placed on a previously placed layer for drying, unless it is shown that ____.

18) The typical lift thickness for soil is _________________ loose, _________________ compacted.

19) The maximum diameter of the material placed in the top 12 inches of an embankment is _________________.

20) The maximum diameter of material that can be placed 9 feet under the embankment surface is _________________.

3

CONSTRUCTION AND ACCEPTANCE TESTING OF SUBGRADE MATERIAL

LEARNING OUTCOMES

- Understand the importance of subgrade and the different types of subgrade material
- Understand the various types and methods of mechanical and chemical stabilization
- Understand the compaction and testing requirements for various subgrade materials

INTRODUCTION

What is Subgrade?

Subgrade is the top surface of an embankment or cut section that is shaped to conform to the typical section upon which the pavement structure and shoulders will be constructed.

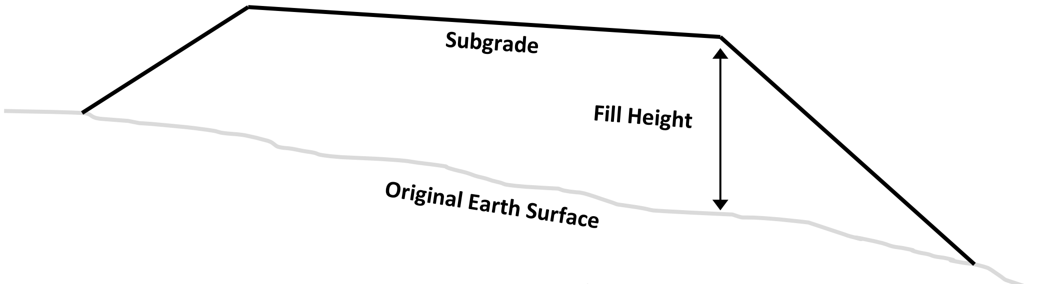


Figure 3.1: Typical Cross-Section for Roadway Fill Section

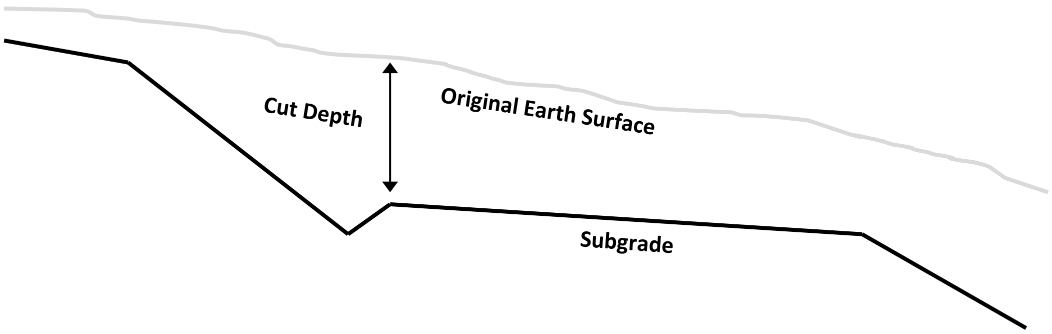


Figure 3.2: Typical Cross-Section for Roadway Cut Section

Importance of Subgrade

Heavy trucks and buses are continually loading our pavements. These loads are transmitted through the pavement to the subgrade. In effect, the loads applied to the surface of the pavement are transmitted through the structure, deforming or otherwise destroying the integrity of the subgrade. How the subgrade is going to react under the application of traffic loads is of great concern. As illustrated in Figure 3.3, how the load gets transferred to the subgrade and how the subgrade can handle that load has a strong influence on the overall quality of the pavement. If the pavement is thin, as shown in the right hand sketch, the stress imposed by the traffic load through the pavement is distributed over a small area, making for high stresses on the subgrade.

If the subgrade is poorly prepared (improper compaction, excessive moisture, etc.) or has a very low strength (such as with highly plastic clays), the subgrade cannot resist these high stresses and ruts will form, which could lead to significant damage to the pavement. If the pavement is thick, as shown in the left hand sketch, the stress imposed by the traffic load through the pavement is distributed over a large area, making for low stresses on the subgrade. Even if the subgrade is made up of low strength soils, such as the highly plastic clays mentioned above, you can still have a good performing pavement because the stress projected through the pavement is lower than it would be with a thin pavement and if the design is done properly, these stresses should be lower than what can be resisted by the subgrade. It is still important to have the subgrade soils properly compacted when a thick pavement is used because rutting can still take place.

As mentioned above, reducing stress can be accomplished by simply building a thicker pavement. This looks great on paper and is practical to a point. But pavement items are very expensive. Optimizing the pavement itself is very important, but there comes a point where this is not practical. Providing a strong subgrade is essential. Increasing the strength of subgrade allows us to use a thinner pavement.

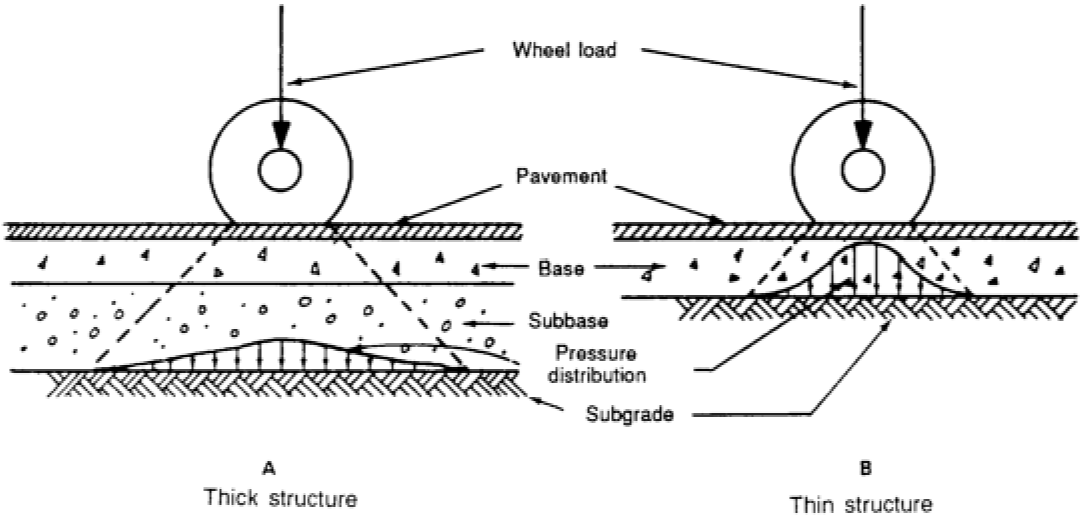


Figure 3.3: Load Distribution Characteristics of Thick versus Thin Pavements

California Bearing Ratio (CBR) test is run on soils to gauge the strength of the subgrade as compared to a dense graded aggregate. CBR is one of the major factors used in pavement design to determine how thick the pavement should be. Since we have chosen a pavement based on certain subgrade conditions, we must have the best subgrade conditions under our pavement for it to perform its job.

To understand the impact of CBR (subgrade strength) on the pavement, let's look at some typical CBR values. A clayey soil generally has a low CBR value (less than 8). Sands are more granular and drain better and will generally have CBR values between 15 and 35. Gravel will have the best CBR values, generally 25 and up. That is why it is suggested to save the best material to cap the subgrade. The higher the CBR of foundation soils you have, the less pavement structure is needed, the more economical the design. CBR values are also used as criteria for borrow material.

Types of Subgrade Material

TABLE 3.1
Type of Subgrade Material

Material Type	Material Description
Material in Place	Soil in a cut section of roadway
Imported Material	Borrow material and regular excavation material
Treated Material	Material in place or imported material May be considered in the design of the pavement structure Improves engineering properties of the soil Provides a solid platform to compact subsequent layers

The specifications list three types of material which are acceptable for use as subgrade. Each type has different characteristics and must be dealt with accordingly.

Material in Place - Whenever the roadway will be in a cut section, subgrade will be in original ground. The density of most soils is at approximately 85 to 90 percent of our Standard Proctor density (VTM-1 or VTM-12) in its natural state. Soil in this condition often falls short of having the strength to support our pavement structure. In order to achieve our desired strength, these soils must be compacted. The specifications require that material in place be scarified to a depth of 6 inches for a distance of 2 feet beyond the proposed edges of pavement on each side. This is illustrated in Figure 3.4 on Page 3-5. This requirement applies to both cut and fill sections.

Imported Material - Subgrade material consisting of imported material is called "borrow material". This material can come from regular excavation from another area in the project, from commercial sources, or from local pits or quarries obtained by the Department or the Contractor. Placement and compaction of borrow material would follow the same procedures and practices that are used when placing and compacting soil taken from a cut site on the project.

Treated Material in Place - For some soils, simply scarifying and compacting will not produce the desired strength needed to support our pavement. In these cases it can be very cost effective to stabilize the subgrade with lime, cement, fly ash or a combination thereof. This provides a solid foundation for the remainder of the pavement. Stabilized subgrade provides two very important benefits:

1) Becomes part of the pavement structure
2) Improves the structural integrity of the layers placed above it

COMPACTION REQUIREMENTS FOR SUBGRADE

Whether subgrade consists of material in place, treated material in place or imported material, it must be compacted to 100% density (95% for soil-lime). Field densities are compared to VTM-1 or VTM-12. VDOT requires 100% density because it promotes uniformity of subgrade and improves the strength of the subgrade. When subgrade material contains large quantities of material retained on the No. 4 sieve, use the table below to determine the minimum required density.

TABLE 3.2
Density Requirements for Subgrade Material

Percent +4 Material	Minimum % Density Required
0 – 50%	100%
51 – 60%	95%
61 – 70%	90%

The moisture requirement for subgrade is optimum moisture ± 20%.

In cut sections, the subgrade should be scarified and re-compacted 2 feet beyond the edge of pavement and six inches deep.

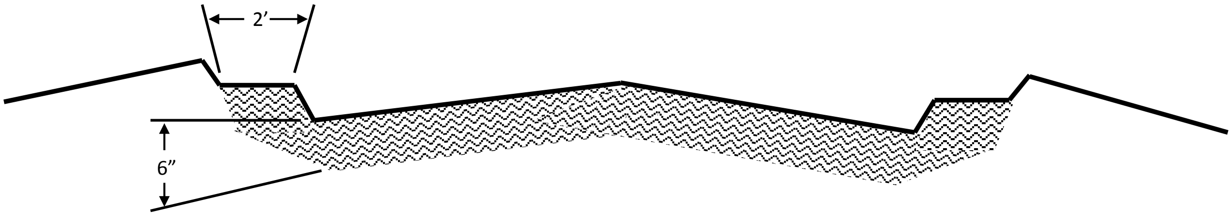


Figure 3.4: Typical Cross-Section of Roadway Subgrade Requiring Scarification

SUBGRADE STABILIZATION

The top of subgrade, as with other portions of an embankment, can be stabilized by two primary methods: mechanical and chemical.

Mechanical Stabilization

In the case of mechanical stabilization, rolling (compaction) is the simplest and most commonly used method. Appendix E details the various types of rollers available and which type roller works best for certain soils. For subgrade stabilization however, the most commonly used rollers are pneumatic, static steel wheel, and vibratory steel wheel. The benefits of rolling include increasing the material density and strength, along with decreasing its permeability and compressibility.

Another method of mechanical stabilization is geosynthetics, which is gaining popularity throughout the commonwealth. The types of geosynthetics that are most likely used for stabilization are geotextiles, geogrids, and geocomposites.

- Geotextiles – consist of synthetic fibers made into flexible, porous fabrics by standard weaving machinery or are matted together in a random nonwoven manner.
- Geogrids – plastics formed into open, gridlike configuration.
- Geocomposites – a combination of Geosynthetics such as a Geotextile attached to a dimpled plastic sheet used for pavement drainage, or a Geotextile attached to a geogrid.

Geotextiles have been used in roadway construction in Virginia since the early 1970's, primarily in erosion and siltation control. In the 1980's, the construction industry began using geosynthetics in earth stabilization applications. The primary benefit of using a geotextile is that you get separation between the poor quality subsoil and the better quality backfill material. An additional benefit of using a geotextile or a geogrid is an increased resistance to spreading by means of the reinforcement. Because of this, the Department can save a substantial amount of money by using geosynthetics to "bridge" soft subgrade areas and reduce or eliminate undercutting. The local District Materials Engineer can give guidance as to the types of materials that can be used and where they can be used.

TABLE 3.3
Types of Mechanical Stabilization

Stabilization Type	Equipment/Material Used	Construction Benefits
Rolling (Compaction)	Fine-Grained Soils (Clays/Silts) ▪ Sheepsfoot Roller ▪ Rubber-Tire Roller ▪ Smooth Wheel Roller Coarse-Grained Soils (Gravel/Sand) ▪ Crawler Tractor ▪ Vibratory Roller ▪ Rubber Tire Roller	▪ Increases density ▪ Increases strength ▪ Decreases permeability ▪ Decreases compressibility
Geosynthetics	▪ Geotextiles ▪ Geogrid ▪ Geocomposites	▪ Increases subgrade strength ▪ Bridges soft subgrade areas ▪ Reinforces base material ▪ Resistance to spreading

Geotextiles are the most widely used geosynthetic. In this chapter we will discuss how we use geotextiles at the subgrade and under embankments. The geotextile performs the primary functions of reinforcement and separation when used at the subgrade and on the embankment footprint. Typically the geotextile is placed in the desired area, pulled tight to limit wrinkles, and if at the subgrade, an overlap of 2 feet is provided at the seams. However, to reinforce an embankment, all seams are to be sewn to allow for the tensile stress to be transmitted. It is critical that the correct geotextile is used in the appropriate place, since the properties of various styles will affect the overall performance of the structure.

Geogrids are also becoming more widely used in Virginia. While these can be used to reinforce a subgrade, or an undercut, they are most likely to be used to reinforce a slope or embankment foundation. Careful attention must be paid to the specifications or contract documents for geogrid selection and installation.

Chemical Stabilization

In the case of chemical stabilization, the procedure is to add a chemical that reacts with the soil and then changes its physical and/or chemical characteristics to form a more stable material. The most commonly used methods of chemical stabilization of subgrade soils are cement, lime, fly ash, lime-fly ash, cement-lime, and salts. These materials are mixed with the subgrade soils and are allowed a curing period to react with the soil and harden.

Some of these materials (such as lime, lime-fly ash, and salts) can be mixed with water to form a slurry and are then pressure injected into a soil mass to form a stable structure foundation or to stabilize a landslide.

Hydraulic Cement Stabilization

Commonly called “soil cement”, hydraulic cement stabilization is the most widely used method of stabilizing soils. The method is acceptable for a wide variety of soils.

- Used in sandy and gravelly soils (10 to 35% fines)
- Used in some fine-grained soils with low plasticity
- Not used in very coarse sands and gravels
- Not used in highly plastic clays
- Not used in organic soils

TABLE 3.4
Hydraulic Cement Stabilization Requirements (By Soil Type)

Soil Type	Usual Range in Cement Required	
	Percent by Volume	Percent by Weight
Clean Gravel	5 – 7	3 – 5
Clean Sand	7 – 9	5 – 8
Dirty Gravel or Sand	7 – 10	5 – 9
Silt	8 – 12	7 – 12
Clay	10 – 14	10 – 16

Hydraulic cement is usually added to existing material in place. This is normally done with a self-propelled, self-powered, rotary mixing or tilling machine. The subgrade layer is scarified to the specified depth, cement and water added, and mixed by the same machine in one pass. Other machines which require a separate pass for each operation may be used but are not common.

The amount of cement to add to the soil to achieve the desired results depends on the soil type and is determined in the design phase by performing laboratory testing. Typical cement contents are shown in the table below. This amount of cement can be specified either by weight or by volume. PCA recommends specifying the cement content by weight; however, VDOT typically specifies the cement by volume since there are fewer field calculations needed to determine application rate.

When using cement stabilization, the control necessary to ensure that a quality product is produced consists of the following:

- Application rate
- Moisture
- Depth control
- Compaction
- Curing

Application Rate. Cement stabilized subgrade is specified as a percentage of cement per unit volume or by unit weight and a depth of manipulation (i.e. 10% cement by volume, 6” depth - 10% cement by weight, 6” depth). Cement can be applied by either using bag cement or bulk loads with the latter being the most common. The application rate depends on the percentage by volume or weight, depth and width of spread. Application rate can be controlled by either a rate per foot basis or a rate per square foot basis.

The application rate is determined prior to placement of the cement to ensure that an adequate amount of cement will be spread to achieve the desired percentage of cement. Both the contractor and inspector should be aware of how much cement is to be applied to achieve the desired outcome.

The following procedure should be used when calculating the application rate by volume.

Example Problem – Application Rate by Volume

Given: The plans call for 12% cement by volume, with an 8" depth. Width of treatment is 28 feet. The net weight of the cement in the tanker is 22.5 tons.

Question: How many feet of roadway should this load of cement treat?

1) Determine the Application Rate using the following formula:

Application Rate = $[(W_t \times D_t)] \times [(D_c \times 94)]$

Where:

W_t = Width of treatment in feet

D_t = Depth of treatment in feet (8" ÷ 12" = 0.666')

D_c = Design cement content (volume in decimal form)

94 = Unit weight of cement in lb/ft^3

Application Rate = [(28 x 0.666) x [(0.12 x 94)]

↓

18.648 x 11.28

↓

Application Rate = 210.35 lb/ft^3

2) Determine the Application Length using the following formula:

$$\text{Application Length} = \frac{(\text{Cement Weight} \times 2000)}{\text{Application Rate}}$$

Where:

Cement Weight = Net weight of cement in tons

Application Rate = Resulting value calculated from Step 1

2000 = Number of pounds in one ton of cement material

$$\text{Application Length} = \frac{(22.5 \text{ x } 2000)}{210.35}$$

$$\downarrow$$

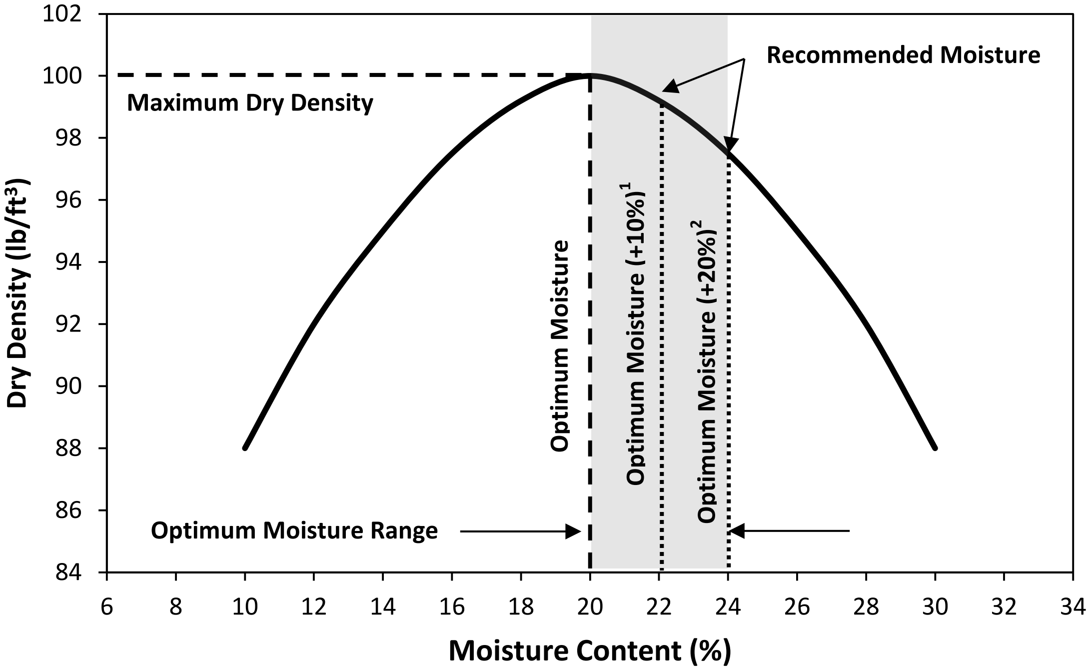
$$\frac{45{,}000}{210.35}$$

$$\downarrow$$

$$\text{Application Length} = \text{214 Feet}$$

Answer: A load of 22.5 tons of cement applied at the rate of 12% by volume for 8" depth of treatment should cover 214 feet by 28 feet in width.

Moisture. Proper moisture control is crucial with cement treated subgrade. Because of the fine-grained cement, the soil has a tendency to "dry out". Best results can be obtained when the mixture is brought to optimum or within 20% above optimum of the original soil. The specifications require the mixture to have moisture of not less than optimum or more than 20% above optimum. This is graphically illustrated in Figure 3.5 below.



[1] Acceptable Range = Up to 20% above Optimum Moisture

[2] Recommended Range = 10% to 20% above Optimum Moisture

Figure 3.5: Moisture Control Chart with Original Proctor Curve

Depth Control. Having the proper depth of treatment is one of the most important factors affecting the final product. Deviation from the specified depth either by an increase or decrease has an effect on the strength of the treated material (see Figure 3.6 below). As stated earlier, stabilized subgrade is part of the pavement structure. If the treated depth is less than that specified, we are compromising the pavement's depth. If the treated depth is greater than that specified, the cement will be dispersed throughout a greater volume and the entire course will be weak.

The general rule of thumb for soil compaction applies here: 8" of loose soil (after mixing) will compact to 6". This should be checked.

After the material has been compacted and tested for density it must be checked for depth. When material in place is tested the aid of a liquid solution of phenolphthalein in distilled water is needed. This can be obtained from your District Materials Personnel. When the solution comes in contact with cement or lime, it turns purple in color. Check the depth of cement by using a pick to dig a hole and, using a medicine dropper, apply the solution to the side of the hole. The purple indicator disappears at the bottom of the cement. A stake placed flat on the ground across the hole and a ruler are used to measure the depth.

If plans called for 6' depth and 10% by volume assuming application rate is correct…

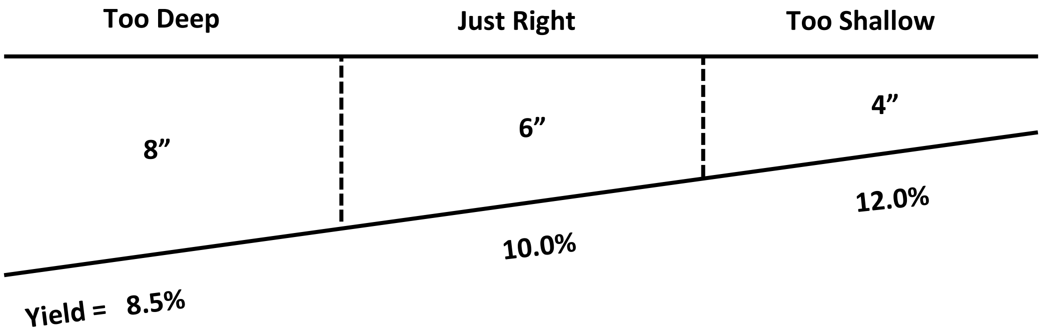


Figure 3.6: Effects of Incorrect Depth on Cement Yield

Compaction. The specifications require that soil cement be compacted to 100% of the maximum density. Compaction equipment is subject to the approval of the Engineer. A sufficient number of compaction units should be provided to ensure that the specified level of density is achieved, and the completion of the compaction of the soil cement section is accomplished within 4 hours from the time water is added to the mixture. The minimum rate of compaction testing is one test per ½ mile for each application width. Any portion on which the density is below the specified density by more than 5 lb/ft^3 shall be removed and replaced.

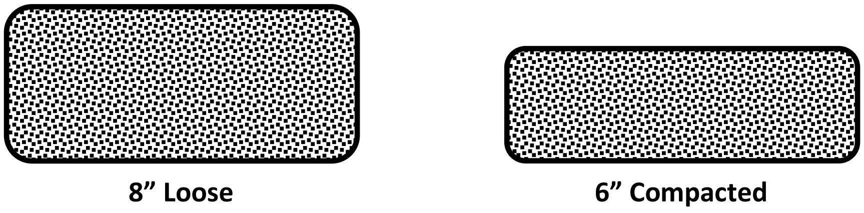


Figure 3.7: Illustration of Typical Compaction Depths (Loose vs. Compacted)

Curing. Just as with hydraulic cement concrete, cement stabilized subgrade must be cured to develop the desired strength. Once the grade has been approved the next course may be placed. In order that the grade does not dry out, the specifications require that it to be kept moist. This will aid the curing process. The contractor may elect to use an asphalt cover material in lieu of moist curing. However, if the next course is not placed within 7 days, it must be protected with an asphalt cover material.

When material may be exposed to freezing temperatures during the first 24 hours of curing, the contractor shall protect the stabilized material from freezing for 7 days or cover the soil-cement surface with the next pavement course within 4 hours after the cement stabilization has been finished as specified.

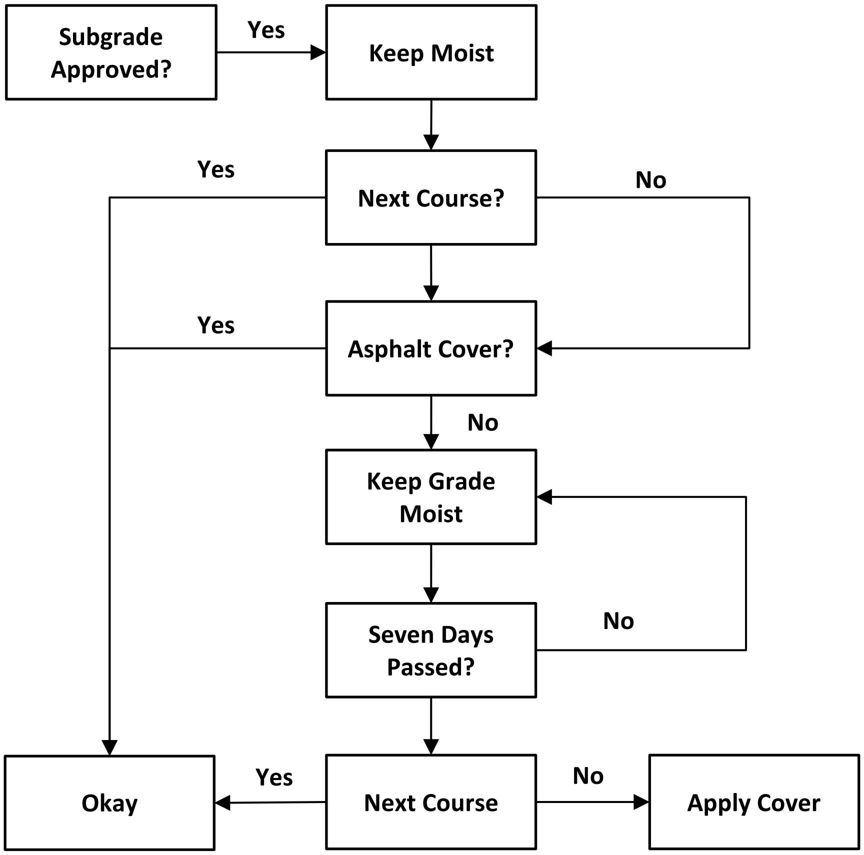


Figure 3.8: Decisional Flow Chart for Curing Process

Lime Stabilization

- Application Rate
- Scarify and pulverize soil to required depth
- Spread lime
- Spray water and mix
- Allow the mix to cure
- Final mixing and compaction

Lime stabilization works very well with fine-grained soils, particularly heavy clays because it changes the plasticity characteristics of the clay. The addition of lime to a wide variety of soils greatly improves its load carrying capacity. It should be noted that although lime can be used with granular soils, you can generally get greater strength gain by using cement for the same money spent to use lime.

The application rate of the lime will be shown on the plans or can be as directed by the Engineer (generally the District Materials Engineer). The lime may be applied to the partially pulverized material as a slurry or in dry form. Hydrated lime or quicklime can be used. When quicklime is used in a dry form, it is to be applied at the same rate as hydrated lime.

Lime stabilization should be done in stages. In the first stage, the prepared roadbed is scarified to the depth and width required for the stabilized layer. After scarifying, the material is to be partially scarified. The depth of scarification, pulverization and blading should be controlled in such a manner that the surface of the roadbed below the scarified material shall remain undisturbed and conform to the established cross section. Prior to the beginning of stabilization work, material retained on the 3” sieve is to be removed from the roadbed.

If quicklime is slaked to produce a slurry, correction factors need to be applied to make sure the proper amount of lime is being used (see Section 306.03 of the specifications for correction factors)..

Lime applied by slurry generally causes less dust problems than using dry lime. However, regardless of the system, the spreading equipment should uniformly distribute the lime without excessive loss. No equipment, except water trucks and equipment used for mixing and spreading, is to travel on the applied lime until properly mixed.

This process generates a lot of heat and there will be a loss of moisture in the soil. Sufficient water should be added to make sure that the moisture content of the mix at time of compaction is not less than the optimum moisture content of the mix, nor more than optimum plus 20 percent of optimum.

Lime and water are mixed throughout the scarified material as thoroughly as practical by using a disc harrow, scarifier tines and blading, or by other approved methods. Spread the mix over the roadway and seal roll with a steel wheel or pneumatic tire roller to retard loss of moisture and allow it to cure. Curing is considered completed when a uniform material is produced in which at least 60 percent of the material (except aggregate particles) passes the No. 4 sieve, or 24 hours have lapsed since the beginning of mixing, whichever occurs first.

Final mixing will take place. If a stationary plant is used to mix the soil and lime, the material can be placed, compacted and finished immediately after mixing.

Unlike soil-cement mixtures, soil-lime mixtures are compacted to a density of 95 percent of the maximum theoretical density of the mixture determined in accordance with VTM-1 or VTM-12. Final rolling is done with a pneumatic tire roller. Final compaction and finishing must be completed within 12 hours after final mixing.

After finishing of the treated subgrade, no vehicles (except the water truck) will be permitted on the compacted soil-lime mix for a period of 7 days, or until the next layer of the pavement structure is placed, whichever is less, to allow for final curing. During the final curing period, the soil-lime mix is lightly sprinkled with water at frequent intervals to prevent drying of the mix. If at the end of 7 days the contractor has not placed the pavement course, the contractor must place liquid asphalt and a cover of fine aggregate on the mix.

Salt Stabilization

Stabilization of soils has been accomplished with salts such as sodium chloride, calcium chloride, or potassium chloride. This method of subgrade treatment has been successful, but the treated material must be covered quickly or the salt will re-dissolve. Chloride is very expensive, thus is not a very cost effective method of treatment. Rusting of equipment by this method is also a problem.

Lime and Fly Ash Stabilization

Fly ash by itself provides no strength gain for soil. However, if lime is added with the fly ash, they will react to provide cementation of the soil.

Lime-Cement Stabilization

In some eastern areas of the state, lime and cement are used together to stabilize soil. The lime is used to dry the silty sands that are virtually saturated, and then cement is added to improve its strength. It is quite expensive, but sometimes may be proven to be cost effective because it does not require undercutting a good quality material that can provide good strength, if dried and treated with cement.

TREATMENT OF UNSUITABLE SUBGRADE MATERIAL

When solid rock is encountered at subgrade, the roadbed must be excavated below the elevation shown on the plans and backfilled in accordance with Road and Bridge Standard RU-1 (606.01).

Other unsuitable materials include saturated material, high plasticity clays, or other low CBR material. These must also be undercut and backfilled with approved material.

PROTECTING THE WORK

After subgrade is finished and has been checked and approved, it must be maintained. Any deficiencies in compaction, grade or moisture must be corrected before subsequent layers can be placed. If subgrade becomes eroded or distorted prior to placing subsequent layers, it must be scarified, reshaped and recompacted to the original requirements. If subgrade becomes unstable after placing any or all of the pavement material, the unstable area must be undercut and reconstructed properly.

The above is a specification requirement. Having to go back and re-work areas which have been completed is time consuming and costly. The same procedures for grading to drain with embankments also apply to protecting the work at any stage of construction.

TESTING AND INSPECTION OF SUBGRADE

After scarifying and compacting, subgrade must be tested for compaction and checked to ensure a typical cross section and uniform grade before subsequent courses can be placed. The minimum rate of density testing for untreated subgrade material in place is one test per 2000 linear feet of roadway (full width). Before pavement items are placed on the subgrade, it must be visually checked for soft spots, depressions, etc. Passing compaction tests don’t necessarily mean the subgrade is ready for the pavement. Any deficiencies must be corrected prior to placing subsequent layers.

OBSTRUCTIONS AT SUBGRADE

The materials exposed at subgrade elevation, or in areas that are to receive fill material must be visually evaluated to determine if construction operations may proceed. If the materials exposed consist of rock, existing hydraulic cement concrete pavement, existing asphalt concrete pavement or unsuitable materials, these must be handled appropriately.

If solid rock is encountered at subgrade elevation, it must be removed to the depth specified in Standard Drawing RU-1, Standard Method for Undercutting Rock. The reason that the rock must be removed is to provide for a uniform base upon which to place the pavement. If the pavement is placed on a base that provides irregular support, then the pavement may deform in the areas where there is limited support.

If existing pavements are encountered, depending on where they are relative to the future subgrade elevation, they are handled differently. It also depends on the type of pavement as to how the materials will be handled. The following paragraphs summarize the procedure for some materials; however, see Section 508.02 of the VDOT Road & Bridge Specifications for more details.

Hydraulic cement concrete pavement and cement-stabilized courses underlying pavement designated for demolition shall be broken down into pieces and either used in fill areas as rock embankment in accordance with the requirements of Section 303 or disposed of at locations selected by the Contractor and approved by the Engineer. If the material is within the proposed roadway prism and more than 3 feet below the subgrade, it may be broken into pieces not more than 18 inches in any dimension, sufficiently displaced to allow for adequate drainage, and left in the roadway prism.

Asphalt concrete pavement that does not overlay or underlie hydraulic cement concrete pavement shall be removed and used in the work as designated on the plans or as directed by the Engineer. When approved by the Engineer, the pavement shall be removed and disposed of at locations selected by the Contractor.

If highly plastic clays, organic materials or very wet materials are encountered at subgrade elevations, these materials must be either removed and replaced or dried out so they can be re-used. The disposition of these types of materials is usually described in the plans.

CHAPTER 3 – STUDY QUESTIONS

1) _______________ is the top surface of the embankment and the foundation for the pavement structure.

2) Subgrade must be scarified for a distance of _______________ beyond the proposed edges of pavement to a depth of _______________ and recompacted to the original requirements.

3) _______________ days after placement of the Cement Stabilized Subgrade the next course of pavement or approved cover material must be applied.

4) True or False. Cement is used with soil or aggregate to make the soil or aggregate more workable.

5) Why is lime used with soil?

6) The tolerance on the optimum moisture content at which aggregate must be compacted is _______________.

7) The tolerance on the optimum moisture content for cement treated subgrade is _______________.

8) The most common type of geosynthetic used is a _______________.

9) True or False. Sewing of embankment stabilization fabric seams is not required.

10) What is the minimum number of tests required for finished subgrade from Station 453+60 to Station 553+60?

11) Cement Stabilized Subgrade has been placed 48 feet in width from Station 392+20 to Station 550+60, with a paver application width of 12 feet. Determine the number of tests required and the density and moisture requirements.

CHAPTER 3 – PRACTICE PROBLEMS

Practice Problem Number 1
Cement Application Rate (Volume Method)

The plans call for 12% cement by volume, 6” depth. Width of treatment is 26 feet. The net weight of the cement in the tanker is 23.09 tons.

How many feet of roadway should this load of cement treat?

Show your work!

CHAPTER 3 – PRACTICE PROBLEMS

Practice Problem Number 2
Cement Application Rate (Volume Method)

The plans call for 6.5% cement by volume, 6” depth. Width of treatment is 24 feet. The net weight of the cement in the tanker is 22 tons.

How many feet of roadway should this load of cement treat?

Show your work!

4

INSTALLATION OF PIPE AND TESTING OF PIPE BACKFILL

LEARNING OUTCOMES

- Understand basic pipe and soil concepts and how they relate to preconstruction issues
- Understand fundamental trench concepts and pipe installation procedures
- Understand inspection requirements and backfill testing frequencies and procedures
- Understand the basic principles of pavement drain construction

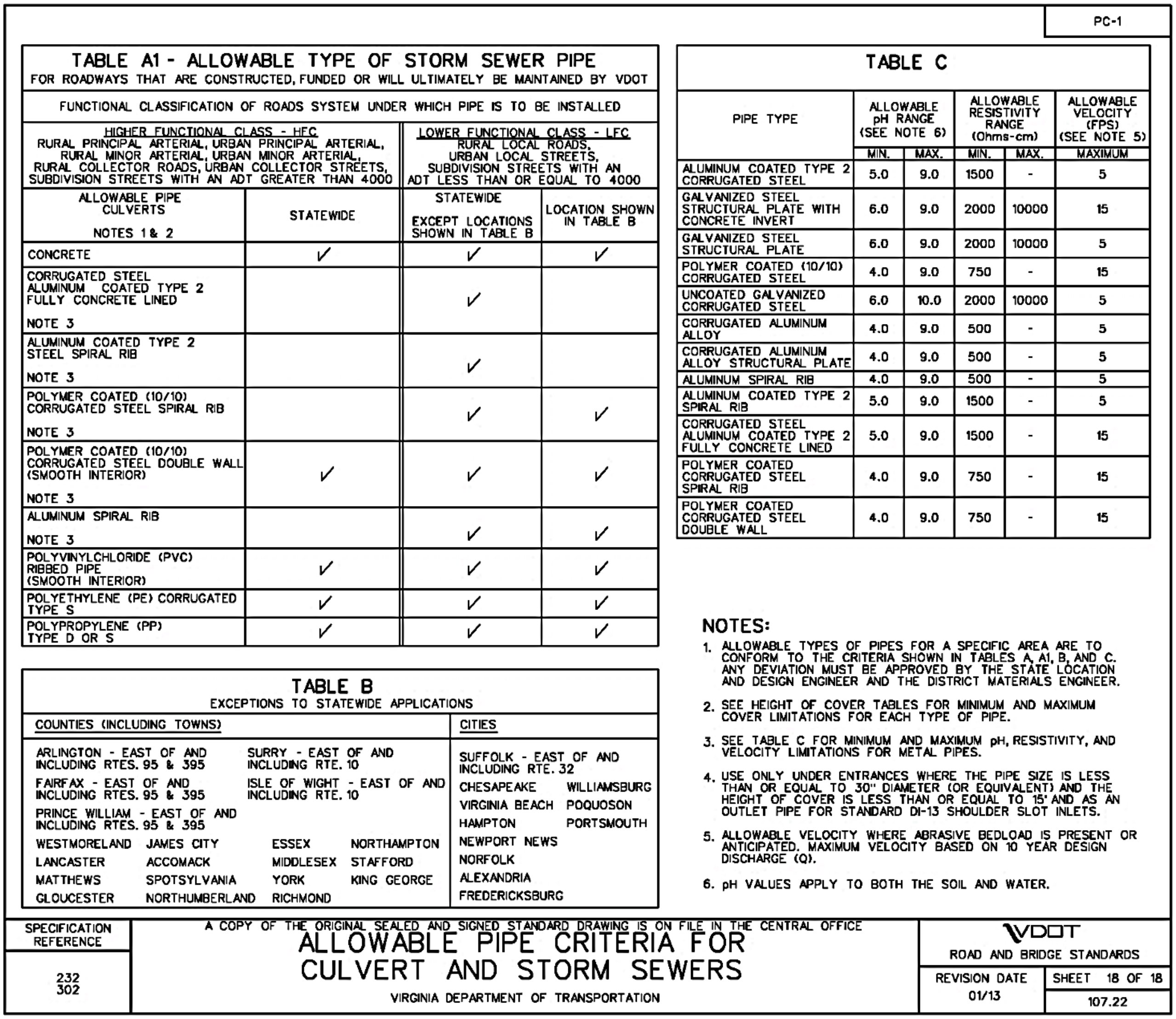
INTRODUCTION

A well installed pipe should stay in service 50 to 100 years with little or no repair. VDOT states 75 years for higher functional classification roads and 50 years for lower functional classification roads. Proper installation is essential to pavement performance as it increases bearing capacity, increases service life and lowers maintenance costs.

Figure 4.1: Precast Concrete Pipe

BASIC PIPE AND SOIL CONCEPTS

The type of pipe selected for a particular application depends on many factors. The function of the pipe, the soil type present in the trench, the depth of the pipe can all influence the type of pipe selected. See the following table for VDOT recommendations.



PC-1

TABLE A1 - ALLOWABLE TYPE OF STORM SEWER PIPE
FOR ROADWAYS THAT ARE CONSTRUCTED, FUNDED OR WILL ULTIMATELY BE MAINTAINED BY VDOT

FUNCTIONAL CLASSIFICATION OF ROADS SYSTEM UNDER WHICH PIPE IS TO BE INSTALLED

	HIGHER FUNCTIONAL CLASS - HFC RURAL PRINCIPAL ARTERIAL, URBAN PRINCIPAL ARTERIAL, RURAL MINOR ARTERIAL, URBAN MINOR ARTERIAL, RURAL COLLECTOR ROADS, URBAN COLLECTOR STREETS, SUBDIVISION STREETS WITH AN ADT GREATER THAN 4000	LOWER FUNCTIONAL CLASS - LFC RURAL LOCAL ROADS, URBAN LOCAL STREETS, SUBDIVISION STREETS WITH AN ADT LESS THAN OR EQUAL TO 4000	
ALLOWABLE PIPE CULVERTS NOTES 1& 2	STATEWIDE	STATEWIDE EXCEPT LOCATIONS SHOWN IN TABLE B	LOCATION SHOWN IN TABLE B
CONCRETE	✓	✓	✓
CORRUGATED STEEL ALUMINUM COATED TYPE 2 FULLY CONCRETE LINED NOTE 3		✓	
ALUMINUM COATED TYPE 2 STEEL SPIRAL RIB NOTE 3		✓	
POLYMER COATED (10/10) CORRUGATED STEEL SPIRAL RIB NOTE 3		✓	✓
POLYMER COATED (10/10) CORRUGATED STEEL DOUBLE WALL (SMOOTH INTERIOR) NOTE 3	✓	✓	✓
ALUMINUM SPIRAL RIB NOTE 3		✓	✓
POLYVINYLCHLORIDE (PVC) RIBBED PIPE (SMOOTH INTERIOR)	✓	✓	✓
POLYETHYLENE (PE) CORRUGATED TYPE S	✓	✓	✓
POLYPROPYLENE (PP) TYPE D OR S	✓	✓	✓

TABLE B
EXCEPTIONS TO STATEWIDE APPLICATIONS

COUNTIES (INCLUDING TOWNS)

ARLINGTON - EAST OF AND INCLUDING RTES. 95 & 395
FAIRFAX - EAST OF AND INCLUDING RTES. 95 & 395
PRINCE WILLIAM - EAST OF AND INCLUDING RTES. 95 & 395
SURRY - EAST OF AND INCLUDING RTE. 10
ISLE OF WIGHT - EAST OF AND INCLUDING RTE. 10
WESTMORELAND
LANCASTER
MATTHEWS
GLOUCESTER
JAMES CITY
ACCOMACK
SPOTSYLVANIA
NORTHUMBERLAND
ESSEX
MIDDLESEX
YORK
RICHMOND
NORTHAMPTON
STAFFORD
KING GEORGE

CITIES

SUFFOLK - EAST OF AND INCLUDING RTE. 32
CHESAPEAKE
VIRGINIA BEACH
HAMPTON
NEWPORT NEWS
NORFOLK
ALEXANDRIA
FREDERICKSBURG
WILLIAMSBURG
POQUOSON
PORTSMOUTH

TABLE C

PIPE TYPE	ALLOWABLE pH RANGE (SEE NOTE 6)		ALLOWABLE RESISTIVITY RANGE (Ohms-cm)		ALLOWABLE VELOCITY (FPS) (SEE NOTE 5)
	MIN.	MAX.	MIN.	MAX.	MAXIMUM
ALUMINUM COATED TYPE 2 CORRUGATED STEEL	5.0	9.0	1500	-	5
GALVANIZED STEEL STRUCTURAL PLATE WITH CONCRETE INVERT	6.0	9.0	2000	10000	15
GALVANIZED STEEL STRUCTURAL PLATE	6.0	9.0	2000	10000	5
POLYMER COATED (10/10) CORRUGATED STEEL	4.0	9.0	750	-	15
UNCOATED GALVANIZED CORRUGATED STEEL	6.0	10.0	2000	10000	5
CORRUGATED ALUMINUM ALLOY	4.0	9.0	500	-	5
CORRUGATED ALUMINUM ALLOY STRUCTURAL PLATE	4.0	9.0	500	-	5
ALUMINUM SPIRAL RIB	4.0	9.0	500	-	5
ALUMINUM COATED TYPE 2 SPIRAL RIB	5.0	9.0	1500	-	5
CORRUGATED STEEL ALUMINUM COATED TYPE 2 FULLY CONCRETE LINED	5.0	9.0	1500	-	15
POLYMER COATED CORRUGATED STEEL SPIRAL RIB	4.0	9.0	750	-	15
POLYMER COATED CORRUGATED STEEL DOUBLE WALL	4.0	9.0	750	-	15

NOTES:

1. ALLOWABLE TYPES OF PIPES FOR A SPECIFIC AREA ARE TO CONFORM TO THE CRITERIA SHOWN IN TABLES A, A1, B, AND C. ANY DEVIATION MUST BE APPROVED BY THE STATE LOCATION AND DESIGN ENGINEER AND THE DISTRICT MATERIALS ENGINEER.
2. SEE HEIGHT OF COVER TABLES FOR MINIMUM AND MAXIMUM COVER LIMITATIONS FOR EACH TYPE OF PIPE.
3. SEE TABLE C FOR MINIMUM AND MAXIMUM pH, RESISTIVITY, AND VELOCITY LIMITATIONS FOR METAL PIPES.
4. USE ONLY UNDER ENTRANCES WHERE THE PIPE SIZE IS LESS THAN OR EQUAL TO 30" DIAMETER (OR EQUIVALENT) AND THE HEIGHT OF COVER IS LESS THAN OR EQUAL TO 15' AND AS AN OUTLET PIPE FOR STANDARD DI-13 SHOULDER SLOT INLETS.
5. ALLOWABLE VELOCITY WHERE ABRASIVE BEDLOAD IS PRESENT OR ANTICIPATED. MAXIMUM VELOCITY BASED ON 10 YEAR DESIGN DISCHARGE (Q).
6. pH VALUES APPLY TO BOTH THE SOIL AND WATER.

SPECIFICATION REFERENCE
232
302

A COPY OF THE ORIGINAL SEALED AND SIGNED STANDARD DRAWING IS ON FILE IN THE CENTRAL OFFICE

ALLOWABLE PIPE CRITERIA FOR
CULVERT AND STORM SEWERS

VIRGINIA DEPARTMENT OF TRANSPORTATION

VDOT
ROAD AND BRIDGE STANDARDS
REVISION DATE 01/13
SHEET 18 OF 18
107.22

When planning a pipeline installation, there are 2 key functions that we must design the pipeline to provide. What are those two functions? Clearly the pipe needs to function as a conduit, as the whole idea of a pipe is to move liquid in a controlled manner and direction. And the pipe must provide structure, because if the ground above the pipe collapses then the pipe can no longer perform as a conduit. Having one of these functions without the other is worthless.

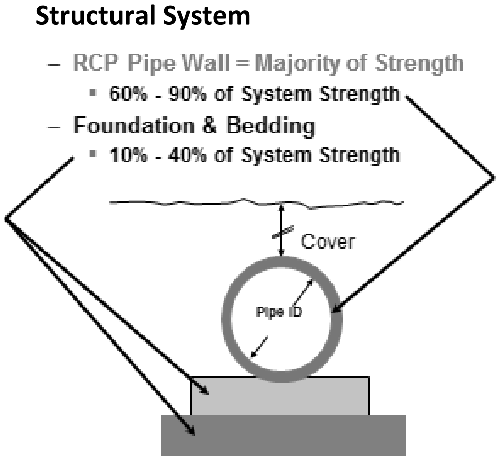


Figure 4.2a: Reinforced Concrete

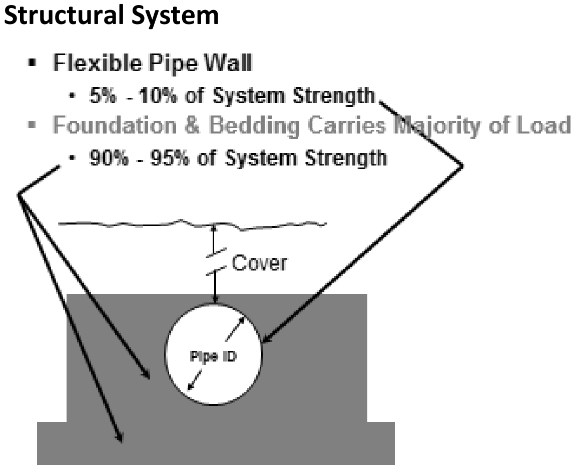


Figure 4.2b: Flexible Pipe

Culverts are generally designed for the loads they must carry after construction is completed. Construction loads often exceed design loads. These heavy loads can cause considerable damage in flexible pipes and can cause D-load cracking in rigid pipes. Additional temporary fill is needed to protect the pipe from construction loads.

Minimum/Maximum Cover

All Culverts

- 24” minimum cover
- Absolute minimum fill height (12”)
- Except for entrances (9” minimum)
- All pipe should have three feet of cover on it before construction traffic is allowed across it.

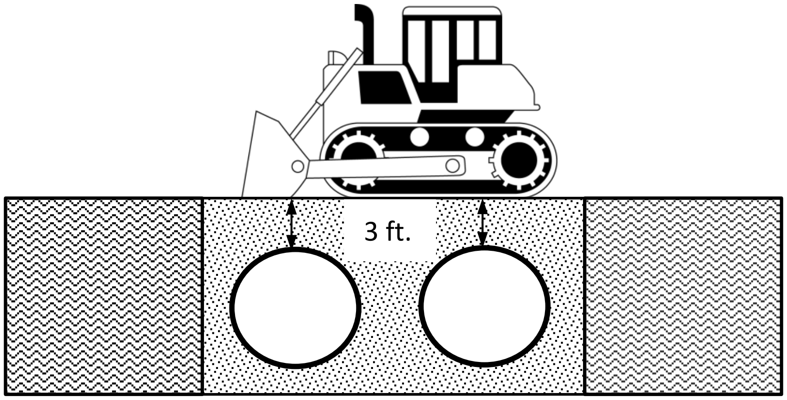
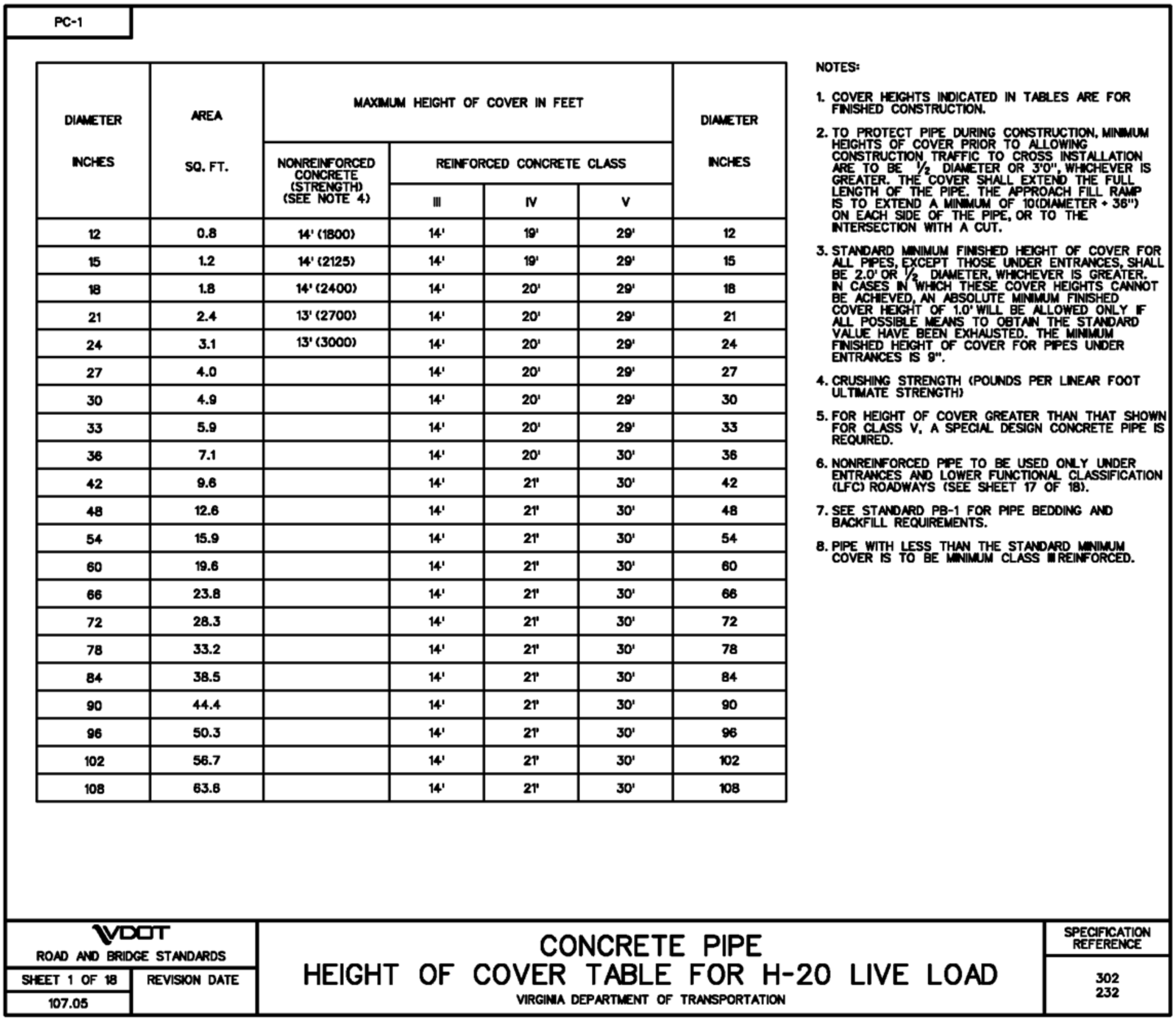


Figure 4.3: Minimum Cover to Allow Construction Traffic over Pipe

The following tables give VDOT specifications for maximum height of cover for some types of pipe.



PC-1

DIAMETER INCHES	AREA SQ. FT.	MAXIMUM HEIGHT OF COVER IN FEET				DIAMETER INCHES
		NONREINFORCED CONCRETE (STRENGTH) (SEE NOTE 4)	REINFORCED CONCRETE CLASS			
			III	IV	V	
12	0.8	14' (1800)	14'	19'	29'	12
15	1.2	14' (2125)	14'	19'	29'	15
18	1.8	14' (2400)	14'	20'	29'	18
21	2.4	13' (2700)	14'	20'	29'	21
24	3.1	13' (3000)	14'	20'	29'	24
27	4.0		14'	20'	29'	27
30	4.9		14'	20'	29'	30
33	5.9		14'	20'	29'	33
36	7.1		14'	20'	30'	36
42	9.6		14'	21'	30'	42
48	12.6		14'	21'	30'	48
54	15.9		14'	21'	30'	54
60	19.6		14'	21'	30'	60
66	23.8		14'	21'	30'	66
72	28.3		14'	21'	30'	72
78	33.2		14'	21'	30'	78
84	38.5		14'	21'	30'	84
90	44.4		14'	21'	30'	90
96	50.3		14'	21'	30'	96
102	56.7		14'	21'	30'	102
108	63.6		14'	21'	30'	108

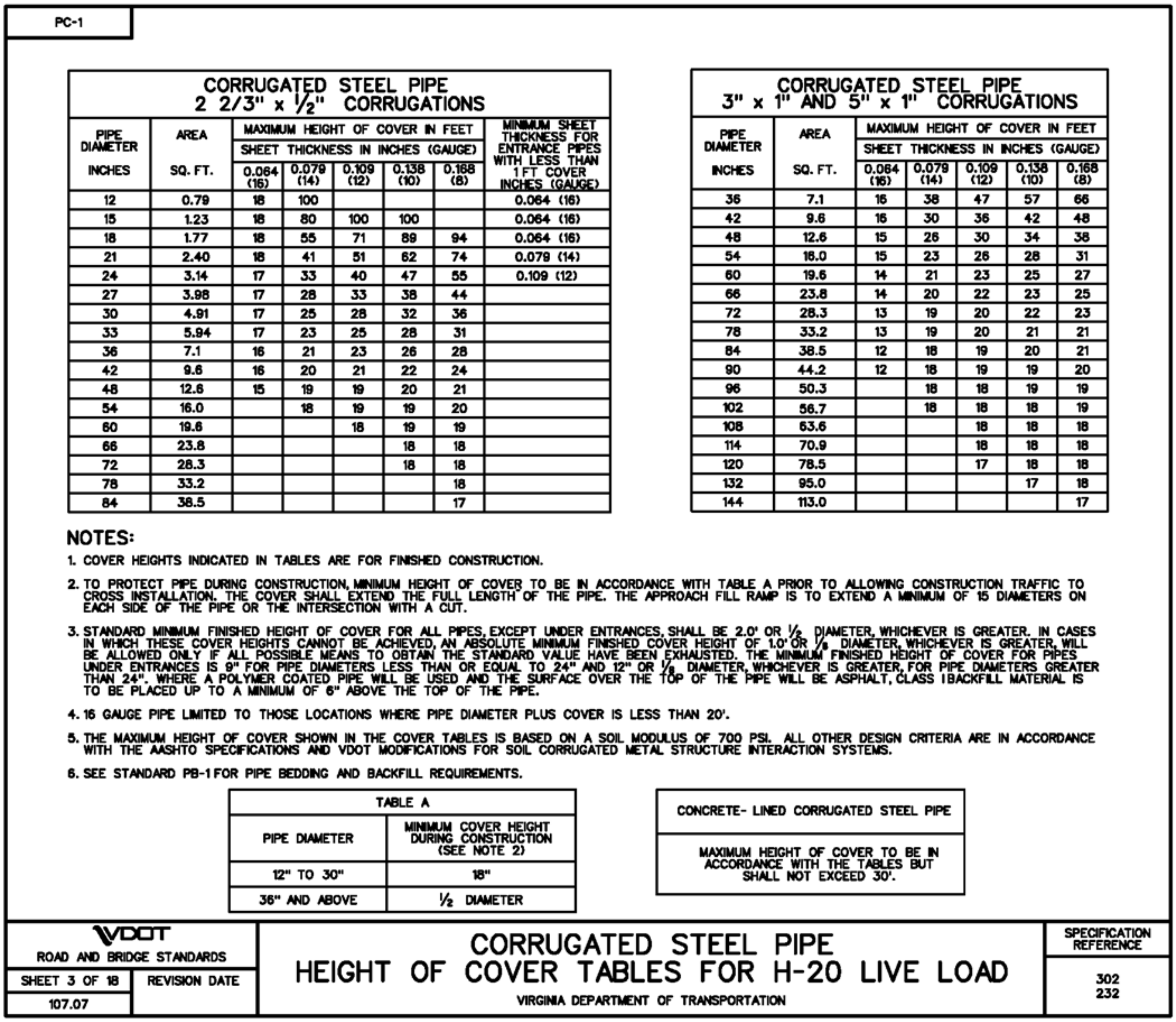
NOTES:

1. COVER HEIGHTS INDICATED IN TABLES ARE FOR FINISHED CONSTRUCTION.
2. TO PROTECT PIPE DURING CONSTRUCTION, MINIMUM HEIGHTS OF COVER PRIOR TO ALLOWING CONSTRUCTION TRAFFIC TO CROSS INSTALLATION ARE TO BE ½ DIAMETER OR 3'0", WHICHEVER IS GREATER. THE COVER SHALL EXTEND THE FULL LENGTH OF THE PIPE. THE APPROACH FILL RAMP IS TO EXTEND A MINIMUM OF 10(DIAMETER + 36") ON EACH SIDE OF THE PIPE, OR TO THE INTERSECTION WITH A CUT.
3. STANDARD MINIMUM FINISHED HEIGHT OF COVER FOR ALL PIPES, EXCEPT THOSE UNDER ENTRANCES, SHALL BE 2.0' OR ½ DIAMETER, WHICHEVER IS GREATER. IN CASES IN WHICH THESE COVER HEIGHTS CANNOT BE ACHIEVED, AN ABSOLUTE MINIMUM FINISHED COVER HEIGHT OF 1.0' WILL BE ALLOWED ONLY IF ALL POSSIBLE MEANS TO OBTAIN THE STANDARD VALUE HAVE BEEN EXHAUSTED. THE MINIMUM FINISHED HEIGHT OF COVER FOR PIPES UNDER ENTRANCES IS 9".
4. CRUSHING STRENGTH (POUNDS PER LINEAR FOOT ULTIMATE STRENGTH)
5. FOR HEIGHT OF COVER GREATER THAN THAT SHOWN FOR CLASS V, A SPECIAL DESIGN CONCRETE PIPE IS REQUIRED.
6. NONREINFORCED PIPE TO BE USED ONLY UNDER ENTRANCES AND LOWER FUNCTIONAL CLASSIFICATION (LFC) ROADWAYS (SEE SHEET 17 OF 18).
7. SEE STANDARD PB-1 FOR PIPE BEDDING AND BACKFILL REQUIREMENTS.
8. PIPE WITH LESS THAN THE STANDARD MINIMUM COVER IS TO BE MINIMUM CLASS III REINFORCED.

VDOT
ROAD AND BRIDGE STANDARDS
SHEET 1 OF 18
REVISION DATE
107.05

CONCRETE PIPE
HEIGHT OF COVER TABLE FOR H-20 LIVE LOAD
VIRGINIA DEPARTMENT OF TRANSPORTATION

SPECIFICATION REFERENCE
302
232



PC-1

CORRUGATED STEEL PIPE
2 2/3" x ½" CORRUGATIONS

PIPE DIAMETER INCHES	AREA SQ. FT.	MAXIMUM HEIGHT OF COVER IN FEET					MINIMUM SHEET THICKNESS FOR ENTRANCE PIPES WITH LESS THAN 1 FT COVER INCHES (GAUGE)
		SHEET THICKNESS IN INCHES (GAUGE)					
		0.064 (16)	0.079 (14)	0.109 (12)	0.138 (10)	0.168 (8)	
12	0.79	18	100				0.064 (16)
15	1.23	18	80	100	100		0.064 (16)
18	1.77	18	55	71	89	94	0.064 (16)
21	2.40	18	41	51	62	74	0.079 (14)
24	3.14	17	33	40	47	55	0.109 (12)
27	3.98	17	28	33	38	44	
30	4.91	17	25	28	32	36	
33	5.94	17	23	25	28	31	
36	7.1	16	21	23	26	28	
42	9.6	16	20	21	22	24	
48	12.6	15	19	19	20	21	
54	16.0		18	19	19	20	
60	19.6			18	19	19	
66	23.8				18	18	
72	28.3				18	18	
78	33.2					18	
84	38.5					17	

CORRUGATED STEEL PIPE
3" x 1" AND 5" x 1" CORRUGATIONS

PIPE DIAMETER INCHES	AREA SQ. FT.	MAXIMUM HEIGHT OF COVER IN FEET				
		SHEET THICKNESS IN INCHES (GAUGE)				
		0.064 (16)	0.079 (14)	0.109 (12)	0.138 (10)	0.168 (8)
36	7.1	16	38	47	57	66
42	9.6	16	30	36	42	48
48	12.6	15	26	30	34	38
54	16.0	15	23	26	28	31
60	19.6	14	21	23	25	27
66	23.8	14	20	22	23	25
72	28.3	13	19	20	22	23
78	33.2	13	19	20	21	21
84	38.5	12	18	19	20	21
90	44.2	12	18	19	19	20
96	50.3		18	18	19	19
102	56.7		18	18	18	19
108	63.6			18	18	18
114	70.9			18	18	18
120	78.5			17	18	18
132	95.0				17	18
144	113.0					17

NOTES:

1. COVER HEIGHTS INDICATED IN TABLES ARE FOR FINISHED CONSTRUCTION.
2. TO PROTECT PIPE DURING CONSTRUCTION, MINIMUM HEIGHT OF COVER TO BE IN ACCORDANCE WITH TABLE A PRIOR TO ALLOWING CONSTRUCTION TRAFFIC TO CROSS INSTALLATION. THE COVER SHALL EXTEND THE FULL LENGTH OF THE PIPE. THE APPROACH FILL RAMP IS TO EXTEND A MINIMUM OF 15 DIAMETERS ON EACH SIDE OF THE PIPE OR THE INTERSECTION WITH A CUT.
3. STANDARD MINIMUM FINISHED HEIGHT OF COVER FOR ALL PIPES, EXCEPT UNDER ENTRANCES, SHALL BE 2.0' OR ½ DIAMETER, WHICHEVER IS GREATER. IN CASES IN WHICH THESE COVER HEIGHTS CANNOT BE ACHIEVED, AN ABSOLUTE MINIMUM FINISHED COVER HEIGHT OF 1.0' OR ⅛ DIAMETER, WHICHEVER IS GREATER, WILL BE ALLOWED ONLY IF ALL POSSIBLE MEANS TO OBTAIN THE STANDARD VALUE HAVE BEEN EXHAUSTED. THE MINIMUM FINISHED HEIGHT OF COVER FOR PIPES UNDER ENTRANCES IS 9" FOR PIPE DIAMETERS LESS THAN OR EQUAL TO 24" AND 12" OR ⅛ DIAMETER, WHICHEVER IS GREATER, FOR PIPE DIAMETERS GREATER THAN 24". WHERE A POLYMER COATED PIPE WILL BE USED AND THE SURFACE OVER THE TOP OF THE PIPE WILL BE ASPHALT, CLASS I BACKFILL MATERIAL IS TO BE PLACED UP TO A MINIMUM OF 6" ABOVE THE TOP OF THE PIPE.
4. 16 GAUGE PIPE LIMITED TO THOSE LOCATIONS WHERE PIPE DIAMETER PLUS COVER IS LESS THAN 20'.
5. THE MAXIMUM HEIGHT OF COVER SHOWN IN THE COVER TABLES IS BASED ON A SOIL MODULUS OF 700 PSI. ALL OTHER DESIGN CRITERIA ARE IN ACCORDANCE WITH THE AASHTO SPECIFICATIONS AND VDOT MODIFICATIONS FOR SOIL CORRUGATED METAL STRUCTURE INTERACTION SYSTEMS.
6. SEE STANDARD PB-1 FOR PIPE BEDDING AND BACKFILL REQUIREMENTS.

TABLE A

PIPE DIAMETER	MINIMUM COVER HEIGHT DURING CONSTRUCTION (SEE NOTE 2)
12" TO 30"	18"
36" AND ABOVE	½ DIAMETER

CONCRETE- LINED CORRUGATED STEEL PIPE

MAXIMUM HEIGHT OF COVER TO BE IN ACCORDANCE WITH THE TABLES BUT SHALL NOT EXCEED 30'.

VDOT
ROAD AND BRIDGE STANDARDS
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CORRUGATED STEEL PIPE
HEIGHT OF COVER TABLES FOR H-20 LIVE LOAD
VIRGINIA DEPARTMENT OF TRANSPORTATION

SPECIFICATION REFERENCE
302
232

PRE-CONSTRUCTION ISSUES

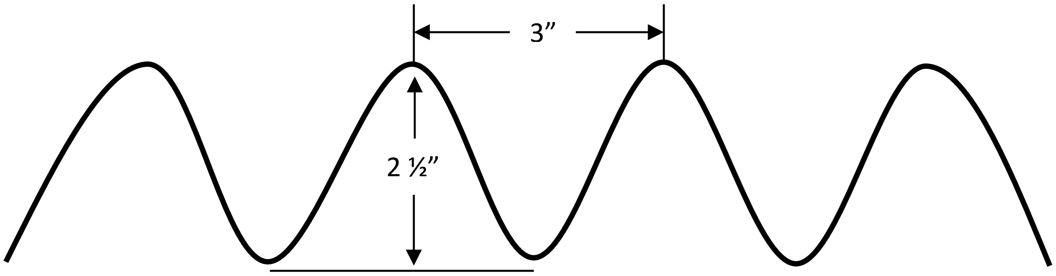
Prior to construction the pipe delivered to the project should be inspected and verified to be the pipe specified for the project. A review of the proper minimum/maximum height of cover for the specific type of pipe should be completed. Inspect how the pipe is being stored on site to ensure no damage is being done to the pipe prior to installation.

Verifying that the correct pipe has been delivered for the applications on your project.

1) Metal pipe gauge: Examples – 12, 14, 16
2) Metal pipe corrugation dimensions: Examples – 2 2/3” x ½”; 3” x 1”
3) Concrete pipe strength: Examples – Class III, IV or V
4) pH and Resistivity - needs to be known by designer

5) Maximum height of cover: Maximum height for each type of pipe must be given
    - Compare information from drainage summary with maximum cover chart for pipe to be used
    - Check standards for minimum height of cover

Measuring Metal Pipe Corrugation – example 3” x 2 ½”



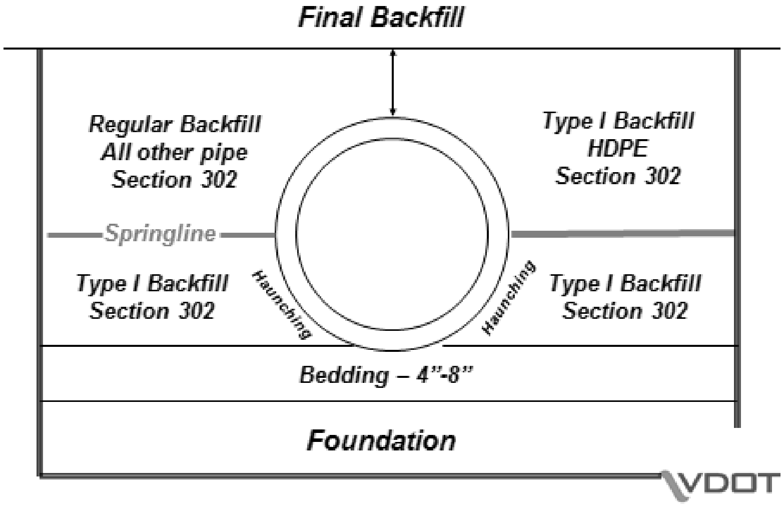
Examples of concrete pipe stamp:

They typically include manufactured date, diameter, pipe type, class, place of manufacturing.

Pipe should be stored in an out of the way location where it will not be damaged. The pipe should be stacked and chocked to avoid movement of the pipe. Pipe should never be stacked on the bells as they could be damaged.

TRENCH FUNDAMENTALS

Trench Terminology



The bedding is typically 4-8" thick. The top few inches should be slightly yielding (loose) and fill the corrugations. Often, shaped beddings are used to insure proper placement and compaction of materials under the pipe haunch.

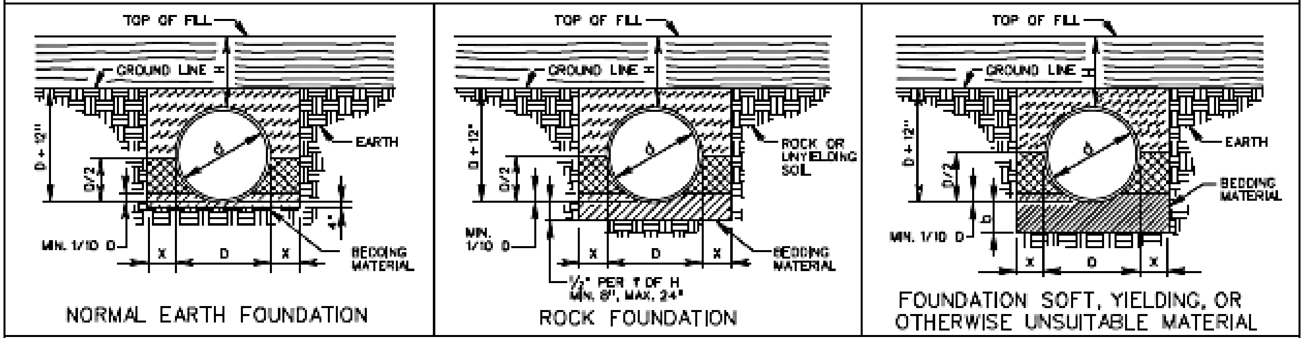
The initial backfill of select Type I backfill protects the pipe during installation from impact damage and extends to the springline of the pipe. In a rigid pipe, this zone has zero effect on the load carrying capacity. In a flexible pipe this zone must protect the pipe from distortions due to loading – extend to 12" above pipe. This zone contains the same select quality backfill material as in the haunch zone for flexible pipe.

Generally excavated embankment material is used as the final backfill. It is placed in 6" loose lifts and compacted to 4". For flexible pipe this begins 12" over top of pipe for smaller pipe and 18" for pipe 54" and larger.

The following drawing provides typical VDOT standards for pipe bedding and backfill.

PB-1

NO PROJECTION OF PIPE ABOVE GROUND LINE

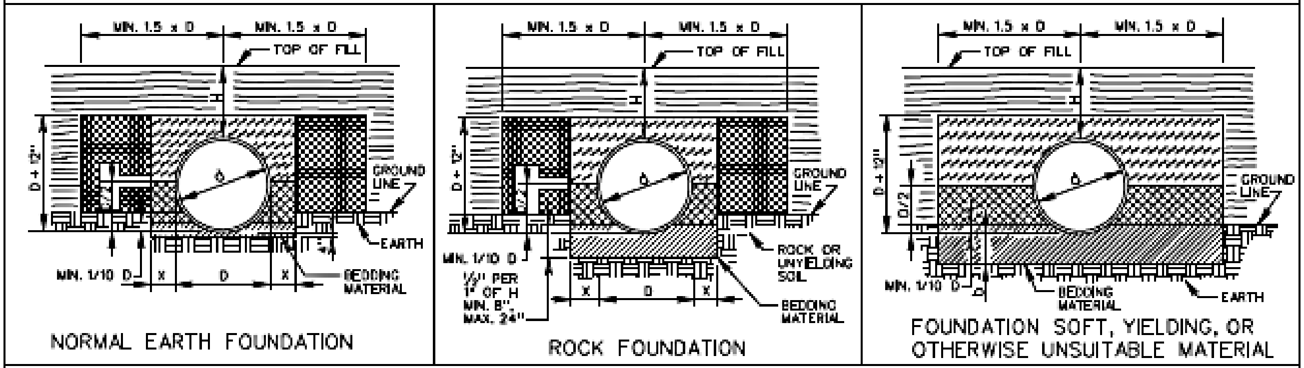


NORMAL EARTH FOUNDATION

ROCK FOUNDATION

FOUNDATION SOFT, YIELDING, OR OTHERWISE UNSUITABLE MATERIAL

PIPE PROJECTION ABOVE GROUND LINE



NORMAL EARTH FOUNDATION

ROCK FOUNDATION

FOUNDATION SOFT, YIELDING, OR OTHERWISE UNSUITABLE MATERIAL

▨ BEDDING MATERIAL IN ACCORDANCE WITH SECTION 302 OF THE ROAD AND BRIDGE SPECIFICATIONS.

▩ CLASS I BACKFILL MATERIAL IN ACCORDANCE WITH SECTION 302 OF THE ROAD AND BRIDGE SPECIFICATIONS.

▨ FOR PLASTIC PIPE CLASS I BACKFILL MATERIAL IN ACCORDANCE WITH SECTION 302 OF THE ROAD AND BRIDGE SPECIFICATIONS.

▨ FOR ALL OTHER PIPE REGULAR BACKFILL MATERIAL IN ACCORDANCE WITH SECTION 302 OF THE ROAD AND BRIDGE SPECIFICATIONS.

☰ EMBANKMENT

▦ REGULAR BACKFILL MATERIAL IN ACCORDANCE WITH SECTION 302 OF THE ROAD AND BRIDGE SPECIFICATIONS.

NOTES:

FOR GENERAL NOTES ON PIPE BEDDING, SEE INSTALLATION OF PIPE CULVERTS AND STORM SEWERS GENERAL NOTES ON SHEET 107.00.

CRUSHED GLASS CONFORMING TO THE SIZE REQUIREMENTS FOR CRUSHER RUN AGGREGATE SIZE 25 AND 26 MAY BE USED IN PLACE OF CLASS I BACKFILL.

VDOT
ROAD AND BRIDGE STANDARDS

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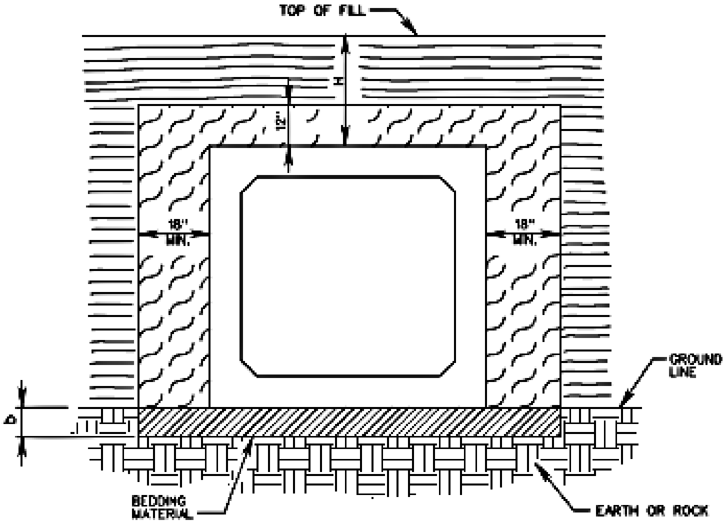
107.01	07/12

INSTALL. OF PIPE CULVERTS AND STORM SEWERS
CIRC. PIPE BEDDING AND BACKFILL - METHOD "A"
VIRGINIA DEPARTMENT OF TRANSPORTATION

SPECIFICATION REFERENCE
302
303

PB-1



H = HEIGHT OF COVER MEASURED FROM TOP OF CULVERT TO FINISHED GRADE.

FOR NORMAL EARTH FOUNDATION:
FOR PRECAST AND CAST IN PLACE BOX CULVERT b = 6"

FOR ROCK FOUNDATION:
FOR PRECAST BOX CULVERT b = ¼" PER 12" OF H - 6" MIN., 24" MAX.
FOR CAST IN PLACE BOX CULVERT b=DEPTH AS SHOWN ON PLANS OR WHERE NO BEDDING IS SPECIFIED BOTTOM SLAB TO BE KEYED INTO EXISTING ROCK FOUNDATION.
FOR SOFT, YIELDING OR OTHERWISE UNSUITABLE FOUNDATION:
FOR PRECAST AND CAST IN PLACE BOX CULVERT
b = DEPTH AS SHOWN ON PLANS OR TO FIRM BEARING SOIL.

▨ BEDDING MATERIAL IN ACCORDANCE WITH SECTION 302 OF THE ROAD AND BRIDGE SPECIFICATIONS.

▨ REGULAR BACKFILL MATERIAL IN ACCORDANCE WITH SECTION 302 OF THE ROAD AND BRIDGE SPECIFICATIONS.

☰ EMBANKMENT

SPECIFICATION REFERENCE
302
303

INSTALLATION OF BOX CULVERT BEDDING AND BACKFILL - METHOD "A"

VIRGINIA DEPARTMENT OF TRANSPORTATION

VDOT
ROAD AND BRIDGE STANDARDS
REVISION DATE
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107.04

INSTALLATION PROCEDURES

General procedures for pipe installation:

1) Locate utilities
2) Excavate trench
3) Explore foundation
4) Place structural bedding material to grade. Do not compact.
5) Install pipe to grade
6) Compact structural bedding outside the middle third of the pipe
7) Place structural bedding in lifts
8) Complete structural backfill operation by working from side to side of the pipe, differential not to exceed 24” or 1/3 size of pipe.

Locate Utilities

Prior to excavating the trench area, all utilities should be located by a qualified contractor.

Excavate Trench

Proper trench widths will allow for proper compaction alongside the pipe. Trench widths may be varied, based on the competency of the in-situ soil, backfill materials, compaction levels and loads. Trenching should be completed in existing soils with sidewalls reasonably vertical to the top of the pipe. It is not appropriate to leave a bench of native soil alongside the pipe during construction. The compaction equipment will ride on the native soil and not allow for proper consolidation of backfill. For positive projection embankment installations, the embankment material should be placed and compacted to a minimum of one foot above the pipe and the trench excavated into the embankment. This prevents disruption of the backfill envelope when removing the shoring or trench box.

Explore Foundation

A stable foundation must be provided to ensure proper line and grade is maintained. Unsuitable foundations must be stabilized at the engineer’s direction. Unsuitable or unstable foundations may be undercut and replaced with a suitable bedding material, placed in 6” lifts. Other methods of stabilization, such as geo-fabrics may be appropriate based on the engineer’s judgment.

The foundation is to be explored below the bottom of the excavation to determine the type and condition of the foundation. The exploration should extend to a depth equal to ½” per foot of fill height or 8”, whichever is greater. If it is a routine entrance, or crossover pipe 12” to 30” in diameter, that is to be installed under fills 15 feet or less in height, no exploration is needed. The Contractor shall report findings of foundation exploration to the Engineer for approval prior to placing pipe.

When standing water is in pipe foundation area, No. 57 stone can be used as a backfill in the sub-foundation. No. 57 stone MUST be capped with a minimum of 4” crusher run prior to placement of pipe or box culvert. Compaction testing on No. 57 stone is not required; seat stone in trench.

Place Bedding

Stable and uniform bedding must be provided for the pipe and any protruding features of its joints and/or fittings. The middle of the bedding, should be loosely placed and not exceed 8 inches. The loosely placed center section of the bedding allows the pipe to seat itself and helps minimize point loads. (Road and Bridge Spec. Section 302.03 Procedures)

When lift holes are provided in concrete pipe or precast box culverts, the Contractor shall install a lift hole plug furnished by the manufacturer. After pipe installation and prior to backfilling, plugs shall be installed from the exterior of the pipe or box culvert and snugly seated.

Install Pipe

The grade of the pipe should always be monitored during installation.

When joining pipe:

- Begin at the downstream end (Bell faces upstream)
- Ensure spigot and bell are clean and free of debris
- Properly lubricate spigot and bell with pipe lubricant
- Is Contractor aware of the maximum insertion angle?
- Fully insert pipe. (Make a Mark on Outside of Pipe)
- Moving pipe around after joining may cause pipe joint to work apart.

Rigid pipe – properly fitted, sealed with rubber, preformed plastic, mastic gaskets

Flexible Pipe – properly aligned and joined with approved coupling bands

Joint Performance Terminology

Soil Tight: A joint that is resistant to infiltration of particles larger than those retained on the No. 200 sieve. Soil-tight joints provide protection against infiltration of backfill material containing high percentage of coarse grain soils, and are influenced by the size of the opening (maximum dimension normal to the direction that the soil may infiltrate) and the length of the channel (length of the path along which the soil may infiltrate).

Silt Tight: A joint that is resistant to infiltration of particles that are smaller than particles passing the No. 200 sieve. Silt-tight joints provide protection against infiltration of the backfill material containing a high percentage of fines, and typically utilize some type of filtering or sealing component, such as an elastomeric rubber seal or geotextile.

Leak Resistant: A joint which limits water leakage at a maximum rate of 200 gallons/inch-diameter/mile/day for the pipeline system for the project specified head or pressure.

Types of Joints for Concrete Pipe

Tongue & Groove: A bell & spigot type joint with straight walls (flush bell). The joint consists of a tongue (male end) and groove (female end) with no defining areas for gasket material placement. Rubber gaskets may be used when the joint slope is five degrees or less, however it is usually limited to mastic or butyl sealants.

Bell and Spigot: A pipe with a flared bell has the outside diameter of the bell larger than the outside diameter of the pipe. Another option with the flared bell is the Modified Tongue & Groove, or Baby Bell which is a cross between a straight walled T&G and a Standard Bell – it does not stick out from the barrel as far as a flared bell.

Confined O-Ring: The first "rubber gasket" joint design established by the industry. The spigot end of the pipe contains a confined groove for the gasket to seat, where an o-ring gasket is placed. This type joint-gasket combination provides a leak resistant joint.

Single Offset: This joint first appeared in the early 1990's. This style of spigot is much easier to manufacture. It is generally easier to install due to less stringent lubrication requirements for the gasket. This type of joint provides a leak resistant joint when a profile gasket is used.

Structural Fill

See Section 302.03 (A)(2)(g) of the *Road and Bridge Specifications* for complete requirements for backfill material.

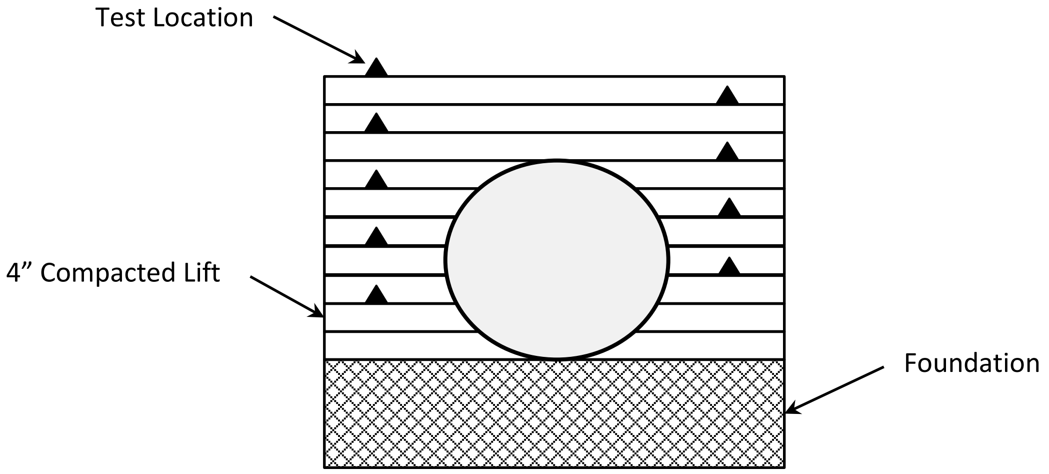
Proper haunching provides support to ensure the pipe's strength is achieved. Care must be exercised to ensure placement and compaction of the embedment material in the haunches. For larger diameter pipe, >30 inches, embedment materials should be worked under the haunches by hand. Haunching material may be Class 1 and must be placed and compacted in 6-inch loose/4-inch compacted maximum lifts, compacted to 95 percent standard proctor density. Backfill material shall be "knifed" into the area along the bottom edge of the pipe. When backfill is below spring line of pipe, compact next to pipe first and work towards the trench wall. When backfill material is above the spring line of the pipe, start at the trench wall and work towards the pipe. Do not compact directly on pipe as it may damage the pipe.

Each layer of Class I and regular backfill material shall be compacted by rolling, tamping with mechanical rammers, or hand tamping with heavy metal tampers with a face of at least 25 square inches. If vibratory rollers are used in the backfill operations, vibratory motors shall not be activated until at least 3 feet of backfill has been placed and compacted over the pipe. Backfill and compaction shall be advanced simultaneously on both sides of the pipe. The fill above the top of the regular backfill shall be installed and completed as specified for embankment construction. Rock more than 2 inches in its greatest dimension shall not be placed within 12 inches of pipe.

Pipe openings in precast drainage units shall not exceed the outside cross sectional dimensions of the pipes by more than a total of 8 inches regardless of the placement of the pipe, their angles of intersection, or shapes of the pipes.

BACKFILL TESTING FREQUENCIES

Typical Pipe and Box Culvert Backfill:



One test per lift on alternating sides of the pipe for each 300 feet of pipe or portion thereof.

Test pattern is to begin after the first 4" lift above bedding and continue to 1 foot above top of the pipe.

Pipe Testing Frequency Example 1:

- Pipe Diameter = 48 in.
- Length of run = 275 ft.
- (Pipe Diameter ÷ lift thickness) + (Fill above pipe ÷ lift thickness) – (1 lift) =
    1) (48 in. ÷ 4 in.) + (12 in. ÷ 4 in.) – 1 (do not test 1st lift) =
    2) 12 + 3 – 1 = 14 tests required per 300' (Answer)

Pipe Testing Frequency Example 2:

- Pipe Diameter = 36 in.
- Length of run = 856 ft.
- (Pipe Diameter ÷ lift thickness) + (Fill above pipe ÷ lift thickness) – (1 lift) =
    3) (36 in. ÷ 4 in.) + (12 in. ÷ 4 in.) – 1 (do not test 1st lift) =
    4) 9 + 3 – 1 = 11 tests required per 300'
    5) Length of run = 856 ft.; therefore 3 sets of tests required
    6) 11 x 3 = 33 tests required for total run (minimum) (Answer)

Backfill around Drop Inlets (minimum)

One test every other lift around the perimeter; beginning after the first 4 inch compacted lift above the bedding and continue to the top of the structure. Stagger tests to ensure consistent compactive effort has been achieved.

Drop Inlet Backfill Frequency Example:

- Depth of Backfill = 9 feet
- Depth of Backfill (ft.) x 12 inches /foot = Depth of backfill in inches
    1) 9ft. x 12 in./ft. = 108 in.
    2) 108 in. – 4 in. (don't test 1st compacted lift) = 104 in.
    3) 104 in. ÷ 8 in. (test every other 4 in. lift) = 13 tests required (minimum) (Answer)

Backfill around Manholes (minimum)

One test every fourth compacted lift around the perimeter; beginning after the first 4 inch compacted lift above the bedding and continue to 5 feet below the top of the structure. In the top 5 feet; perform one test every other lift around the perimeter and continue to the top of the structure.

Manhole Backfill Frequency Example:

- Depth of Backfill = 9 feet
- Depth of Backfill (ft.) – 5 ft. = Depth of Backfill below top 5 feet
    1) 9 ft. – 5 ft. = 4 ft.
    2) 4 ft. x 3 lifts/ft. = 12 lifts
    3) 12 lifts – 1 lift (skip first lift) = 11 lifts
    4) 11lifts ÷ 4 (test every fourth compacted lift) = 2.75, round up to 3 tests in bottom 4 ft. of backfill
- Top 5 ft. of backfill x 3 lifts/ft. = 15 lifts
    5) 15 ifts ÷2 (one test every other lift) = 7.5, round up to 8 tests in the top 5 ft. of backfill
    6) Total tests required = (Number of test below 5 ft.) + (Number of test above 5 ft.)
    7) 3 + 8 = 11 tests required (minimum)

NOTE: Compaction Tests are required on stone backfill (Class I backfill and bedding material); consult the District Materials Division for Maximum Dry Density and Optimum Moisture Content targets for the specific material being used.

POST-INSTALLATION INSPECTION

The following is an excerpt from Virginia Test Method – 123 Post Installation Inspection of Buried Storm Drain Pipe and Pipe Culverts covering the scope of post installation pipe inspection.

For all roadway projects that are constructed by private contractors for VDOT and for all roadway projects constructed by others that are or will be proposed to be accepted into the VDOT highway system, a visual/video camera post installation inspection is required on all storm sewer pipes and for a selected number of pipe culverts in accordance with the instructions contained in this VTM and Section 302.03 of the VDOT Road and Bridge Specifications. The video camera inspection is to be conducted with a VDOT representative present.

The inspection can be conducted manually if adequate crawl/walking space and ventilation is available to safely conduct the inspection and the individual(s) conducting the inspection have undergone training on working in confined spaces in accordance with VDOT's current Safety Policy and Procedure #8 Confined Space Entry Policy and Procedure - General, or the inspection can be conducted with a video camera. If the inspection is to be conducted with a video camera, the video camera shall have fully articulating lenses that will provide a 360 degree inspection of the pipe/culvert, including each joint and any deficient areas of the pipe/culvert, as well as a means to measure deformations/deflections of the pipe (items such as a laser range finder or other appropriate device for taking such measurements as specified herein and approved by the Engineer).

If the inspection is conducted manually, the person performing the inspection may use a standard video camera or a digital camera to document any observed deficiencies. If the mandrel test is to be performed to mechanically measure deformations/deflections of the pipe/culvert, the mandrel used shall be a nine (or greater odd number) arm mandrel, and shall be sized and inspected by the Engineer prior to testing. The diameter of the mandrel at any point shall not be less than the allowable percent deflection of the certified actual mean diameter of the pipe or culvert being tested. The mandrel shall be fabricated of metal, fitted with pulling rings at each end, stamped or engraved on some segment other than a runner with the nominal pipe/culvert size and mandrel outside diameter. The mandrel shall be pulled through the pipe or culvert by hand with a rope or cable. Where applicable, pulleys may be incorporated into the system to change the direction of pull so that inspection personnel need not physically enter the pipe, culvert or manhole.

A copy of the Storm Sewer/Culvert Inspection Report (inspection report)including any video tape/Digital Video Recording (DVD)/digital photographs shall be provided to the VDOT Inspector within two business days of the completion of the inspection and made part of the project records. Additionally, a copy shall be furnished to local VDOT Asset Management personnel to document the pipe/culvert condition at that point in time. The video tape/DVD/digital photographs should be of such clarity, detail and resolution as to clearly show the conditions of the interior of the pipe/culvert and detect any defects within the pipe or culvert as specified herein. Post installation inspections shall be conducted no sooner than 30 days after completion of installation and placement of final cover (except for pavement structure).

From this we can highlight the following requirements:

- Visual/ Video Inspection is required on:
    - All Storm Sewer Pipes (100%)
    - Selected Number of Pipe Culverts (>10%)

- Must be done with VDOT Rep Present
- Conducted no sooner than 30 days after completion of Installation and placement of final cover (except pavement).

When performing a manual visual inspection:

- There must be adequate crawl/walking space and VDOT Safety Policy and Procedure #8 Confined Space Entry Policy and Procedure must be followed.
- A standard Video/ Digital Camera can be used.
- A mandrel is needed for Flexible Pipe to measure deflection.
- Cracks shall be digitally scanned to allow for accurate measurement.

If the inspection is conducted by video:

- The video camera must have fully articulated lenses (360 degree inspection).
- The camera must have the means to measure deformation/deflection of the pipe.
- All cracks shall be digitally scanned to allow for accurate measurement.

Deficiencies found may include: but are not limited to, the following:

- Crushed, collapsed or deformed pipe or joints
- Alignment defects
- Improper Joints (allow infiltration of soil)
- Misaligned joints (allow debris accumulation)
- Pipe Penetrations (guardrails, utilities, etc.)
- Debris in the pipe
- Coatings free of cracks, scratches and peeling
- Cracks (longitudinal and circumferential)
- Spalls and Slabbing
- For metal and plastic pipe – localized buckling, bulging, cracking at bolt holes, flattening, or racking, etc.

Refer to *VDOT Road and Bridge Specifications, Section 302.03 Procedures (d) Post Installation Inspection* for detail requirements and remediation procedures.

PAVEMENT DRAINS

Pavement subsurface drainage is essential in obtaining a well performing pavement, whether it is flexible, rigid or composite. A drained pavement structure has a higher bearing capacity that can effectively support traffic loadings, and lead to long lasting pavement at the least maintenance cost.

A trench at the edge of the pavement provides a cavity with the least resistance for water to flow and accommodate pavement drainage. The trench's dimensions and location are typically 1 foot wide and 2 to 4 inches below the subgrade and adjacent to the pavement edge. The specific locations are shown on the plans. There is a variety of pavement under/edge drains in the VDOT Road and Bridge Standards Volume 1 (108.01-108.09) with each addressing a specific geometric condition and groundwater condition.

The most common underdrains are known as UD-4 and UD-7. The UD-4 is used with new construction, while the UD-7 is used for retrofitting existing pavements. These underdrains are segmented systems with outlets spaced at 250 to 350 feet.

The components of an underdrain system are:

1) Trench
2) Non-woven geotextile drainage fabric
3) Perforated longitudinal pipe (min. stiffness 35 psi) is the collecting conduit
4) Aggregate backfill (#8 or #57)
5) Non-perforated smooth wall outlet pipe (min. pipe stiffness 65 psi)
6) An end-wall for the protection of the outlet pipe.

The above components are designed to perform three functions to aid in draining water from the pavement; these are:

- Intercept
- Collect
- Discharge

Following is a general guide on the installation of underdrain/edge drain systems:

1) Excavate trench making sure the side walls are stable
2) Remove any sloughed materials from the trench
3) The dug out material is picked up with conveyor belt and loaded in trucks or piled on one side then picked up by a front end loader.
4) Provide a minimum 0.5 to 1% longitudinal slope to enhance positive drainage.
5) Open only as much trench as can be safely maintained by available equipment.
6) Line the trench with the non-woven drainage fabric.
7) Install the longitudinal perforated pipe at the bottom of the trench without bedding material.

8) At the end of the run (250-350 feet) a 45-degree elbow is used to connect the longitudinal pipe to the non-perforated outlet pipe to force the collected water to discharge. The side is called the drainage side.
9) The outlet pipe is connected to the back of the end-wall.
10) Backfill the trench using clean #8 or #57 aggregate as soon as practical, but not later than the end of each working day.
11) Backfill depth is at least equal to the diameter of the pipe.
12) Backfill is usually placed loosely and heaped above the finished level.
13) Use vibratory plate with a welded foot to compact the aggregate backfill.
14) Fold the drainage fabric to provide 100% overlap at the top of the trench.
15) In the case of UD-4, the Open Graded Drainage Layer (OGDL) is placed on top of the completed trench.
16) In the case of UD-7, as asphalt concrete cap is used to complete the backfilling and provide the final surface that is even with the shoulder.
17) Once the system has been installed, it is critical that inspection is performed to ensure that there are no areas that are crushed, clogged or otherwise non-functioning. Inspection is performed in accordance with VTM-108.

CHAPTER 4 – STUDY QUESTIONS

1) What should be located before starting to dig?

2) True or False. When moving concrete pipe you should pick it up by one end.

3) What are the testing requirements for backfilling around pipe?

4) What is the maximum size a rock to be placed within 12 inches of a pipe?

5) True or False. You do not have to place pipe bedding material down first when installing a UD-4.

6) Where can the typical underdrain drawings be found?

7) What is the maximum height of cover for a 48 inch pipe diameter Class IV concrete pipe culvert?

8) A 36 inch diameter pipe, 290 feet long, is placed on a project as a drainage culvert. What is the minimum number of density tests that should be run on the backfill material?

9) When can No. 57 stone be used?

10) What is the maximum backfill lift thickness?

11) Pipe openings in precast drainage structures shall not exceed the outside cross sectional dimensions of the pipe by more than how much?

12) How long after installation is complete can the video inspection can be done?

13) What is the maximum allowed crack size of a rigid pipe?

14) What is the maximum deflection allowed for flexible pipe?

15) What end of the pipe system do you start installation? Upstream or down- stream?

16) What is the level of compaction required for pipe backfill?

17) What is the minimum amount of cover over pipe allowed for design loads?

18) What is the minimum amount of cover over pipe to prevent damage from construction loads?

5

ESTABLISHING THEORETICAL AND TARGET VALUES FOR DENSITY AND MOISTURE CONTENT

LEARNING OUTCOMES

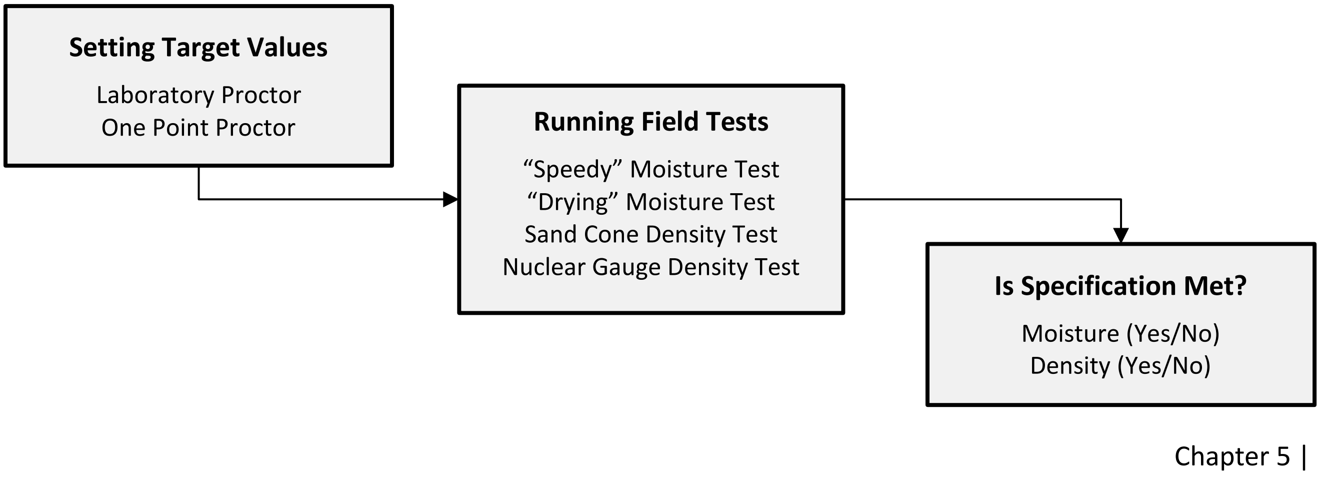
- Understand how the moisture-density relationship impacts soils and soil-aggregate mixtures
- Understand the procedures for determining the wet density of soil using the one-point proctor method
- Understand the procedures for determining moisture using a “hot plate” or “speedy” moisture device
- Understand how to establish target values for field testing using the moisture-density curves method

INTRODUCTION

When soil is being placed as fill material it must be put down in layers called lifts and compacted with some form of compaction equipment before the next lift is placed. Specifications for this work are given in the Virginia Department of Transportation’s Road and Bridge Specifications, Section 303.04 (h), Sec. 305.02 (a) 1 and are summarized in Appendices B and C of this Study Guide. Generally, the specifications call for the soil to be compacted to a minimum of 95% of the theoretical maximum density, with a moisture content of ± 20% of the theoretical optimum moisture. These theoretical values are referred to as the testing targets.

Refer to the flow chart below to see the overall procedure for determining if fill material meets the specifications. First, the target values for density and moisture content must be determined. This chapter will discuss the various methods for determining the target values of various soil materials.

SOILS DENSITY TESTING FLOW CHART



LABORATORY PROCTOR

AASHTO T 99/T 180 – MOISTURE-DENSITY RELATIONSHIP OF SOILS AND SOIL-AGGREGATE MIXTURES

SUMMARY OF PROCEDURE

This procedure determines the moisture-density relationship of soils and soil-aggregate mixtures. It is sometimes referred to as the standard proctor or the modified proctor test. A quantity of soil or soil and aggregate mixture is prepared at a determinable moisture content and compacted in a standard mold using a manual or mechanical rammer. The wet mass of this compacted sample is divided by the volume of the mold to determine the wet density. Moisture content testing on the material from the compacted mass is used to determine the dry density of this material. This procedure is repeated at varied moisture contents and the results are plotted on a graph as shown in Figure 5.1. A smooth line is drawn through the points to obtain a curve. The maximum density and optimum moisture content are determined by selecting a point at the peak of the curve.

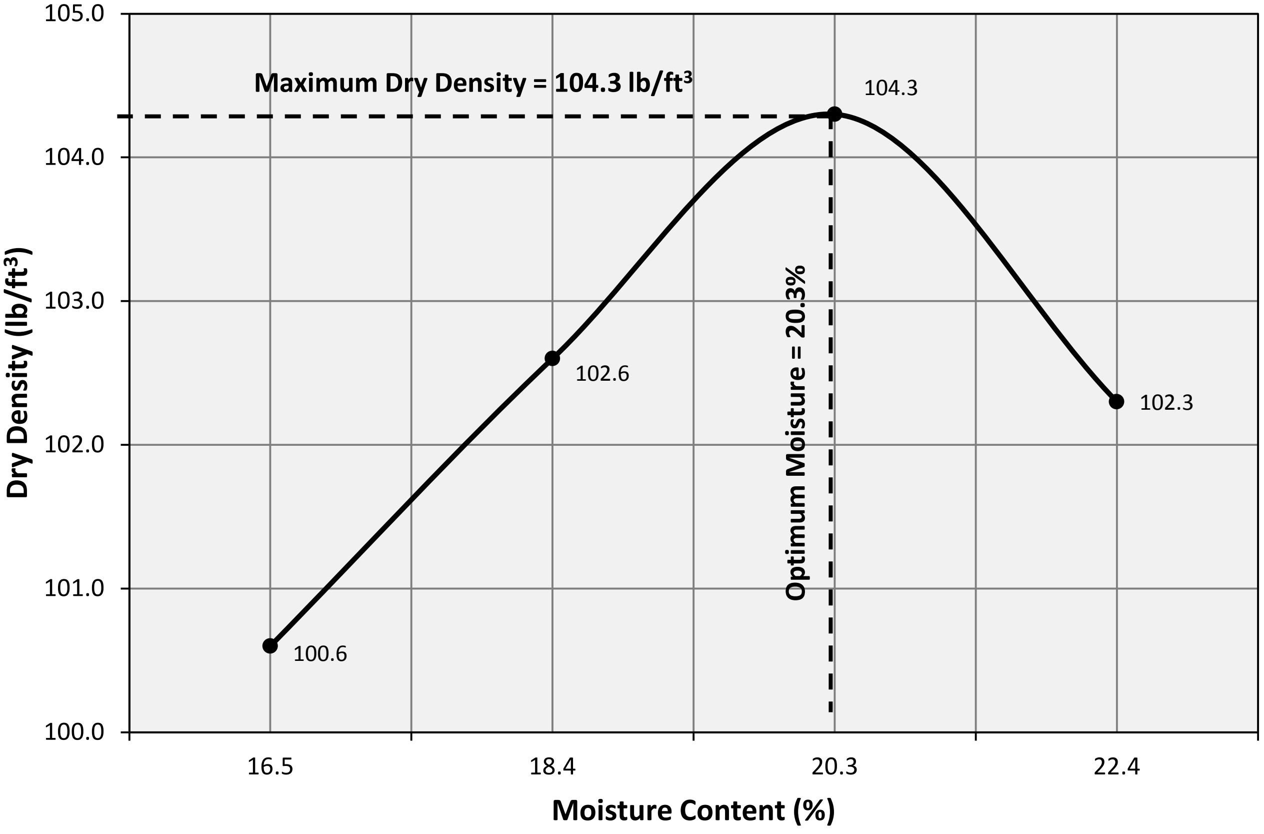


Figure 5.1: Example Moisture-Density Curve

TYPICAL TEST RESULTS

Typical maximum density and optimum moisture that can be expected as the result of a standard compaction test (AASHTO T 99) are given below (Table 5.1). A modified compaction test (AASHTO T 180) will yield 10 to 15 percent higher maximum densities and 20 to 30 percent lower optimum moisture due to the greater compactive effort used (as described in Table 5.2).

TABLE 5.1
Typical Values of Maximum Density and Optimum Moisture for Common Types of Soil (AASHTO T-99)

Unified Soil	Soil Description	Maximum Density Range kg/m^3 (lb/ft^3)	Optimum Moisture Range (%)
CH	Highly Plastic Clays	1200-1680 (75-105)	19-36
CL	Silty Clays	1520-1920 (95-120)	12-24
ML	Silty and Clayey Silts	1520-1920 (95-120)	12-24
SC	Clayey Sands	1680-2000 (105-125)	11-19
SM	Silty Sands	1760-2000 (110-125)	11-16
SP	Poorly-graded Sands	1600-1920 (100-120)	12-21
SW	Well-graded Sands	1760-2080 (110-130)	9-16
GC	Clayey Gravel w/sands	1840-2080 (115-130)	9-14
GP	Poorly-graded gravels	1840-2000 (115-125)	11-14
GW	Well-graded Gravels	2000-2160 (125-135)	8-11

TABLE 5.2
Differences Between Standard (T 99) and Modified (T 180) Moisture-Density Tests

Equipment/Procedures	Standard	Modified
Rammers Mass (Manual and Mechanical)	2.495 kg (5.5 lb)	4.536 kg (10.0 lb)
Drop of Rammer to Soil Surface	305 mm (12.0 in)	475 mm (18.0 in)
Number of Layers Placed when Filling Mold	3	5

TESTING EQUIPMENT

Before beginning any procedure, you must first assemble all the equipment you will need to perform the test. You will need the following equipment per AASHTO T 99/T 180 as shown in Figure 5.2 above, Tables 5.2 and 5.3, and as indicated below.

1) Rammers: The difference between the two procedures (standard and modified) is the mass and freefall of the rammer used to compact the soil or soil and aggregate mixture in the mold and the number of layers placed into the compaction mold for compaction.

2) Mechanical compacting ram: If a mechanical compacting ram is used, it must be calibrated to produce results repeatable with the manual methods using ASTM method D2168.

3) Compaction block, with a mass not less than 90 kg (200 lb).

4) Molds: Depending on the method, either a 101.6 mm (4 in.) or a 152.4 mm (6 in.) mold, solid wall metal cylinder, with dimensions and capacities as shown in Table 5.3.

5) Scales and balances meeting state requirements.

Figure 5.2 Apparatus for T 99 and T 180

6) Oven, stove or other drying device, meeting state requirements.

7) Straightedge: At least 250 mm (10 in.) length, made of hardened steel with one beveled edge. The straightedge is used to plane the surface of the soil even with the top of the mold. The straightedge should not be so flexible that it leaves a concave surface when trimming the soil from the top of the compacted sample.

8) Engineering Curve

9) Sieves: 50.0 mm (2 in.), 19.0 mm (3/4 in.), and a 4.75 mm (No. 4) conforming to the requirements of AASHTO M92.

10) Mixing Tools: Sample pans, spoons, scoops, trowels, used for mixing the sample with water.

11) Containers: Corrosion resistant with close fitting lids to retain moisture content of prepared soil samples.

12) Graduated cylinders for adding water.

TESTING METHODS

AASHTO T 99 and T 180 stipulate four distinct test methods for these procedures, which are Method A, Method B, Method C, and Method D (Table 5.3). The method to be used should be indicated in the applicable specification.

TABLE 5.3
Moisture-Density Methods and Associated Mold Sizes

	Method A	**Method B**	**Method C**	**Method D**
Mold Size	101.6 mm (4 in)	152.4 mm (6 in)	101.6 mm (4 in)	152.4 mm (6 in)
Material Size	Passing 4.75 mm (No. 4)	Passing 4.75 mm (No. 4)	Passing 19.0 mm (3/4 in)	Passing 19.0 mm (3/4 in)
Blow Per Layer	25	56	25	56
Standard (T 99)	3 Layers using 2.495 kg (5.5 lb) rammer, 305 mm (12 in) drop			
Modified (T 180)	5 Layers using 4.536 kg (10 lb) rammer, 457 mm (18 in) drop			

Use caution when selecting the test method to be used. AASHTO test method designations are distinct from ASTM methods listed in D 698 and D 1557. ASTM also contains three Methods (A, B, or C) which correspond to different mold dimensions than the AASHTO counterparts.

The step by step procedures for AASHTO T 99 and T 180 are essentially the same. The differences in the two procedures are indicated in Table 5.3. AASHTO T 99 will always use 3 layers and a 2.495 kg (5.5 lb) rammer with 305 mm (12 in) drop for all methods. AASHTO T 180 will always use 5 layers and a 4.536 kg (10 lb) rammer with 457 mm (18 in.) drop.

AASHTO stipulates for each method that material must pass the designated sieve (Table 5.3). Any material retained on the designated sieves is discarded, unless the oversize correction procedure is to be used, (See “Oversize Material Replacement” on next page.)

Sample Preparation

1) If the sample is wet, dry it until it becomes friable under a trowel. Aggregations in a friable soil sample will break apart easily. Avoid breaking apart the natural particles when breaking up the soil aggregations.

2) Sieve the sample over the specified sieve for the method being performed. Discard any oversize material retained on the specified sieve.

   NOTE: Oversize Material Replacement - It may be necessary to maintain the same percentage of coarse material in the lab sample as was found in the field. If oversize material replacement is required, the material to be tested should be screened through a 50 mm (2 in.) and 19 mm (3/4 in.) sieve, to ascertain the amount of material retained on the 19 mm (3/4 in.) sieve. An equal mass of material which passes the 19 mm (3/4 in.) sieve, but is retained on the 4.75 mm (No. 4) sieve, is then obtained from the remaining portion of the sample. This material is recombined with the test sample prior to compaction. When this procedure is followed, it is necessary to prepare a larger quantity of material for testing.

3) Thoroughly mix the remaining sample. Obtain at least enough material to fill the mold when compacted and provide enough extra material to ensure adequate material for the determination of moisture content and increase in density as more water is added.

   NOTE: This method uses the same soil or soil-aggregate sample for each “point” on the density curve. If the soil or soil-aggregate mixture to be tested is a clayey material which will not easily mix with water, or where the soil material is fragile and will break apart from the repeated blows of the compaction rammer, it may be necessary to prepare individual portions for each density point. In most cases enough material should be sampled from the field to permit four individual “points” starting 4% below the anticipated optimum moisture content, and then each subsequent “point” increased by 2% moisture. Optimum moisture content should be “bracketed” by the prepared samples in order to provide a more accurate moisture-density curve.

4) Prepare the sample(s) and mix with water to produce the desired moisture content. If the four "points" are prepared in advance, store the prepared material in moisture tight containers. The following example illustrates how to calculate the amount of water to be added to the soil or soil-aggregate material as a percentage of the sample’s original mass.

   A sample of 6090 g needs to be prepared with approximately 2% additional moisture. Therefore, 6090 g is multiplied by 1.02 to yield a sample mass of 6210 g.

   6090 x 1.02 = 6210 g

   6210 – 6090 = 120 g

   Therefore, 120 g of water should be added to bring the moisture content up by approximately 2%. Since water has a mass of one gram per milliliter, 120 mL of water should be added.

Test Procedure

1) Record the mass of the mold and base plate (without the extension collar) to the nearest 5 grams.

   NOTE: While compacting the sample, make sure the mold rests on a rigid and stable foundation or base which will not move.

2) Place a representative portion of the sample into the mold. Place material layers using three approximately equal lifts, to give a total compacted depth of about 127 mm (5 in.) for the standard method (AASHTO T 99). Place five approximately equal layers to give a total compacted depth of about 127 mm (5 in.) for the modified method (AASHTO T 180).

3) Use the 2.495 kg (5.5 lb) rammer for standard moisture density test (AASHTO T 99) or the 4.536 kg (10 lb) rammer for modified moisture density test (AASHTO T 180).

4) Apply the required number of blows to the specimen layer (25 blows for Methods A and C, 56 blows for Methods B and D).

5) When compacting the specimen using the manual rammer, uniformly distribute the blows over the entire surface area of the sample.

   NOTE: Do not lift the rammer and sleeve from the surface of the sample while compacting. Also, hold the rammer perpendicular to the sample and mold during compaction.

6) Repeat Steps 1 through 5 for each subsequent layer.

7) Remove the extension collar from the mold and trim the sample even with the top edge of the mold using a straightedge. Clean the mold and base plate of any loose particles. If there are voids in the surface of the compacted sample, fill them with loose soil collected from around the baseplate. Re-trim the sample even with the top edge of the mold. Clean mold of loose particles if necessary.

8) Weigh the mold with sample and record to the nearest 5 grams.

9) Remove the compacted soil or soil-aggregate sample from the mold and slice vertically through the center of the specimen. Obtain a representative sample from one of the cut faces, determine the moist mass immediately and record. Dry in accordance with MARTCP SA 1.3, to determine moisture content.

10) Break up the remainder of the sample from the mold. Add the broken up sample to the remainder of the sample being used for the test.

11) Add additional water to the sample to increase the overall moisture content by about 2% (as described in Step 4 of Sample Preparation). The increased moisture content should never be more than 4%. If separate density points were prepared prior to performing the procedure, skip this step. Continue compacting samples with moisture contents increasing by roughly 2% until there is a drop or no change in the calculated wet density.

Calculations

1) Calculate the wet density of the material as follows:

    a. Methods A & C: (volume of four inch mold = 0.0333 ft^3)

$$W_{wet} = \frac{(W_{s+m} - W_m)}{0.0333\ ft^3} \times \frac{2.205\ lb}{1\ kg} = (W_{s+m} - W_m) \times 66.22$$

    b. Methods B & D: (volume of six inch mold = 0.075 ft^3)

$$W_{wet} = \frac{(W_{s+m} - W_m)}{0.075\ ft^3} \times \frac{2.205\ lb}{1\ kg} = (W_{s+m} - W_m) \times 29.40$$

Where:

W_{wet} = Wet Density (lb/ft^3)

W_{s+m} = Mass of the wet sample and mold (kg)

W_m = Mass of the mold (kg)

2.205 lb = 1 kg

2) Calculate the moisture content for each compacted sample by dividing the water content (loss between wet mass and dry mass of moisture sample) by the dry mass of the sample and multiplying by 100.

$$W_{\%} = \frac{(W_{wet} - W_{dry})}{(W_{dry} - W_{con})} \times 100$$

Where:

$W_{\%}$ = Percent Moisture

W_{wet} = Weight of Wet Aggregate and Container (g or lb)

W_{dry} = Weight of Dry Aggregate and Container (g or lb)

W_{con} = Weight of the Container (g or lb)

3) Calculate the dry density for each compacted sample based on the corresponding moisture sample for each compacted specimen.

$$D_{dry} = \frac{D_{wet}}{100 + W_{\%}} \times 100$$

Where:

D_{dry} = Dry Density (kg/m^3 or lb/ft^3)

D_{wet} = Wet Density (kg/m^3 or lb/ft^3)

$W_{\%}$ = Moisture Content of Sample

4) Plot each compaction point for dry density on graph paper with density on the y-axis and moisture content on the x-axis as shown on Figure 6.7.

5) Form a smooth line using the engineer's curve by connecting the plotted points to form two curves. As close as possible to the intersection, round the peak to form a smooth, continuous line.

6) The moisture content corresponding to the peak of the curve will be termed the "optimum moisture content."

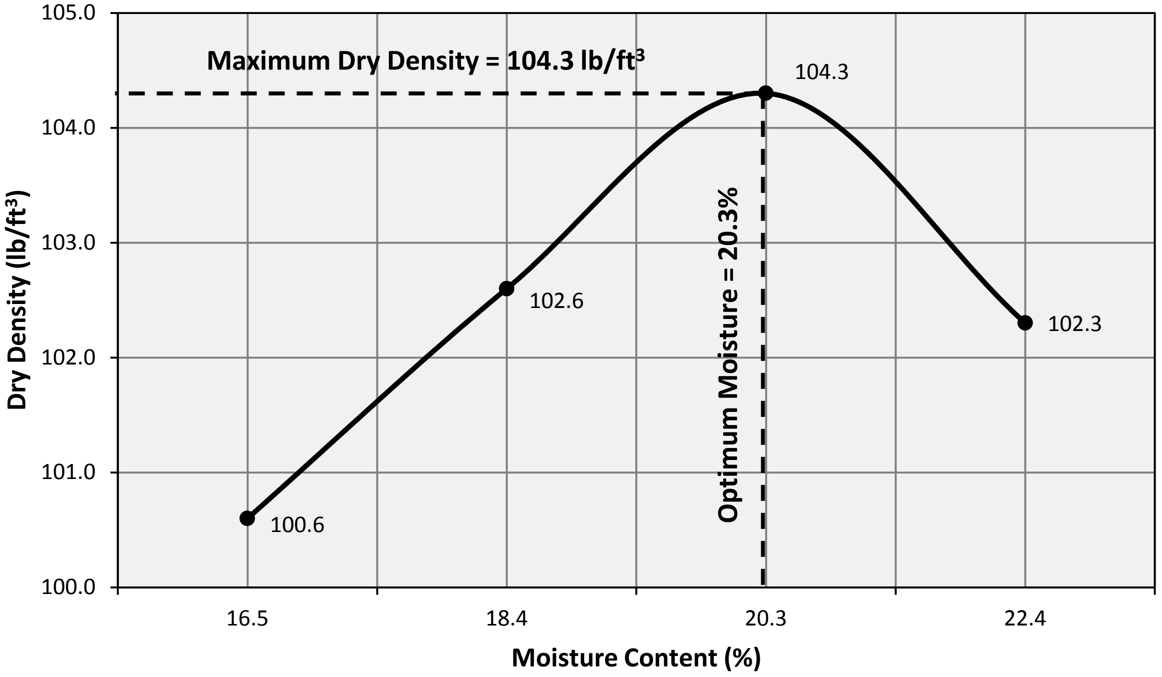
7) The dry density corresponding to the peak of the curve will be termed "maximum dry density."

Example Calculation

The following example moisture density relationship (Table 5.4) is calculated as a Modified (AASHTO T 180), Method A (Large Rammer, Small Mold). Remember that the mass of the wet soil needs to be expressed per the unit volume of the mold used. The mass of the wet soil in kilograms is multiplied by 66.22 to determine the wet density in lb/ft^3.

TABLE 5.4
Modified Method A Moisture-Density Relationship Computation

Point No.	1	2	3	4
Mass of Mold and Soil (kg)	6.065	6.130	6.190	6.185
(-) Mass of Mold (kg)	4.295	4.295	4.295	4.295
(=) Mass of Wet Soil (kg)	1.770	1.835	1.895	1.890
Wet Density (lb/ft^3)	117.2	121.5	125.5	125.2
A = Mass of Container and Wet Soil (g)	373.5	397.5	385.2	387.3
B = Mass of Container and Dry Soil (g)	336.9	354.9	339.7	338.9
C = Mass of Container (g)	115.2	123.2	115.4	122.8
W = Moisture Content (%)	16.5	18.4	20.3	22.4
D_{dry} = Dry Density (lb/ft^3)	100.6	102.6	104.3	102.3



Common Testing Errors

1) The soil is not thoroughly mixed to achieve uniform moisture.
2) The wrong mold is used for the test.
3) The mold is out of calibration tolerances.
4) The compaction block is not of sufficient mass (200 lbs.).
5) The compaction block is unstable.
6) The wrong rammer is used for the test.
7) The drop of the rammer is incorrect.
8) The manual rammer is not lifted to the full stroke.
9) The manual rammer is not held vertically when the blows are delivered.
10) The rammer is not properly cleaned between uses.
11) The mechanical rammer is out of calibration.
12) The wrong number of blows is delivered with the rammer.
13) The mechanical rammer has the wrong compaction face.
14) The lifts vary in thickness.
15) The straightedge may become worn with use - replace as necessary.
16) The sample is not properly dried or the moisture content sample is improperly taken.
17) The points are not plotted correctly on the graph.

ONE POINT PROCTOR

A one point proctor is run after the material has been placed and bladed off to determine the optimum moisture and maximum dry density. This information will be compared to the field density test, which is run on the same soil, to determine the percentage of compaction achieved by the contractor's operations.

The information for the one point proctor goes on form TL-125A. The test is run as follows:

1) Obtain a representative sample.

2) Weigh the mold and base plate and record on line B of the worksheet. Attach the collar.

3) Pass the soil that was removed through a No.4 sieve.

4) Place the mold on a hard stable surface. Place the material passing the No. 4 sieve in three approximately equal layers, compacting each layer 25 times with the hand held hammer – 5.5 lbs. dropped 12 inches.

Note: A satisfactory base is defined by AASHTO as a concrete block weighing at least 200 lbs. supported by a relatively stable foundation or a concrete floor; a concrete box culvert or a bridge abutment will certainly meet these conditions.

5) After the soil is compacted, remove the collar, and use a straightedge with a beveled edge to strike off the surface evenly. Be careful to avoid removal of the soil within the mold. Should surface voids be created, take enough soil from the trimming to fill the void and apply pressure with a finger to compact the soil in the void. Once the sample has been trimmed, weigh the mold and wet soil, record the weight on line A.

Subtract line B from line A to determine the wet soil weight and record on line C. Multiply line C by 30 to determine the wet density of the soil and record on line D.

Wet Density = Wt. of Wet Soil x 30

Proctor mold volume = 1/30 cubic foot

6) The Moisture Content of the Soil is determined by the use of a field hot plate to dry the soil and then calculate the moisture content as in the laboratory or the Speedy Moisture Tester can be used.

7) Record the Speedy Dial reading from the test on line E and the moisture content from the chart that comes with the test unit on line F.

8) Now that the wet density and the moisture content have been determined, use the one point proctor typical moisture density curves set C worksheet to determine the maximum dry density of the soil.

   Take the values from line D (wet density of soil) and line F (moisture content of soil) and locate this point on the Typical Moisture-Density curves set C. Find the curve where the wet density and moisture content lines intersect and go to the upper right hand corner of the graph and read the Maximum Dry Density and Optimum Moisture Content that correspond to that curve.

Form TL-125A (Rev. 07/15)

VIRGINIA DEPARTMENT OF TRANPORTATION
MATERIALS DIVISION
WORKSHEET FOR ONE-POINT PROCTOR

Route No. 726

County Pittsylvania

Project No. 0726-071-274, C501

Inspector Your Name

FHWA No. AS-414(101)

Field Test No.		1	2	3
Date of Test		3/5/2015		
Location of Test	Station Number – ft. (m)	27+50		
	Reference to Center Line – ft. (m)	3' Rt. C/L		
Reference Elevation	Original Ground – ft. (m)	+10 ft.		
	Finished Grade – ft. (m)	-26 ft.		
Type of Roller		Sheepsfoot		
A. Weight (mass) of mold and wet soil – lb. (kg)		13.57		
B. Weight (mass) of mold – lb. (kg)		9.34		
C. Weight (mass) of wet soil (A - B) – lb. (kg)		4.23		
D. Wet density of soil (Line C x 30 lb/ft^3) or (Line C x 1060 kg/m^3)		126.9		
E. "Speedy" Dial Reading				
F. Moisture Content (%) from Speedy Chart				
G. Maximum Dry Density – lb/ft^3 (kg/m^3)				
H. Optimum Moisture (%)				
I. Field Density – lb/ft^3 (kg/m^3) from TL-125				
J. No. 4 (+4.75 mm) material from field density hole				
K. Corrected Maximum Density – lb/ft^3 (kg/m^3)				
L. Compaction (%)				

Line D = Line C x 30

Line D = 4.23 x 30
Line D = 126.9

Comments:

BY: ____________________

TITLE: ____________________

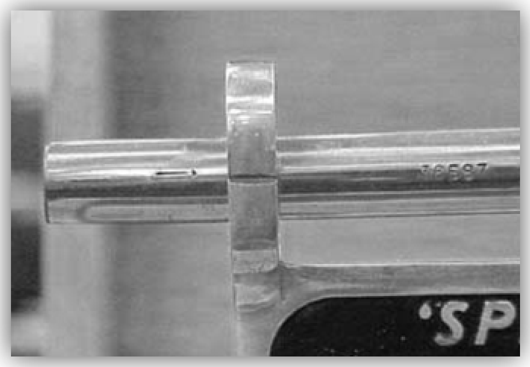
THE "SPEEDY" MOISTURE TESTER
INSTRUCTIONS FOR USE

AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS
AASHTO DESIGNATION: T-217-96

This method of test is intended to determine the moisture content of soils by means of a calcium carbide gas pressure moisture tester (speedy moisture tester).

1) Place three scoops (approximately 24g) of calcium carbide in the body of the moisture tester.

2) Weigh a sample of –4 material the exact weight specified by the manufacturer of the instrument in the balance provided (20 or 26g), and place the sample in the cap of the tester. If the moisture content of the sample exceeds the limit of the pressure gauge, a one-half size sample must be used and the dial reading must be multiplied by 2.



3) Place two 1¼" steel balls in the body of the tester with the calcium carbide (do not allow the steel balls to fall to the bottom of the tester, since this might cause damage to the dial).

4) With the pressure vessel in an approximately horizontal position, insert the cap in the pressure vessel and seal the unit by tightening the clamp, taking care that no carbide comes in contact with the soil until complete seal is achieved.

5) Raise the moisture tester to a vertical position so that the soil in the cap will fall into the pressure

6) Shake the instrument vigorously so that all lumps will be broken up to permit the calcium carbide to react with all available free moisture. The instrument should be shaken with a rotating motion so the steel balls will not damage the instrument or cause soil particles to become embedded in the orifice leading to the pressure diaphragm.

7) Shaking should continue for at least one minute with granular soils and for up to three minutes for other soils so as to permit complete reaction between the calcium carbide and the free moisture. Time should be permitted to allow dissipation of the heat generated by the chemical reaction. (Manufacturer suggests rotating the device for 10 seconds and resting for 20 seconds. Repeat the shake-rest cycle for a total of 3 minutes.)

8) When the needle stops moving, read the dial while holding the instrument in a horizontal position at eye level.

9) Record the dial reading and then determine the moisture content of the soil on a dry weight basis from the moisture chart.

10) With the cap of the instrument pointed away from the operator, slowly release the gas pressure, empty the pressure vessel and examine the material for lumps. If the sample is not completely pulverized, the test should be repeated using a new sample.

NOTE:

a) This method shall not be used on granular materials having particles large enough to affect the accuracy of the test - in general any appreciable amount retained on the No. 4 sieve.

b) Care must be exercised to prevent the calcium carbide from coming into direct contact with water.

c) When removing the cap, care should be taken to point the instrument away from the operator to avoid breathing the fumes, and away from any potential source of ignition for the acetylene gas.

SPEEDY MOISTURE CHART

SPEEDY	MOIST.	SPEEDY	MOIST.	SPEEDY	MOIST.	SPEEDY	MOIST.	SPEEDY	MOIST.	SPEEDY	MOIST.	SPEEDY	MOIST.
READ.	CONT.	READ.	CONT.	READ.	CONT.	READ.	CONT.	READ.	CONT.	READ.	CONT.	READ.	CONT.
1.0	1.0	8.2	9.0	15.4	18.3	22.6	29.2	29.8	42.5	37.0	58.8	44.2	79.2
1.2	1.3	8.4	9.2	15.6	18.5	22.8	29.6	30.0	42.9	37.2	59.3	44.4	79.9
1.4	1.5	8.6	9.5	15.8	18.8	23.0	30.2	30.2	43.3	37.4	59.8	44.6	80.5
1.6	1.8	8.8	9.7	16.0	19.1	23.2	30.6	30.4	43.8	37.6	60.3	44.8	81.2
1.8	2.0	9.0	9.9	16.2	19.4	23.4	30.9	30.6	44.2	37.8	60.8	45.0	81.8
2.0	2.2	9.2	10.1	16.4	19.6	23.6	31.3	30.8	44.6	38.0	61.3	45.2	82.5
2.2	2.4	9.4	10.4	16.6	19.9	23.8	31.6	31.0	45.0	38.2	61.8	45.4	83.2
2.4	2.6	9.6	10.6	16.8	20.2	24.0	31.9	31.2	45.4	38.4	62.4	45.6	83.1
2.6	2.9	9.8	10.8	17.0	20.5	24.2	32.3	31.4	45.8	38.6	62.9	45.8	84.5
2.8	3.1	10.0	11.1	17.2	20.8	24.4	32.7	31.6	46.2	38.8	63.5	46.0	85.2
3.0	3.3	10.2	11.4	17.4	21.1	24.6	33.0	31.8	46.7	39.0	64.0	46.2	85.9
3.2	3.5	10.4	11.6	17.6	21.4	24.8	33.4	32.0	47.1	39.2	64.5	46.4	86.6
3.4	3.7	10.6	11.9	17.8	21.7	25.0	33.7	32.2	47.5	39.4	65.0	46.6	87.3
3.6	4.0	10.8	12.1	18.0	22.0	25.2	34.1	32.4	48.0	39.6	65.6	46.8	88.0
3.8	4.2	11.0	12.4	18.2	22.3	25.4	34.5	32.6	48.4	39.8	66.1	47.0	88.7
4.0	4.4	11.2	12.7	18.4	22.6	25.6	34.9	32.8	48.8	40.0	66.7	47.2	89.4
4.2	4.6	11.4	12.9	18.6	23.0	25.8	35.4	33.0	49.3	40.2	67.2	47.4	90.2
4.4	4.8	11.6	13.2	18.8	23.2	26.0	35.7	33.2	49.7	40.4	67.8	47.6	90.8
4.6	5.1	11.8	13.4	19.0	23.5	26.2	35.9	33.4	50.2	40.6	68.4	47.8	91.6
4.8	5.3	12.0	13.7	19.2	23.8	26.4	36.3	33.6	50.6	40.8	68.9	48.0	92.3
5.0	5.5	12.2	13.9	19.4				33.8	51.1	41.0	69.5	48.2	93.1
5.2	5.7	12.4	14.2	19.6				34.0	51.6	41.2	70.1	48.4	93.8
5.4	5.9	12.6	14.4	19.8				34.2	52.0	41.4	70.7	48.6	94.6
5.6	6.2	12.8	14.7	20.0	25.1	27.2	37.8	34.4	52.5	41.6	71.3	48.8	95.3
5.8	6.4	13.0	15.0	20.2	25.4	27.4	38.2	34.6	52.9	41.8	71.9	49.0	96.1
6.0	6.6	13.2	15.3	20.4	25.7	27.6	38.5	34.8	53.4	42.0	72.5	49.2	96.9
6.2	6.8	13.4	15.5	20.6	26.0	27.8	38.9	35.0	53.9	42.2	73.0	49.4	97.6
6.4	7.0	13.6	15.8	20.8	26.3	28.0	39.3	35.2	54.4	42.4	73.6	49.6	98.4
6.6	7.3	13.8	16.1	21.0	26.6	28.2	39.7	35.4	54.8	42.6	74.2	49.8	99.2
6.8	7.5	14.0	16.4	21.2	26.9	28.4	40.1	35.6	55.3	42.8	74.8	50.0	----
7.0	7.7	14.2	16.6	21.4	27.3	28.6	40.5	35.8	55.8	43.0	75.5		
7.2	7.9	14.4	16.9	21.6	27.6	28.8	40.9	36.0	56.3	43.2	76.1		
7.4	8.1	14.6	17.1	21.8	28.0	29.0	41.3	36.2	56.8	43.4	76.7		
7.6	8.4	14.8	17.4	22.0	28.3	29.2	41.5	36.4	57.2	43.6	77.3		
7.8	8.6	15.0	17.7	22.2	28.6	29.4	41.7	36.6	57.5	43.8	78.0		
8.0	8.8	15.2	18.0	22.4	28.9	29.6	42.1	36.8	58.3	44.0	78.6		

Speedy Reading for Proctor

Dial Reading = 12.4
Moisture Content = 14.2%

Form TL-125A (Rev. 07/15)

VIRGINIA DEPARTMENT OF TRANPORTATION
MATERIALS DIVISION
WORKSHEET FOR ONE-POINT PROCTOR

Route No. 726

County Pittsylvania

Project No. 0726-071-274, C501

Inspector Your Name

FHWA No. AS-414(101)

Field Test No.		1	2	3
Date of Test		3/5/2015		
Location of Test	Station Number – ft. (m)	27+50		
	Reference to Center Line – ft. (m)	3’ Rt. C/L		
Reference Elevation	Original Ground – ft. (m)	+10 ft.		
	Finished Grade – ft. (m)	-26 ft.		
Type of Roller		Sheepsfoot		
A. Weight (mass) of mold and wet soil – lb. (kg)		13.57		
B. Weight (mass) of mold – lb. (kg)		9.34		
C. Weight (mass) of wet soil (A - B) – lb. (kg)		4.23		
D. Wet density of soil (Line C x 30 lb/ft^3) or (Line C x 1060 kg/m^3)		126.9		
E. “Speedy” Dial Reading		12.4		
F. Moisture Content (%) from Speedy Chart		14.2		
G. Maximum Dry Density – lb/ft^3 (kg/m^3)				
H. Optimum Moisture (%)				
I. Field Density – lb/ft^3 (kg/m^3) from TL-125				
J. No. 4 (+4.75 mm) material from field density hole				
K. Corrected Maximum Density – lb/ft^3 (kg/m^3)				
L. Compaction (%)				

From Speedy Chart

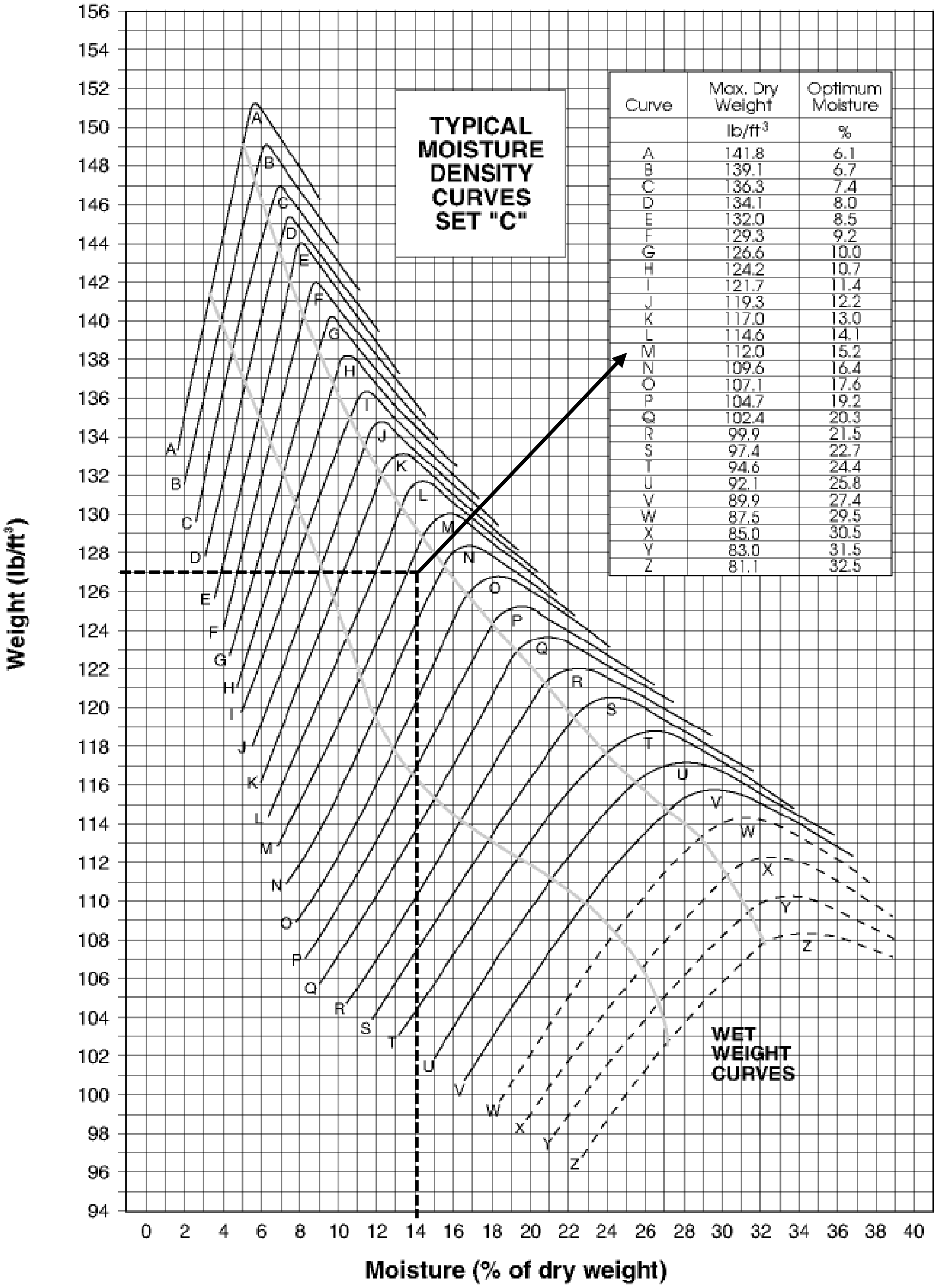
Dial Reading = 12.4
Moisture Content = 14.2

Comments:

BY:

TITLE:

The wet density of the soil is 126.9 lb/ft^3. The moisture content is 14.2 percent. Find the wet density on the vertical axis, and the moisture content on the horizontal axis. Using a straightedge, extend the lines until they intersect. They intersect nearest to Line M. Go to the chart in the upper right hand corner and record the data from Line M. The Maximum Dry Density is 112.0 lb/ft^3, and the optimum moisture is 15.2 percent. These values are recorded on Lines G and H of the one point proctor report (Form TL-125A).



Curve	Max. Dry Weight	Optimum Moisture
	lb/ft^3	%
A	141.8	6.1
B	139.1	6.7
C	136.3	7.4
D	134.1	8.0
E	132.0	8.5
F	129.3	9.2
G	126.6	10.0
H	124.2	10.7
I	121.7	11.4
J	119.3	12.2
K	117.0	13.0
L	114.6	14.1
M	112.0	15.2
N	109.6	16.4
O	107.1	17.6
P	104.7	19.2
Q	102.4	20.3
R	99.9	21.5
S	97.4	22.7
T	94.6	24.4
U	92.1	25.8
V	89.9	27.4
W	87.5	29.5
X	85.0	30.5
Y	83.0	31.5
Z	81.1	32.5

Form TL-125A (Rev. 07/15)

VIRGINIA DEPARTMENT OF TRANPORTATION
MATERIALS DIVISION
WORKSHEET FOR ONE-POINT PROCTOR

Route No. 726

County Pittsylvania

Project No. 0726-071-274, C501

Inspector Your Name

FHWA No. AS-414(101)

Field Test No.		1	2	3
Date of Test		3/5/2015		
Location of Test	Station Number – ft. (m)	27+50		
	Reference to Center Line – ft. (m)	3’ Rt. C/L		
Reference Elevation	Original Ground – ft. (m)	+10 ft.		
	Finished Grade – ft. (m)	-26 ft.		
Type of Roller		Sheepsfoot		
A. Weight (mass) of mold and wet soil – lb. (kg)		13.57		
B. Weight (mass) of mold – lb. (kg)		9.34		
C. Weight (mass) of wet soil (A - B) – lb. (kg)		4.23		
D. Wet density of soil (Line C x 30 lb/ft^3) or (Line C x 1060 kg/m^3)		126.9		
E. “Speedy” Dial Reading		12.4		
F. Moisture Content (%) from Speedy Chart		14.2		
G. Maximum Dry Density – lb/ft^3 (kg/m^3)		112.0		
H. Optimum Moisture (%)		15.2		
I. Field Density – lb/ft^3 (kg/m^3) from TL-125				
J. No. 4 (+4.75 mm) material from field density hole				
K. Corrected Maximum Density – lb/ft^3 (kg/m^3)				
L. Compaction (%)				

From Moisture-Density Chart

Max. Dry Density = 112.0
Opt. Moisture = 15.2

Comments: Optimum Moisture Range = 12.2 – 18.2 %
15.2 x 0.2 = 3.04 or 3.0
15.2 – 3.0 = 12.2 (Lower Limit)
15.2 + 3.0 = 18.2 (Upper Limit)

BY: ____________________

TITLE: ____________________

FIELD MOISTURE CONTENTDETERMINATION OF FIELD MOISTURE CONTENT BY DRYING (MARTCP METHOD SA-1.3)

Scope

The moisture content of a material influences its ability or inability to be excavated, consolidated, moved, screened, weighed, dried out, or reabsorbed. Moisture content calculations used for soils and aggregates are by convention figured as the mass of water driven out of the material through drying over the dry mass of the material. The moisture content is used to calculate a variety of properties, including density, plasticity, permeability, and more.

Materials and Equipment

1) An electric hot plate or a gas burner
2) Scale or balance as required by state specifications.
3) Metal container, such as a large frying pan or equivalent.
4) Pointing trowel or large spoon.

Test procedure

1) Select a representative quantity of material based on the following table, or state specifications:

TABLE 5.5
Aggregate Moisture Content Test Sample Sizes

Nominal Maximum Size, mm (in)	Minimum Sample Size, grams (lbs)
4.75 (No. 4)	500 (1.1)
9.5 (3/8)	1500 (3.3)
12.5 (1/2)	2000 (4.4)
19.0 (3/4)	3000 (6.6)
25.0 (1)	4000 (8.8)
37.5 (1 ½)	6000 (13.2)
50.0 (2)	8000 (17.6)

All soils moisture content sample sizes must be a minimum of 500 grams.

2) Weigh a clean, dry container.

3) Place the sample in the container and weigh.

4) Place the container on the stove or hot plate and, while drying, mix the sample continuously to expedite drying and prevent burning of the aggregate. Always use a low flame or heat setting.

5) When the sample looks dry, remove it from the stove, cool, and weigh. Put sample back on the stove, continue drying for another two to three minutes, cool, and reweigh. When a constant weight has been achieved, the sample is dry. Record the weight of the sample and the container. Note: Care must be taken to avoid losing any of the sample.

Common Testing Errors

- Spillage or loss of sample – loss of sample voids test results.
- Insufficient sample quantity (size) to yield accurate results.
- Overheating sample during drying process causing a loss of organic material or partial oxidation of other sample constituents.

Calculations

1) Moisture content of aggregate:

$$W_{\%} = \frac{(W_{wet} - W_{dry})}{(W_{dry} - W_{con})} \times 100$$

Where:

$W_{\%}$ = Percent Moisture

W_{wet} = Weight of Wet Aggregate and Container (g or lb)

W_{dry} = Weight of Dry Aggregate and Container (g or lb)

W_{con} = Weight of the Container (g or lb)

2) Example Problem:

$$W_{\%} = \frac{(W_{wet} - W_{dry})}{(W_{dry} - W_{con})} \times 100$$

Where:

$W_{\%}$ = Percent Moisture

W_{wet} = 589.6 grams

W_{dry} = 536.2 grams

W_{con} = 149.8 grams

$$W_{\%} = \frac{(589.6 - 536.2)}{(536.2 - 149.8)} \times 100$$

$$\downarrow$$

$$\frac{53.4}{386.4} \times 100$$

$$\downarrow$$

$$0.1381 \times 100$$

$$\downarrow$$

$$W_{\%} = 13.8\%$$

3) Report the moisture content according to required state specifications.

CHAPTER 5 – STUDY QUESTIONS

1) What are the three differences between AASHTO T-99 and AASHTO T-180?

2) __________ layers of soil are required to make a standard proctor mold and each layer must be compacted __________ blows with a __________ lb. hammer dropped __________ inches.

3) The moisture content corresponding to the peak of the curve will be termed the __________________________ and the density corresponding to the peak of the curve will be termed the __________________________.

4) __________ scoops of reagent are placed in the body of the “speedy” moisture tester.

5) According to AASHTO, the base on which the proctor test molds are made must weigh at least __________ lbs.

6) If the dial on the Speedy exceeds __________, a half-size sample must be used and the dial reading must be ____________________.

7) The proctor is run on soil which passes the __________ sieve.

8) Rotate the Speedy for ____________, rest for _____________ for a period of _____________.

.

9) Calculate the moisture content using the following information:

W_{wet} = 10.85

W_{dry} = 10.05

W_{con} = 1.69

CHAPTER 5 – PRACTICE PROBLEMS

Practice Problem Number 1
Establishing Target Densities (One-Point Proctor)

A. Complete the one-point proctor form (Form TL-125A) on soil using the information provided.

Date: Today's Date
Compacted Depth of Lift: 6"

Weight of Mold + Weight of Soil = 8.45 lbs.
Weight of Mold = 4.41 lbs.
Speedy Dial Reading = 13.2

B. Answer the following questions.

a) What is the maximum dry density?

b) What is the optimum moisture and optimum moisture range?

c) A nuclear density test determines the dry density to be 102 lb/ft^3 with a moisture content of 18.2%. Does this test pass?

Form TL-125A (Rev. 07/15)

VIRGINIA DEPARTMENT OF TRANPORTATION
MATERIALS DIVISION
WORKSHEET FOR ONE-POINT PROCTOR

Route No. 635 **County** Amherst

Project No. 0635-005-187, C501 **Inspector** ______

FHWA No. FH-151(102)

Field Test No.		1	2	3
Date of Test				
Location of Test	Station Number – ft. (m)	77+50		
	Reference to Center Line – ft. (m)	7' Lt. C/L		
Reference Elevation	Original Ground – ft. (m)	+10 ft.		
	Finished Grade – ft. (m)	-23 ft.		
Type of Roller		Sheepsfoot		
A. Weight (mass) of mold and wet soil – lb. (kg)				
B. Weight (mass) of mold – lb. (kg)				
C. Weight (mass) of wet soil (A - B) – lb. (kg)				
D. Wet density of soil (Line C x 30 lb/ft^3) or (Line C x 1060 kg/m^3)				
E. "Speedy" Dial Reading				
F. Moisture Content (%) from Speedy Chart				
G. Maximum Dry Density – lb/ft^3 (kg/m^3)				
H. Optimum Moisture (%)				
I. Field Density – lb/ft^3 (kg/m^3) from TL-125				
J. No. 4 (+4.75 mm) material from field density hole				
K. Corrected Maximum Density – lb/ft^3 (kg/m^3)				
L. Compaction (%)				

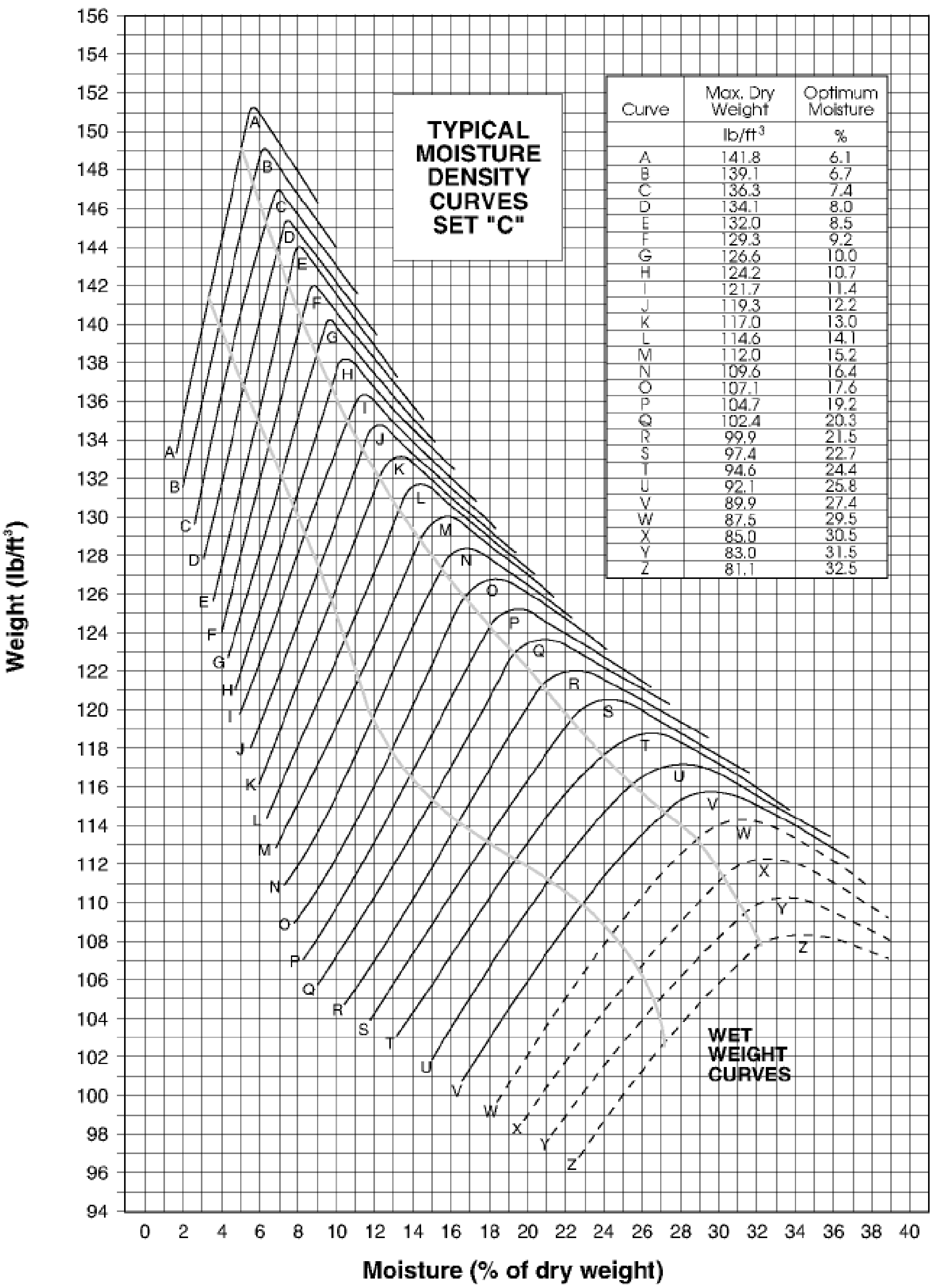
Comments:

BY: ______

TITLE: ______

SPEEDY MOISTURE CHART

SPEEDY MOIST.		SPEEDY MOIST.		SPEEDY MOIST.		SPEEDY MOIST.		SPEEDY MOIST.		SPEEDY MOIST.		SPEEDY MOIST.	
READ.	CONT.	READ.	CONT.	READ.	CONT.	READ.	CONT.	READ.	CONT.	READ.	CONT.	READ.	CONT.
1.0	1.0	8.2	9.0	15.4	18.3	22.6	29.2	29.8	42.5	37.0	58.8	44.2	79.2
1.2	1.3	8.4	9.2	15.6	18.5	22.8	29.6	30.0	42.9	37.2	59.3	44.4	79.9
1.4	1.5	8.6	9.5	15.8	18.8	23.0	30.2	30.2	43.3	37.4	59.8	44.6	80.5
1.6	1.8	8.8	9.7	16.0	19.1	23.2	30.6	30.4	43.8	37.6	60.3	44.8	81.2
1.8	2.0	9.0	9.9	16.2	19.4	23.4	30.9	30.6	44.2	37.8	60.8	45.0	81.8
2.0	2.2	9.2	10.1	16.4	19.6	23.6	31.3	30.8	44.6	38.0	61.3	45.2	82.5
2.2	2.4	9.4	10.4	16.6	19.9	23.8	31.6	31.0	45.0	38.2	61.8	45.4	83.2
2.4	2.6	9.6	10.6	16.8	20.2	24.0	31.9	31.2	45.4	38.4	62.4	45.6	83.1
2.6	2.9	9.8	10.8	17.0	20.5	24.2	32.3	31.4	45.8	38.6	62.9	45.8	84.5
2.8	3.1	10.0	11.1	17.2	20.8	24.4	32.7	31.6	46.2	38.8	63.5	46.0	85.2
3.0	3.3	10.2	11.4	17.4	21.1	24.6	33.0	31.8	46.7	39.0	64.0	46.2	85.9
3.2	3.5	10.4	11.6	17.6	21.4	24.8	33.4	32.0	47.1	39.2	64.5	46.4	86.6
3.4	3.7	10.6	11.9	17.8	21.7	25.0	33.7	32.2	47.5	39.4	65.0	46.6	87.3
3.6	4.0	10.8	12.1	18.0	22.0	25.2	34.1	32.4	48.0	39.6	65.6	46.8	88.0
3.8	4.2	11.0	12.4	18.2	22.3	25.4	34.5	32.6	48.4	39.8	66.1	47.0	88.7
4.0	4.4	11.2	12.7	18.4	22.6	25.6	34.9	32.8	48.8	40.0	66.7	47.2	89.4
4.2	4.6	11.4	12.9	18.6	23.0	25.8	35.4	33.0	49.3	40.2	67.2	47.4	90.2
4.4	4.8	11.6	13.2	18.8	23.2	26.0	35.7	33.2	49.7	40.4	67.8	47.6	90.8
4.6	5.1	11.8	13.4	19.0	23.5	26.2	35.9	33.4	50.2	40.6	68.4	47.8	91.6
4.8	5.3	12.0	13.7	19.2	23.8	26.4	36.3	33.6	50.6	40.8	68.9	48.0	92.3
5.0	5.5	12.2	13.9	19.4	24.1	26.6	36.6	33.8	51.1	41.0	69.5	48.2	93.1
5.2	5.7	12.4	14.2	19.6	24.4	26.8	37.0	34.0	51.6	41.2	70.1	48.4	93.8
5.4	5.9	12.6	14.4	19.8	24.8	27.0	37.4	34.2	52.0	41.4	70.7	48.6	94.6
5.6	6.2	12.8	14.7	20.0	25.1	27.2	37.8	34.4	52.5	41.6	71.3	48.8	95.3
5.8	6.4	13.0	15.0	20.2	25.4	27.4	38.2	34.6	52.9	41.8	71.9	49.0	96.1
6.0	6.6	13.2	15.3	20.4	25.7	27.6	38.5	34.8	53.4	42.0	72.5	49.2	96.9
6.2	6.8	13.4	15.5	20.6	26.0	27.8	38.9	35.0	53.9	42.2	73.0	49.4	97.6
6.4	7.0	13.6	15.8	20.8	26.3	28.0	39.3	35.2	54.4	42.4	73.6	49.6	98.4
6.6	7.3	13.8	16.1	21.0	26.6	28.2	39.7	35.4	54.8	42.6	74.2	49.8	99.2
6.8	7.5	14.0	16.4	21.2	26.9	28.4	40.1	35.6	55.3	42.8	74.8	50.0	----
7.0	7.7	14.2	16.6	21.4	27.3	28.6	40.5	35.8	55.8	43.0	75.5		
7.2	7.9	14.4	16.9	21.6	27.6	28.8	40.9	36.0	56.3	43.2	76.1		
7.4	8.1	14.6	17.1	21.8	28.0	29.0	41.3	36.2	56.8	43.4	76.7		
7.6	8.4	14.8	17.4	22.0	28.3	29.2	41.5	36.4	57.2	43.6	77.3		
7.8	8.6	15.0	17.7	22.2	28.6	29.4	41.7	36.6	57.5	43.8	78.0		
8.0	8.8	15.2	18.0	22.4	28.9	29.6	42.1	36.8	58.3	44.0	78.6		



Curve	Max. Dry Weight	Optimum Moisture
	lb/ft³	%
A	141.8	6.1
B	139.1	6.7
C	136.3	7.4
D	134.1	8.0
E	132.0	8.5
F	129.3	9.2
G	126.6	10.0
H	124.2	10.7
I	121.7	11.4
J	119.3	12.2
K	117.0	13.0
L	114.6	14.1
M	112.0	15.2
N	109.6	16.4
O	107.1	17.6
P	104.7	19.2
Q	102.4	20.3
R	99.9	21.5
S	97.4	22.7
T	94.6	24.4
U	92.1	25.8
V	89.9	27.4
W	87.5	29.5
X	85.0	30.5
Y	83.0	31.5
Z	81.1	32.5

CHAPTER 5 – PRACTICE PROBLEMS

Practice Problem Number 2
Establishing Target Densities (One-Point Proctor)

A. Complete the one-point proctor form (Form TL-125A) on soil using the information provided.

Date: Today's Date
Compacted Depth of Lift: 6"

Weight of Mold + Weight of Soil = 13.56 lbs.
Weight of Mold = 9.51 lbs.
Speedy Dial Reading = 16.0

B. Answer the following questions.

a) What is the maximum dry density?

b) What is the optimum moisture and optimum moisture range?

c) A nuclear density test determines the dry density to be 96.2 lb/ft^3 with a moisture content of 15.8%. Does this test pass?

Form TL-125A (Rev. 07/15)

VIRGINIA DEPARTMENT OF TRANPORTATION
MATERIALS DIVISION
WORKSHEET FOR ONE-POINT PROCTOR

Route No. 635 **County** Amherst

Project No. 0635-005-187, C501 **Inspector** ______

FHWA No. FH-151(102)

Field Test No.		1	2	3
Date of Test				
Location of Test	Station Number – ft. (m)	87+50		
	Reference to Center Line – ft. (m)	10’ Rt. C/L		
Reference Elevation	Original Ground – ft. (m)	+20 ft.		
	Finished Grade – ft. (m)	-23 ft.		
Type of Roller		Sheepsfoot		
A. Weight (mass) of mold and wet soil – lb. (kg)				
B. Weight (mass) of mold – lb. (kg)				
C. Weight (mass) of wet soil (A - B) – lb. (kg)				
D. Wet density of soil (Line C x 30 lb/ft^3) or (Line C x 1060 kg/m^3)				
E. “Speedy” Dial Reading				
F. Moisture Content (%) from Speedy Chart				
G. Maximum Dry Density – lb/ft^3 (kg/m^3)				
H. Optimum Moisture (%)				
I. Field Density – lb/ft^3 (kg/m^3) from TL-125				
J. No. 4 (+4.75 mm) material from field density hole				
K. Corrected Maximum Density – lb/ft^3 (kg/m^3)				
L. Compaction (%)				

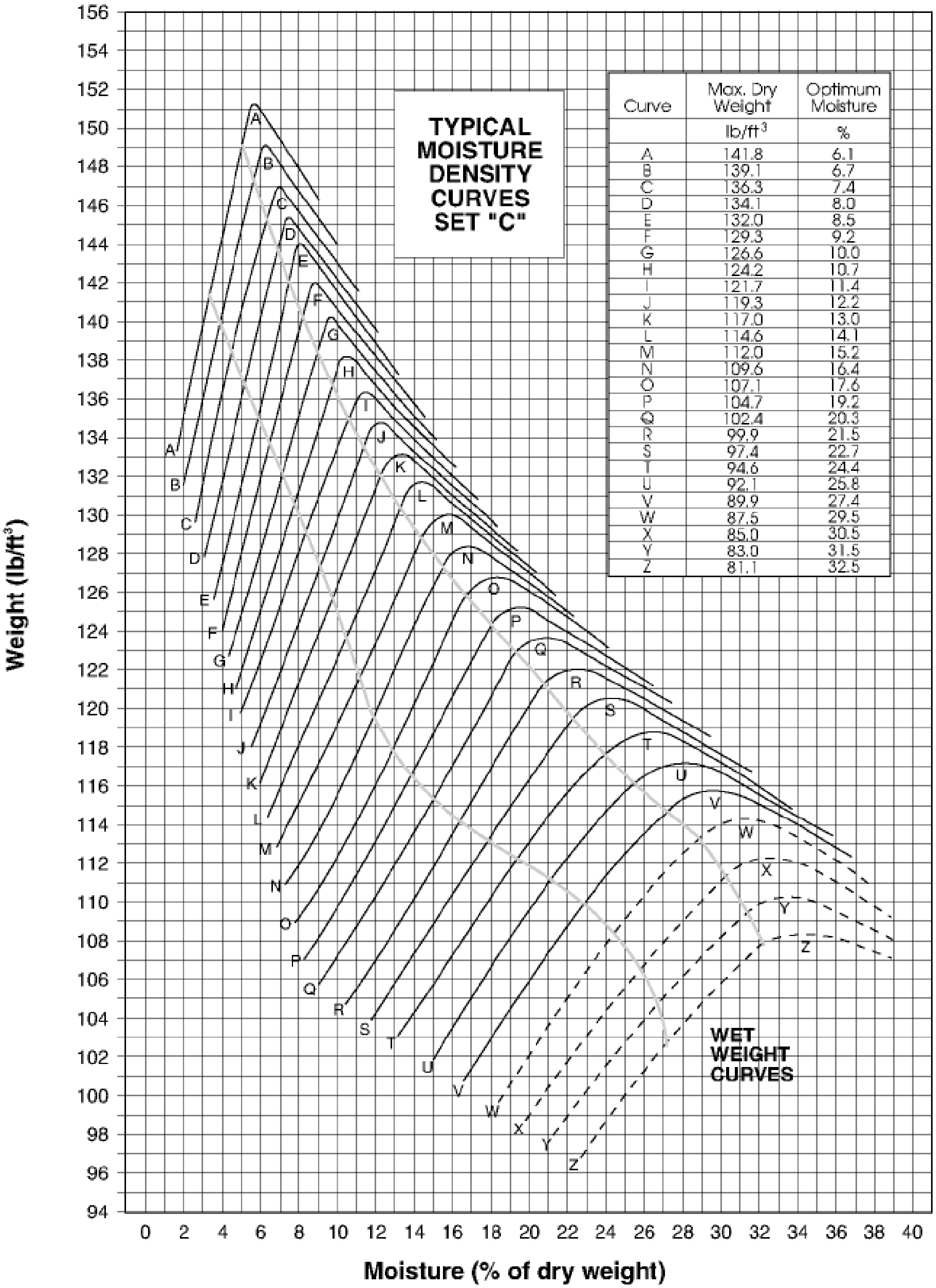
Comments:

BY: ______

TITLE: ______

SPEEDY MOISTURE CHART

SPEEDY MOIST.		SPEEDY MOIST.		SPEEDY MOIST.		SPEEDY MOIST.		SPEEDY MOIST.		SPEEDY MOIST.		SPEEDY MOIST.	
READ.	CONT.	READ.	CONT.	READ.	CONT.	READ.	CONT.	READ.	CONT.	READ.	CONT.	READ.	CONT.
1.0	1.0	8.2	9.0	15.4	18.3	22.6	29.2	29.8	42.5	37.0	58.8	44.2	79.2
1.2	1.3	8.4	9.2	15.6	18.5	22.8	29.6	30.0	42.9	37.2	59.3	44.4	79.9
1.4	1.5	8.6	9.5	15.8	18.8	23.0	30.2	30.2	43.3	37.4	59.8	44.6	80.5
1.6	1.8	8.8	9.7	16.0	19.1	23.2	30.6	30.4	43.8	37.6	60.3	44.8	81.2
1.8	2.0	9.0	9.9	16.2	19.4	23.4	30.9	30.6	44.2	37.8	60.8	45.0	81.8
2.0	2.2	9.2	10.1	16.4	19.6	23.6	31.3	30.8	44.6	38.0	61.3	45.2	82.5
2.2	2.4	9.4	10.4	16.6	19.9	23.8	31.6	31.0	45.0	38.2	61.8	45.4	83.2
2.4	2.6	9.6	10.6	16.8	20.2	24.0	31.9	31.2	45.4	38.4	62.4	45.6	83.1
2.6	2.9	9.8	10.8	17.0	20.5	24.2	32.3	31.4	45.8	38.6	62.9	45.8	84.5
2.8	3.1	10.0	11.1	17.2	20.8	24.4	32.7	31.6	46.2	38.8	63.5	46.0	85.2
3.0	3.3	10.2	11.4	17.4	21.1	24.6	33.0	31.8	46.7	39.0	64.0	46.2	85.9
3.2	3.5	10.4	11.6	17.6	21.4	24.8	33.4	32.0	47.1	39.2	64.5	46.4	86.6
3.4	3.7	10.6	11.9	17.8	21.7	25.0	33.7	32.2	47.5	39.4	65.0	46.6	87.3
3.6	4.0	10.8	12.1	18.0	22.0	25.2	34.1	32.4	48.0	39.6	65.6	46.8	88.0
3.8	4.2	11.0	12.4	18.2	22.3	25.4	34.5	32.6	48.4	39.8	66.1	47.0	88.7
4.0	4.4	11.2	12.7	18.4	22.6	25.6	34.9	32.8	48.8	40.0	66.7	47.2	89.4
4.2	4.6	11.4	12.9	18.6	23.0	25.8	35.4	33.0	49.3	40.2	67.2	47.4	90.2
4.4	4.8	11.6	13.2	18.8	23.2	26.0	35.7	33.2	49.7	40.4	67.8	47.6	90.8
4.6	5.1	11.8	13.4	19.0	23.5	26.2	35.9	33.4	50.2	40.6	68.4	47.8	91.6
4.8	5.3	12.0	13.7	19.2	23.8	26.4	36.3	33.6	50.6	40.8	68.9	48.0	92.3
5.0	5.5	12.2	13.9	19.4	24.1	26.6	36.6	33.8	51.1	41.0	69.5	48.2	93.1
5.2	5.7	12.4	14.2	19.6	24.4	26.8	37.0	34.0	51.6	41.2	70.1	48.4	93.8
5.4	5.9	12.6	14.4	19.8	24.8	27.0	37.4	34.2	52.0	41.4	70.7	48.6	94.6
5.6	6.2	12.8	14.7	20.0	25.1	27.2	37.8	34.4	52.5	41.6	71.3	48.8	95.3
5.8	6.4	13.0	15.0	20.2	25.4	27.4	38.2	34.6	52.9	41.8	71.9	49.0	96.1
6.0	6.6	13.2	15.3	20.4	25.7	27.6	38.5	34.8	53.4	42.0	72.5	49.2	96.9
6.2	6.8	13.4	15.5	20.6	26.0	27.8	38.9	35.0	53.9	42.2	73.0	49.4	97.6
6.4	7.0	13.6	15.8	20.8	26.3	28.0	39.3	35.2	54.4	42.4	73.6	49.6	98.4
6.6	7.3	13.8	16.1	21.0	26.6	28.2	39.7	35.4	54.8	42.6	74.2	49.8	99.2
6.8	7.5	14.0	16.4	21.2	26.9	28.4	40.1	35.6	55.3	42.8	74.8	50.0	----
7.0	7.7	14.2	16.6	21.4	27.3	28.6	40.5	35.8	55.8	43.0	75.5		
7.2	7.9	14.4	16.9	21.6	27.6	28.8	40.9	36.0	56.3	43.2	76.1		
7.4	8.1	14.6	17.1	21.8	28.0	29.0	41.3	36.2	56.8	43.4	76.7		
7.6	8.4	14.8	17.4	22.0	28.3	29.2	41.5	36.4	57.2	43.6	77.3		
7.8	8.6	15.0	17.7	22.2	28.6	29.4	41.7	36.6	57.5	43.8	78.0		
8.0	8.8	15.2	18.0	22.4	28.9	29.6	42.1	36.8	58.3	44.0	78.6		



Curve	Max. Dry Weight	Optimum Moisture
	lb/ft³	%
A	141.8	6.1
B	139.1	6.7
C	136.3	7.4
D	134.1	8.0
E	132.0	8.5
F	129.3	9.2
G	126.6	10.0
H	124.2	10.7
I	121.7	11.4
J	119.3	12.2
K	117.0	13.0
L	114.6	14.1
M	112.0	15.2
N	109.6	16.4
O	107.1	17.6
P	104.7	19.2
Q	102.4	20.3
R	99.9	21.5
S	97.4	22.7
T	94.6	24.4
U	92.1	25.8
V	89.9	27.4
W	87.5	29.5
X	85.0	30.5
Y	83.0	31.5
Z	81.1	32.5

CHAPTER 5 – PRACTICE PROBLEMS

Practice Problem Number 3
Establishing Target Densities (One-Point Proctor)

A. Complete the one-point proctor form (Form TL-125A) on soil using the information provided.

Date: Today's Date
Compacted Depth of Lift: 6"

Weight of Mold + Weight of Soil = 8.43 lbs.
Weight of Mold = 4.40 lbs.
Speedy Dial Reading = 14.0

B. Answer the following questions.

a) What is the maximum dry density?

b) What is the optimum moisture and optimum moisture range?

Form TL-125A (Rev. 07/15)

VIRGINIA DEPARTMENT OF TRANPORTATION
MATERIALS DIVISION
WORKSHEET FOR ONE-POINT PROCTOR

Route No. 615 **County** Campbell

Project No. 0615-015-186, C501 **Inspector** ______

FHWA No. FH-132(104)

Field Test No.		1	2	3
Date of Test				
Location of Test	Station Number – ft. (m)	87+40		
	Reference to Center Line – ft. (m)	10’ Rt. C/L		
Reference Elevation	Original Ground – ft. (m)	+13 ft.		
	Finished Grade – ft. (m)	-7 ft.		
Type of Roller		Sheepsfoot		
A. Weight (mass) of mold and wet soil – lb. (kg)				
B. Weight (mass) of mold – lb. (kg)				
C. Weight (mass) of wet soil (A - B) – lb. (kg)				
D. Wet density of soil (Line C x 30 lb/ft^3) or (Line C x 1060 kg/m^3)				
E. “Speedy” Dial Reading				
F. Moisture Content (%) from Speedy Chart				
G. Maximum Dry Density – lb/ft^3 (kg/m^3)				
H. Optimum Moisture (%)				
I. Field Density – lb/ft^3 (kg/m^3) from TL-125				
J. No. 4 (+4.75 mm) material from field density hole				
K. Corrected Maximum Density – lb/ft^3 (kg/m^3)				
L. Compaction (%)				

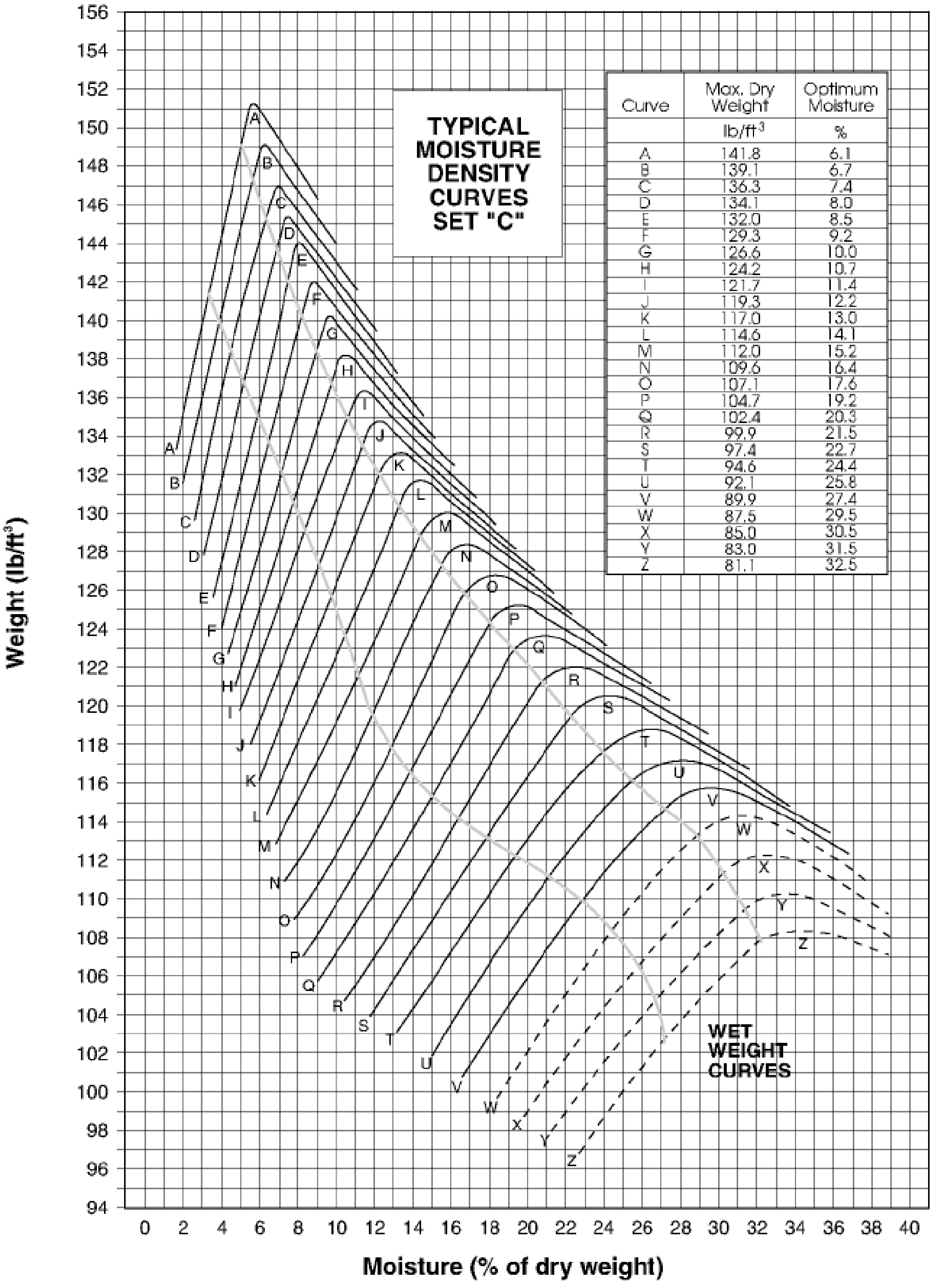
Comments:

BY: ______

TITLE: ______

SPEEDY MOISTURE CHART

SPEEDY MOIST.		SPEEDY MOIST.		SPEEDY MOIST.		SPEEDY MOIST.		SPEEDY MOIST.		SPEEDY MOIST.		SPEEDY MOIST.	
READ.	CONT.	READ.	CONT.	READ.	CONT.	READ.	CONT.	READ.	CONT.	READ.	CONT.	READ.	CONT.
1.0	1.0	8.2	9.0	15.4	18.3	22.6	29.2	29.8	42.5	37.0	58.8	44.2	79.2
1.2	1.3	8.4	9.2	15.6	18.5	22.8	29.6	30.0	42.9	37.2	59.3	44.4	79.9
1.4	1.5	8.6	9.5	15.8	18.8	23.0	30.2	30.2	43.3	37.4	59.8	44.6	80.5
1.6	1.8	8.8	9.7	16.0	19.1	23.2	30.6	30.4	43.8	37.6	60.3	44.8	81.2
1.8	2.0	9.0	9.9	16.2	19.4	23.4	30.9	30.6	44.2	37.8	60.8	45.0	81.8
2.0	2.2	9.2	10.1	16.4	19.6	23.6	31.3	30.8	44.6	38.0	61.3	45.2	82.5
2.2	2.4	9.4	10.4	16.6	19.9	23.8	31.6	31.0	45.0	38.2	61.8	45.4	83.2
2.4	2.6	9.6	10.6	16.8	20.2	24.0	31.9	31.2	45.4	38.4	62.4	45.6	83.1
2.6	2.9	9.8	10.8	17.0	20.5	24.2	32.3	31.4	45.8	38.6	62.9	45.8	84.5
2.8	3.1	10.0	11.1	17.2	20.8	24.4	32.7	31.6	46.2	38.8	63.5	46.0	85.2
3.0	3.3	10.2	11.4	17.4	21.1	24.6	33.0	31.8	46.7	39.0	64.0	46.2	85.9
3.2	3.5	10.4	11.6	17.6	21.4	24.8	33.4	32.0	47.1	39.2	64.5	46.4	86.6
3.4	3.7	10.6	11.9	17.8	21.7	25.0	33.7	32.2	47.5	39.4	65.0	46.6	87.3
3.6	4.0	10.8	12.1	18.0	22.0	25.2	34.1	32.4	48.0	39.6	65.6	46.8	88.0
3.8	4.2	11.0	12.4	18.2	22.3	25.4	34.5	32.6	48.4	39.8	66.1	47.0	88.7
4.0	4.4	11.2	12.7	18.4	22.6	25.6	34.9	32.8	48.8	40.0	66.7	47.2	89.4
4.2	4.6	11.4	12.9	18.6	23.0	25.8	35.4	33.0	49.3	40.2	67.2	47.4	90.2
4.4	4.8	11.6	13.2	18.8	23.2	26.0	35.7	33.2	49.7	40.4	67.8	47.6	90.8
4.6	5.1	11.8	13.4	19.0	23.5	26.2	35.9	33.4	50.2	40.6	68.4	47.8	91.6
4.8	5.3	12.0	13.7	19.2	23.8	26.4	36.3	33.6	50.6	40.8	68.9	48.0	92.3
5.0	5.5	12.2	13.9	19.4	24.1	26.6	36.6	33.8	51.1	41.0	69.5	48.2	93.1
5.2	5.7	12.4	14.2	19.6	24.4	26.8	37.0	34.0	51.6	41.2	70.1	48.4	93.8
5.4	5.9	12.6	14.4	19.8	24.8	27.0	37.4	34.2	52.0	41.4	70.7	48.6	94.6
5.6	6.2	12.8	14.7	20.0	25.1	27.2	37.8	34.4	52.5	41.6	71.3	48.8	95.3
5.8	6.4	13.0	15.0	20.2	25.4	27.4	38.2	34.6	52.9	41.8	71.9	49.0	96.1
6.0	6.6	13.2	15.3	20.4	25.7	27.6	38.5	34.8	53.4	42.0	72.5	49.2	96.9
6.2	6.8	13.4	15.5	20.6	26.0	27.8	38.9	35.0	53.9	42.2	73.0	49.4	97.6
6.4	7.0	13.6	15.8	20.8	26.3	28.0	39.3	35.2	54.4	42.4	73.6	49.6	98.4
6.6	7.3	13.8	16.1	21.0	26.6	28.2	39.7	35.4	54.8	42.6	74.2	49.8	99.2
6.8	7.5	14.0	16.4	21.2	26.9	28.4	40.1	35.6	55.3	42.8	74.8	50.0	----
7.0	7.7	14.2	16.6	21.4	27.3	28.6	40.5	35.8	55.8	43.0	75.5		
7.2	7.9	14.4	16.9	21.6	27.6	28.8	40.9	36.0	56.3	43.2	76.1		
7.4	8.1	14.6	17.1	21.8	28.0	29.0	41.3	36.2	56.8	43.4	76.7		
7.6	8.4	14.8	17.4	22.0	28.3	29.2	41.5	36.4	57.2	43.6	77.3		
7.8	8.6	15.0	17.7	22.2	28.6	29.4	41.7	36.6	57.5	43.8	78.0		
8.0	8.8	15.2	18.0	22.4	28.9	29.6	42.1	36.8	58.3	44.0	78.6		



Curve	Max. Dry Weight	Optimum Moisture
	lb/ft^3	%
A	141.8	6.1
B	139.1	6.7
C	136.3	7.4
D	134.1	8.0
E	132.0	8.5
F	129.3	9.2
G	126.6	10.0
H	124.2	10.7
I	121.7	11.4
J	119.3	12.2
K	117.0	13.0
L	114.6	14.1
M	112.0	15.2
N	109.6	16.4
O	107.1	17.6
P	104.7	19.2
Q	102.4	20.3
R	99.9	21.5
S	97.4	22.7
T	94.6	24.4
U	92.1	25.8
V	89.9	27.4
W	87.5	29.5
X	85.0	30.5
Y	83.0	31.5
Z	81.1	32.5

CHAPTER 5 – PRACTICE PROBLEMS

Practice Problem Number 4
Establishing Target Densities (One-Point Proctor)

A. Complete the one-point proctor form (Form TL-125A) on soil using the information provided.

Date: Today's Date
Compacted Depth of Lift: 6"

Weight of Mold + Weight of Soil = 13.56 lbs.
Weight of Mold = 9.51 lbs.
Speedy Dial Reading = 16.2

B. Answer the following questions.

a) What is the maximum dry density?

b) What is the optimum moisture and optimum moisture range?

Form TL-125A (Rev. 07/15)

VIRGINIA DEPARTMENT OF TRANPORTATION
MATERIALS DIVISION
WORKSHEET FOR ONE-POINT PROCTOR

Route No. 632 **County** Amherst

Project No. 0632-005-184, C501 **Inspector**

FHWA No. FH-130(101)

Field Test No.		7		
Date of Test				
Location of Test	Station Number – ft. (m)	120+40		
	Reference to Center Line – ft. (m)	13’ Rt. C/L		
Reference Elevation	Original Ground – ft. (m)	+16 ft.		
	Finished Grade – ft. (m)	-7 ft.		
Type of Roller		Sheepsfoot		
A. Weight (mass) of mold and wet soil – lb. (kg)				
B. Weight (mass) of mold – lb. (kg)				
C. Weight (mass) of wet soil (A - B) – lb. (kg)				
D. Wet density of soil (Line C x 30 lb/ft^3) or (Line C x 1060 kg/m^3)				
E. “Speedy” Dial Reading				
F. Moisture Content (%) from Speedy Chart				
G. Maximum Dry Density – lb/ft^3 (kg/m^3)				
H. Optimum Moisture (%)				
I. Field Density – lb/ft^3 (kg/m^3) from TL-125				
J. No. 4 (+4.75 mm) material from field density hole				
K. Corrected Maximum Density – lb/ft^3 (kg/m^3)				
L. Compaction (%)				

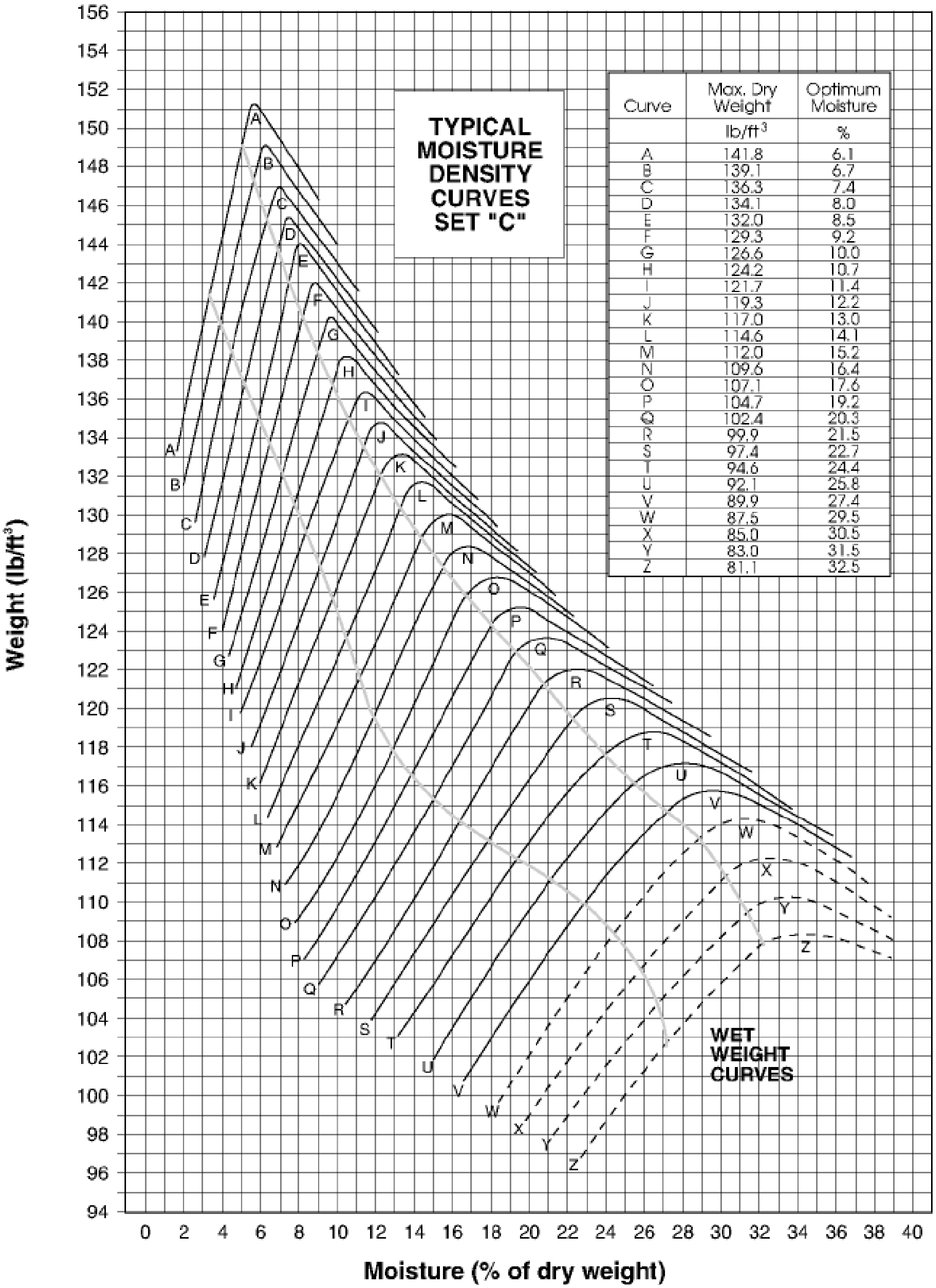
Comments:

BY:

TITLE:

SPEEDY MOISTURE CHART

SPEEDY MOIST.		SPEEDY MOIST.		SPEEDY MOIST.		SPEEDY MOIST.		SPEEDY MOIST.		SPEEDY MOIST.		SPEEDY MOIST.	
READ.	CONT.	READ.	CONT.	READ.	CONT.	READ.	CONT.	READ.	CONT.	READ.	CONT.	READ.	CONT.
1.0	1.0	8.2	9.0	15.4	18.3	22.6	29.2	29.8	42.5	37.0	58.8	44.2	79.2
1.2	1.3	8.4	9.2	15.6	18.5	22.8	29.6	30.0	42.9	37.2	59.3	44.4	79.9
1.4	1.5	8.6	9.5	15.8	18.8	23.0	30.2	30.2	43.3	37.4	59.8	44.6	80.5
1.6	1.8	8.8	9.7	16.0	19.1	23.2	30.6	30.4	43.8	37.6	60.3	44.8	81.2
1.8	2.0	9.0	9.9	16.2	19.4	23.4	30.9	30.6	44.2	37.8	60.8	45.0	81.8
2.0	2.2	9.2	10.1	16.4	19.6	23.6	31.3	30.8	44.6	38.0	61.3	45.2	82.5
2.2	2.4	9.4	10.4	16.6	19.9	23.8	31.6	31.0	45.0	38.2	61.8	45.4	83.2
2.4	2.6	9.6	10.6	16.8	20.2	24.0	31.9	31.2	45.4	38.4	62.4	45.6	83.1
2.6	2.9	9.8	10.8	17.0	20.5	24.2	32.3	31.4	45.8	38.6	62.9	45.8	84.5
2.8	3.1	10.0	11.1	17.2	20.8	24.4	32.7	31.6	46.2	38.8	63.5	46.0	85.2
3.0	3.3	10.2	11.4	17.4	21.1	24.6	33.0	31.8	46.7	39.0	64.0	46.2	85.9
3.2	3.5	10.4	11.6	17.6	21.4	24.8	33.4	32.0	47.1	39.2	64.5	46.4	86.6
3.4	3.7	10.6	11.9	17.8	21.7	25.0	33.7	32.2	47.5	39.4	65.0	46.6	87.3
3.6	4.0	10.8	12.1	18.0	22.0	25.2	34.1	32.4	48.0	39.6	65.6	46.8	88.0
3.8	4.2	11.0	12.4	18.2	22.3	25.4	34.5	32.6	48.4	39.8	66.1	47.0	88.7
4.0	4.4	11.2	12.7	18.4	22.6	25.6	34.9	32.8	48.8	40.0	66.7	47.2	89.4
4.2	4.6	11.4	12.9	18.6	23.0	25.8	35.4	33.0	49.3	40.2	67.2	47.4	90.2
4.4	4.8	11.6	13.2	18.8	23.2	26.0	35.7	33.2	49.7	40.4	67.8	47.6	90.8
4.6	5.1	11.8	13.4	19.0	23.5	26.2	35.9	33.4	50.2	40.6	68.4	47.8	91.6
4.8	5.3	12.0	13.7	19.2	23.8	26.4	36.3	33.6	50.6	40.8	68.9	48.0	92.3
5.0	5.5	12.2	13.9	19.4	24.1	26.6	36.6	33.8	51.1	41.0	69.5	48.2	93.1
5.2	5.7	12.4	14.2	19.6	24.4	26.8	37.0	34.0	51.6	41.2	70.1	48.4	93.8
5.4	5.9	12.6	14.4	19.8	24.8	27.0	37.4	34.2	52.0	41.4	70.7	48.6	94.6
5.6	6.2	12.8	14.7	20.0	25.1	27.2	37.8	34.4	52.5	41.6	71.3	48.8	95.3
5.8	6.4	13.0	15.0	20.2	25.4	27.4	38.2	34.6	52.9	41.8	71.9	49.0	96.1
6.0	6.6	13.2	15.3	20.4	25.7	27.6	38.5	34.8	53.4	42.0	72.5	49.2	96.9
6.2	6.8	13.4	15.5	20.6	26.0	27.8	38.9	35.0	53.9	42.2	73.0	49.4	97.6
6.4	7.0	13.6	15.8	20.8	26.3	28.0	39.3	35.2	54.4	42.4	73.6	49.6	98.4
6.6	7.3	13.8	16.1	21.0	26.6	28.2	39.7	35.4	54.8	42.6	74.2	49.8	99.2
6.8	7.5	14.0	16.4	21.2	26.9	28.4	40.1	35.6	55.3	42.8	74.8	50.0	----
7.0	7.7	14.2	16.6	21.4	27.3	28.6	40.5	35.8	55.8	43.0	75.5		
7.2	7.9	14.4	16.9	21.6	27.6	28.8	40.9	36.0	56.3	43.2	76.1		
7.4	8.1	14.6	17.1	21.8	28.0	29.0	41.3	36.2	56.8	43.4	76.7		
7.6	8.4	14.8	17.4	22.0	28.3	29.2	41.5	36.4	57.2	43.6	77.3		
7.8	8.6	15.0	17.7	22.2	28.6	29.4	41.7	36.6	57.5	43.8	78.0		
8.0	8.8	15.2	18.0	22.4	28.9	29.6	42.1	36.8	58.3	44.0	78.6		



Curve	Max. Dry Weight	Optimum Moisture
	lb/ft³	%
A	141.8	6.1
B	139.1	6.7
C	136.3	7.4
D	134.1	8.0
E	132.0	8.5
F	129.3	9.2
G	126.6	10.0
H	124.2	10.7
I	121.7	11.4
J	119.3	12.2
K	117.0	13.0
L	114.6	14.1
M	112.0	15.2
N	109.6	16.4
O	107.1	17.6
P	104.7	19.2
Q	102.4	20.3
R	99.9	21.5
S	97.4	22.7
T	94.6	24.4
U	92.1	25.8
V	89.9	27.4
W	87.5	29.5
X	85.0	30.5
Y	83.0	31.5
Z	81.1	32.5

6

FIELD MOISTURE AND DENSITY TESTING WITH THE NUCLEAR GAUGE

LEARNING OUTCOMES

- Understand the components of the nuclear gauge and how it is used to measure moisture and density
- Understand the procedures for evaluating moisture and density using the direct transmission method
- Understand the basic regulations that govern the storage, transport, and use of the nuclear gauge
- Understand basic maintenance techniques and procedures for emergency response

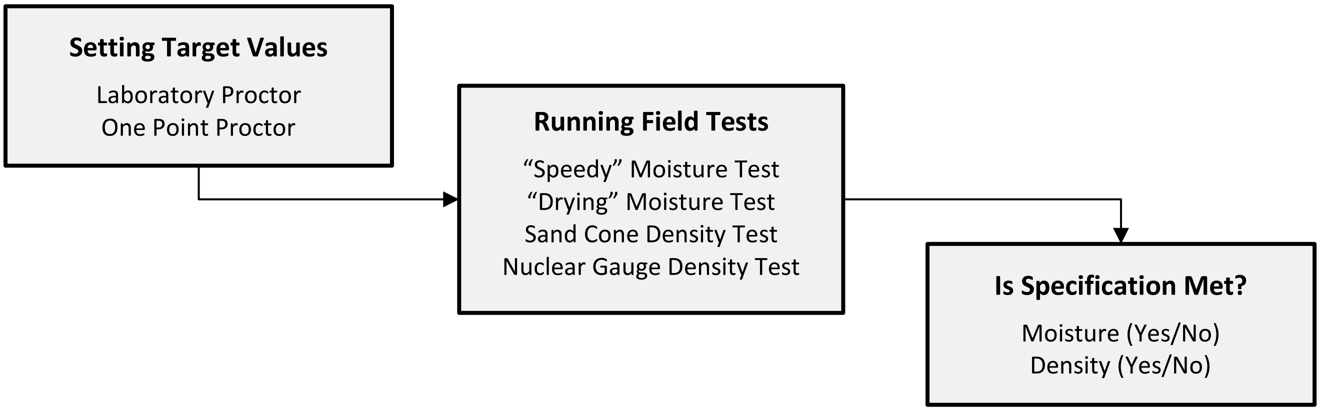
INTRODUCTION

After placement and compaction of the embankment material by the contractor, the inspector then conducts a field density test and a field moisture content test on the lift. The results of these field tests are compared to the target values (see Chapter 5) to determine if the contractor has met specifications for density and moisture content of that lift.

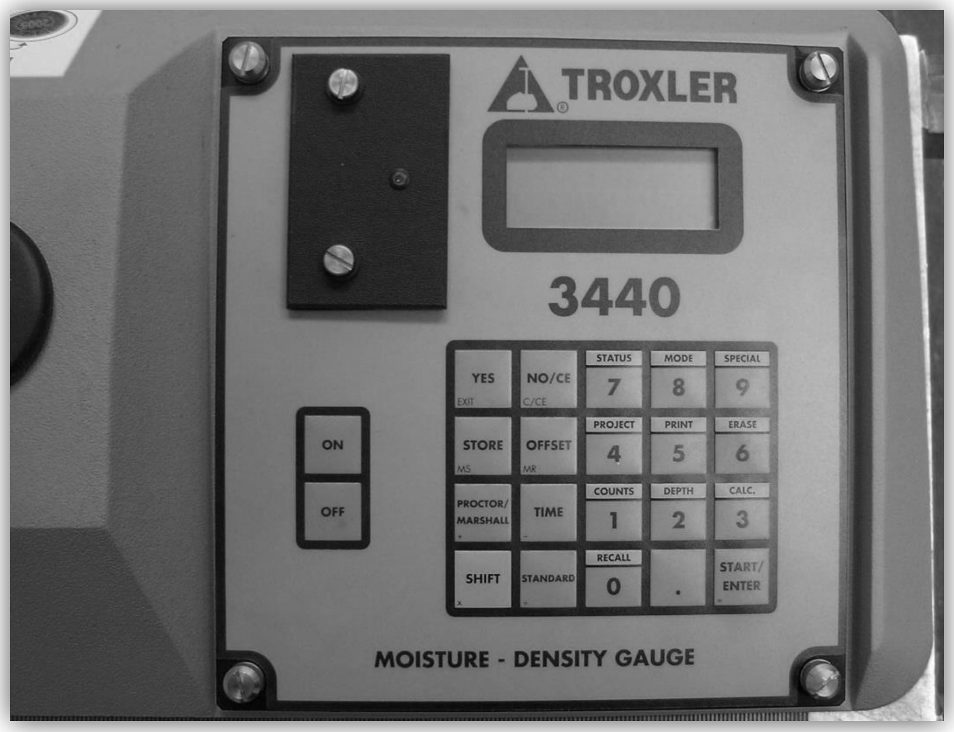
Section 303.04(h) and 305.03(a) of 2007 Road and Bridge Specifications stipulates that field density determinations are to be performed in accordance with the following AASHTO tests:

- T191- Density of Soil in Place by the Sand Cone Method
- T310- Density of Soil in Place by the Nuclear Gauge

SOIL DENSITY TESTING FLOW CHART



TROXLER 3440 NUCLEAR GAUGE (FOR SOILS AND AGGREGATE MATERIAL)



DETERMINING FIELD DENSITY & MOISTURE CONTENT WITH THE NUCLEAR GAUGE

The Nuclear Moisture Density device (or Nuclear Gauge) is specifically designed to measure the moisture and density of soils, aggregates, cement, and lime treated materials, and to measure the density of asphalt concrete. It offers the Inspector and Contractor a method of obtaining fast, accurate and in-place measurement of densities and moisture. With suitable calibrations, the device gives results which are comparable to those given by the Sand Cone or Volume Meter Test.

The device uses a small radioactive source which sends radiation through the material being tested, giving data which can be correlated to density and/or moisture. While no radiation hazard is imposed on the operator when following the normal procedures of use, a potential hazard does exist if improperly used. Three ways to limit exposure to radiation are time, distance, and shielding.

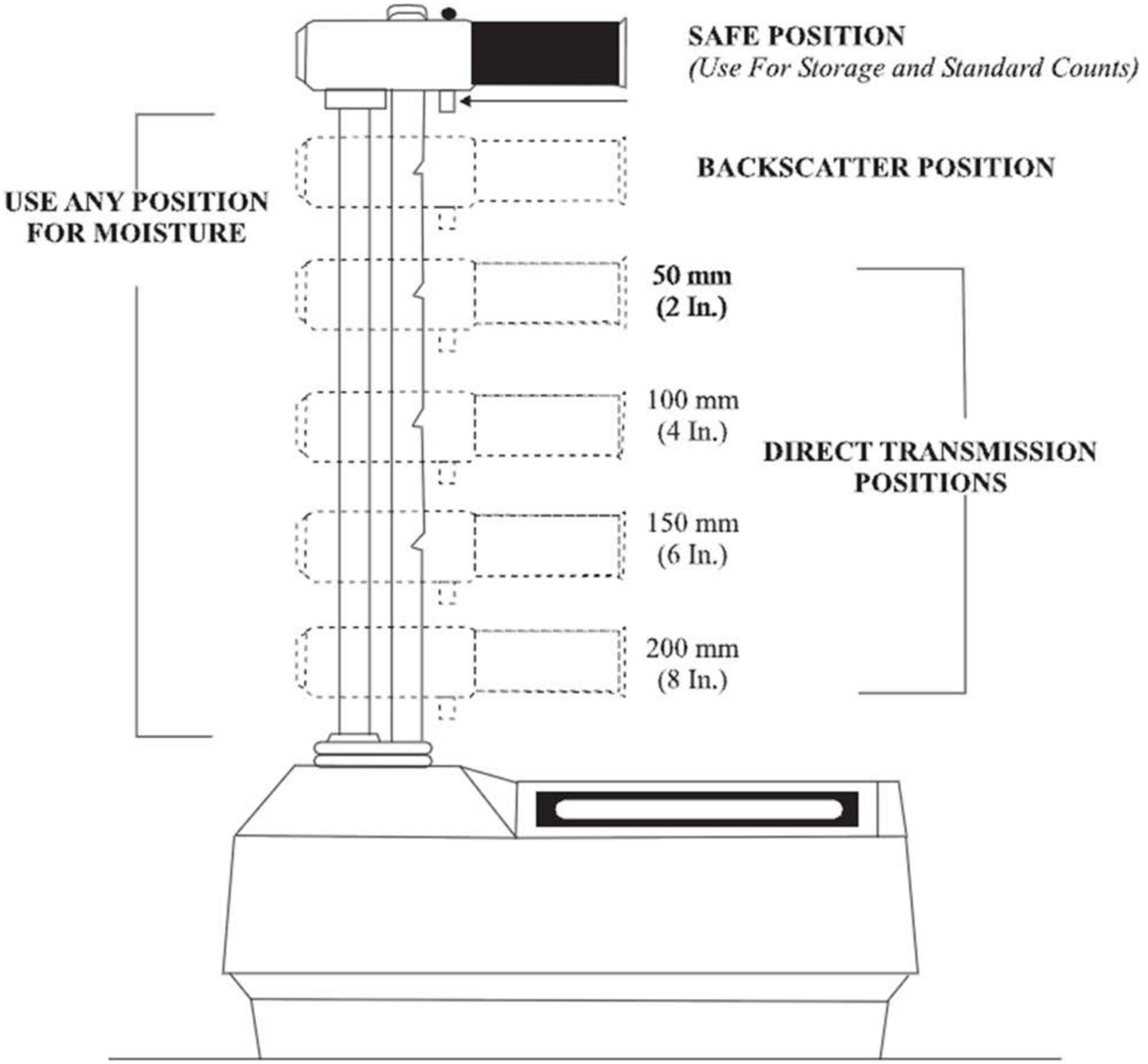
Before operating a nuclear gauge a person must pass a Nuclear Safety course and be issued a thermoluminescent dosimeter (TLD) badge. The badge measures exposure to radiation and is to be worn whenever operating a nuclear gauge. The TLD is to be stored at least 10 feet from the gauge. Two gauges should not be operated within 33 feet of one another. In case of an accident, maintain a 20 foot radius around the accident site.

COMPONENTS OF THE NUCLEAR GAUGE

A small radioactive source is located in the tip of the stainless steel rod which is primarily used for density testing, whereas another source is located inside the device which is used specifically for taking moisture determinations simultaneously. The probe rod is capable of being moved to the various desired depths, as shown on the following pages. The positions are stamped on the guide rod for easy determination of the proper depths.

The 3440 Nuclear Gauge provides three different count times to be used for taking readings. The 15 second setting is recommended to be used only in the roller pattern test method (Backscatter Method). The one minute setting is used for all embankment and subgrade materials. The four minute setting is generally used for calibration.

TROXLER 3440 NUCLEAR GAUGE (HANDLE POSITIONS)



TROXLER 3440 NUCLEAR GAUGE (BASE AND DISPLAY SCREEN)

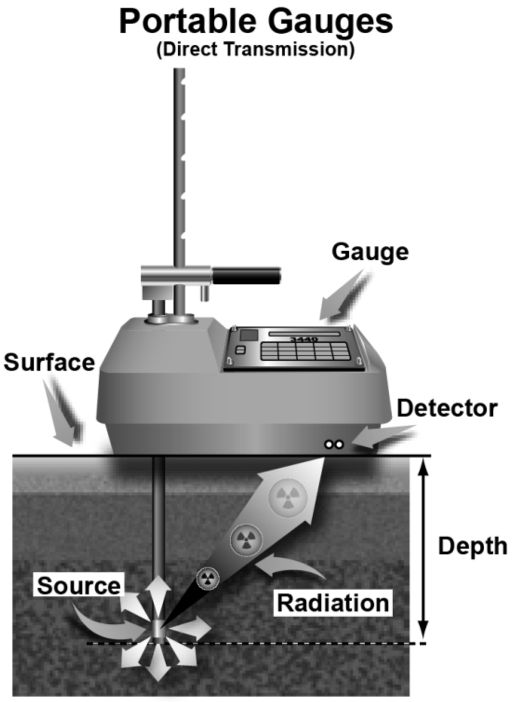
NUCLEAR GAUGE - THEORY OF OPERATIONS

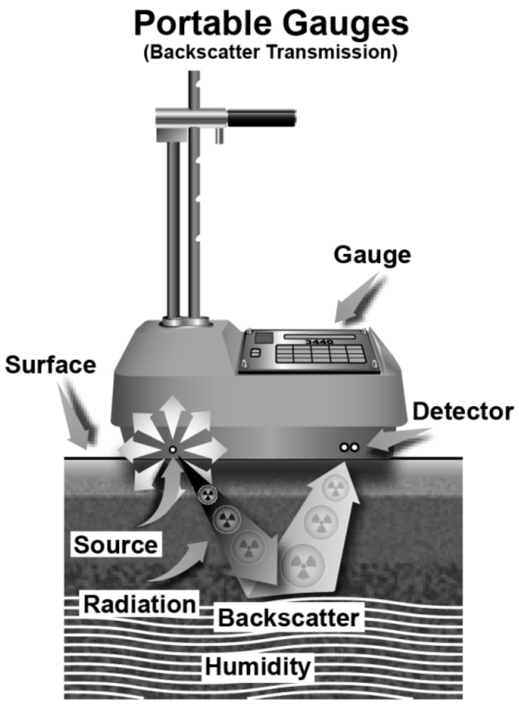
The Nuclear Gauge is specifically designed to measure the moisture content and density of soils, aggregates, cement and lime treated materials, and to measure the density of Bituminous Concrete. It offers the inspector a method of obtaining fast, accurate, in-place measurement of density and moisture. With suitable laboratory calibrations, and proper field operation of the gauge, the device gives results which are comparable to those given by the sand cone or volume meter tests.

The tip of the source rod contains a small radioactive source (Cesium–137) which emits gamma rays. Detectors in the base of the gauge measure this radiation and calculate the density of the material. The gauge has two modes to measure density: the direct transmission mode and backscatter mode.

In the Direct Transmission mode, the source rod is inserted into the material to be tested to the desired depth of test. The 6 inch depth is the most recommended depth for testing densities and moisture content simultaneously in soils used in backfills, embankments and subgrade. The 4 inch depth is used for backfilling around pipe and abutments where hand tamping and pneumatic tamping is used. The 8 inch depth is only used when specified on the contract.

In the backscatter mode, the gauge is placed on the material to be tested and the source rod is locked in the first position below the SAFE position. Since the rod is flush with the bottom of the gauge and no hole is required for the rod, the backscatter mode is used only in conjunction with the roller pattern/control strip method for testing densities on asphalt concrete and all aggregate material such as base, subbase, and select materials.





The gauge has an internal radioactive source (Americium–241: Beryllium) that emits neutrons which measure the hydrogen to determine moisture content. Any position below the SAFE position can be used to determine moisture content.

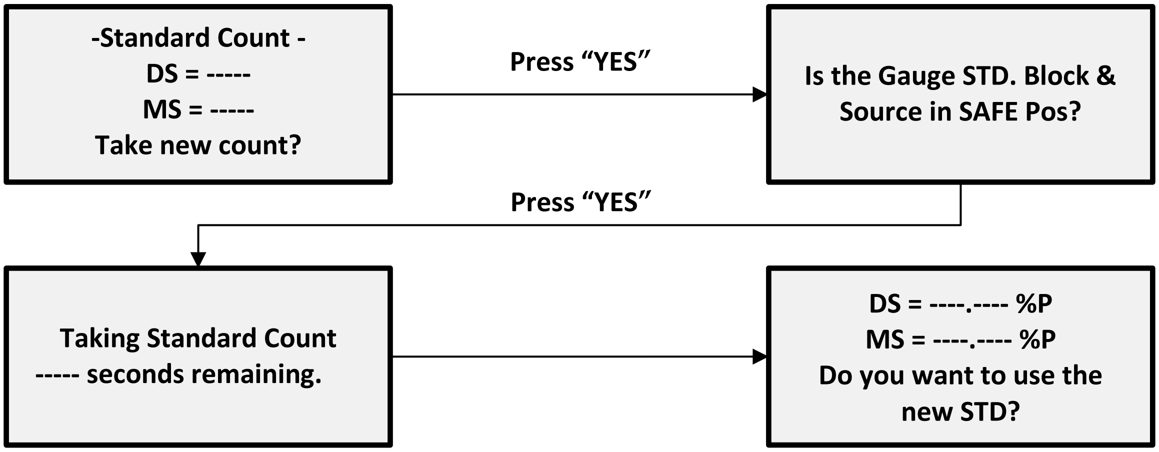
Problems may arise when testing materials containing mica, boron, cadmium and chlorine or when testing heavy clays and organic material. It is permissible to use the Speedy Moisture Tester to verify nuclear results.

Like the conventional test, the operator must compare the results from the nuclear gauge to the one point proctor or laboratory proctor. The nuclear density is compared to the maximum dry density to calculate the percent density and the moisture content from the nuclear gauge is compared to the optimum moisture limits.

PRETEST WARM-UP PROCEDURES FOR THE 3440 NUCLEAR GAUGE

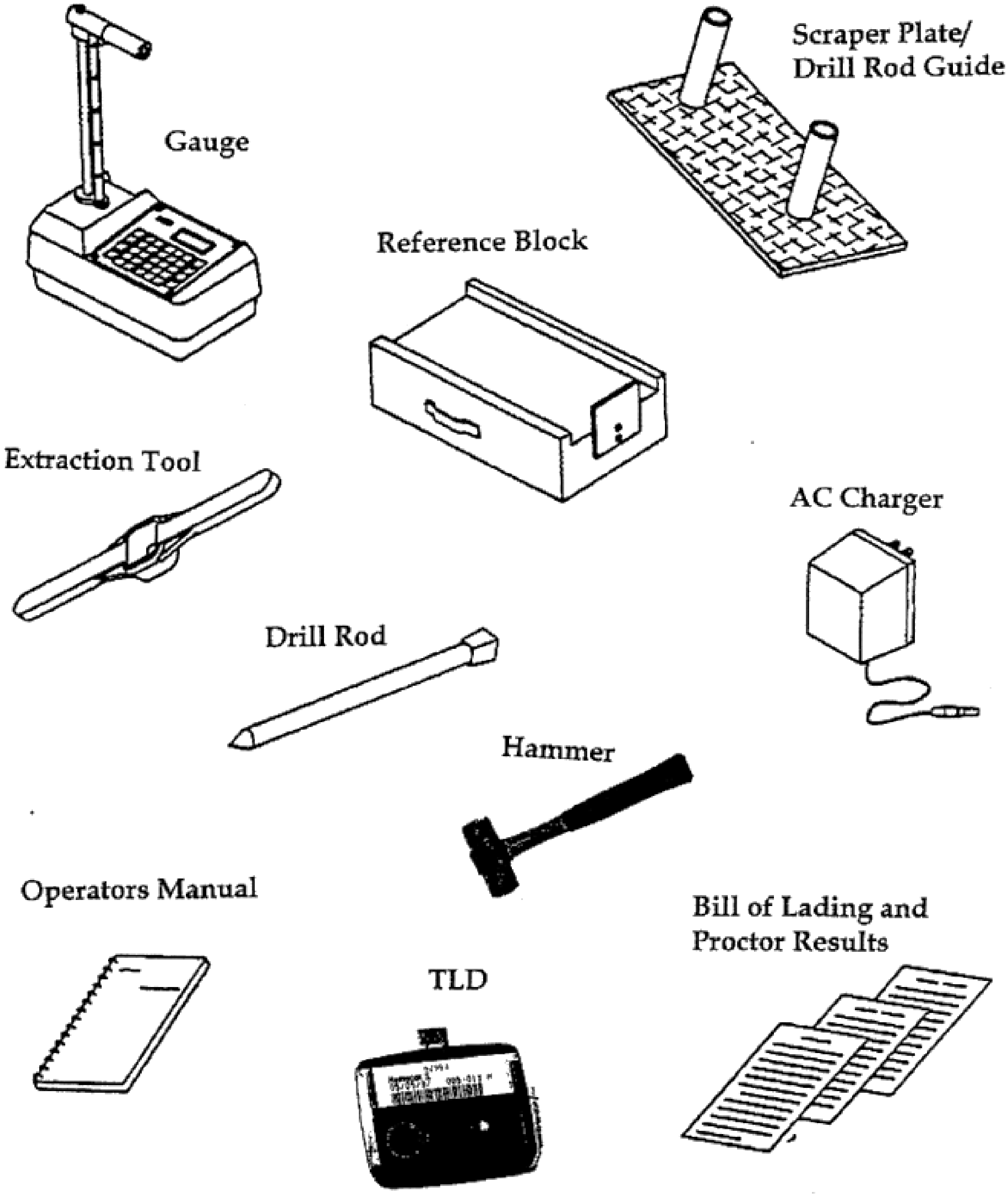
The standard count should be taken daily before any testing is done to check gauge operation and allow the gauge to compensate for natural source decay. The 3440 gauge should be turned on and allowed to go through the self-test (RAM TEST) before beginning. (NOTE: It is very important that the RAM TEST display has ended before proceeding. During the test, the screen will display a count down from 300 seconds and then display READY on the screen.)

Place the reference block on a flat surface with a minimum density of 100 lbs/ft^3 at least 10 feet from any structure and 33 feet from any other radioactive source, in the same manner as when using any other model gauge. Place the gauge on the reference block, making sure that it is seated flat and within the raised edges, with the right side of the gauge pushed firmly against the metal plate on the block. Press STANDARD on the finger keypad for the display:



Press "YES" to enter the new counts into memory. NOTE: If the screen displays an "F" instead of a "%P", first look to see if you are too close to any structure or another gauge. Then press "NO" and take a new set of counts. If the second set fails, press "YES and take three (3) new standard counts. Refer to the gauge manual for more detailed instructions.

Nuclear Gauge Equipment Needed For Soil Testing



NUCLEAR TESTING PROCEDURES FOR EMBANKMENTS

A construction project presents various situations in which compaction data is required. Depending upon the material to be tested, there are different testing methods that can be used to obtain the data. One method is used for testing embankment and subgrades; while another method is used for aggregate base, subbase, and select material and asphalt concrete.

When performing a test, some preliminary test information must be obtained by conducting a One-Point Proctor. This test establishes the maximum obtainable Dry Density and Optimum Moisture Content for particular embankment material. This test should be run while the contractor is compacting the soil layer to be tested.

If an appreciable amount of +4 Material (rock fragment, gravel, shale, etc.) is noticed in the soil layer, refer to VTM-1 and VTM 12, for proper testing instructions. Contact the Quarry or the District Materials Division for the specific gravity of the +4 material when encountered.

Embankment/Subgrade Testing Procedures (Direct Transmission Method)

1) The test site must be properly selected and prepared. Choose a test site on the compacted layer of soil (or soil mixture) represented by the One-Point Proctor Test. Standard Counts should have been taken in the morning and are good for that entire day’s use.

2) Turn the gauge on to allow the device to warm up before testing is to begin. This should be done while the test site is being prepared for testing.

3) To obtain accurate results, the nuclear device must be seated flush against the compacted layer of soil. Level an area to place the device, either with a shovel or the scraper plate. If significant voids remain in the area where the device is to be placed, the voids should be filled with small amounts of soil common to the site, and lightly tamped in place with the scraper plate and excess material removed.

4) To take a Direct Transmission Density Test and a Moisture Test follow the procedure listed below.

    a) Place the drill rod guide on the test site and insert the drill rod into the guide sleeve. Place one foot on the drill rod guide to keep it in position. Drive the rod 2 inches deeper than the depth of test.

b) Carefully remove the rod and drill rod guide. Place the gauge over the hole and extend the source rod into the hole to the required test depth. This should be done in a manner which prevents the source rod from disturbing the sides of the hole.

c) Make sure that the gauge is resting flush on the surface and that the source rod is in the locked position. Gently pull on the gauge housing so that the extended source rod will be tight against the hole.

d) Confirm that the gauge is on and then press "TIME" on the keypad and select one minute. The display panel will read "COUNT TIME 1 min." and then return to "READY". Pressing "SHIFT8" on the keypad will allow you to select the Soils Mode and the display will read "READY".

e) To begin the test, press "START/ENTER". After the gauge completes its count, the display will show "%PR" (Percent Compaction), "DD" (Dry Density), "WD" (Wet Density), "M" (Moisture) and "%M" (Moisture Content). Record these figures on the Form TL-124 (Report on Nuclear Embankment Densities).

f) Now that the direct transmission and moisture tests are completed, gently retract handle to the safe position, turn the power switch off, return the device to the field carrying case, and finish completing the Form TL-124 (Report on Nuclear Embankment Densities).

Taking tests in the Backscatter Position (Asphalt and Aggregate Only):

5) If for any reason a backscatter-density and moisture test is required by the Materials Engineer or representative of the Materials Division, follow the procedure listed below:

    a) Place the device on the prepared test site and lower the handle to the Backscatter Position.

    b) With the “TIME” set on 1 minute, press the “START/ENTER” button.

    c) When the display appears record the results on the Form TL-124.

Only use this method of test when instructed by District Materials Technicians.

NOTE: When making density tests in close places, such as trenches and sidewalls, background effects will be encountered that will give incorrect density-moisture readings. If this occurs, see instructions for background calculations on Page 6-18 of this chapter.

Filling out the Form TL-124:

1) Fill in Line E (Maximum Dry Density) which is transferred from Line G of the One-Point Proctor (Form TL-125).

2) Fill in Line F (Optimum Moisture) which is transferred from Line H of the One-Point Proctor (Form TL-125).

3) Fill in Lines A through D and Line J using the information on the 3440 Nuclear Gauge Display Screen.

4) Fill in Line K (Percent Minimum Density Required). Density Requirements are located in Appendix C.

5) Calculate the Percent Density (Line J) by dividing the Dry Density (Line C) by the Maximum Dry Density (Line E) and then multiplying by 100.

Lines G, H & I are only used when +4 Material has been encountered. When 10% or more +4 Material is encountered, the Dry Density (Line C) is divided by the Corrected Maximum Dry Density (Line H) and then multiplied by 100 to obtain the percent compaction. (See Line J.)

Also when 10% or more +4 Material is encountered, it is necessary to do a moisture correction which will be entered on Line I. This will be discussed in Chapter 7.

Form TL-124 (Rev. 07/15)

VIRGINIA DEPARTMENT OF TRANPORTATION
MATERIALS DIVISION
REPORT ON NUCLEAR EMBANKMENT DENSITIES (UNIT MASSES)

Report No. 1-21A-1 **Date** 06/22/2015 **Sheet No.** 1 **of** 1
Route No. 17 **County** Campbell
Project No. 0017-015-104, C503
FHWA No. None
Testing for Embankment
Model No. 3440 **Serial No.** 23456 **Calibration Date** 02/10/2015

STANDARD COUNT DATA

Density 2830 **Moisture** 701

Test No.			**1**	**2**	**3**	**4**
Location	Station ft. (m)		585+00			
of	Ref. to center line ft. (m)		at. C/L			
Test	Elevation		+8 / -4			
Compaction Depth of Lift in. (mm)			6”			
Method of Compaction			Sheepsfoot			
A. Wet Density (lbs/ft^3), Wet Unit Mass (kg/m^3)		=				
B. Moisture Unit Mass (lbs/ft^3 or kg/m^3)		=				
C. Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) (A-B)		=				
D. Moisture Content (B ÷ C) x 100		=				
E. Maximum Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) Lab Proctor or One Point Proctor		=	124.2			
F. Percent Optimum Moisture from Lab or One Point Proctor		=	10.7 8.6 – 12.8			
G. Percent of Plus #4, (plus 4.75 mm)		=				
H. Corrected Max. Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3)		=				
I. Corrected Optimum Moisture		=				
J. Percent Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) (C ÷ E) x 100 or (C ÷ H) x 100		=				
K. Percent Minimum Density Required		=				

One-Point Proctor Results

Max. Dry Density (TL-125 Line G)

Optimum Moisture (TL-125 Line H)

Comments:

BY:

TITLE:

Form TL-124 (Rev. 07/15)

VIRGINIA DEPARTMENT OF TRANPORTATION
MATERIALS DIVISION
REPORT ON NUCLEAR EMBANKMENT DENSITIES (UNIT MASSES)

Report No. 1-21A-1 **Date** 06/22/2015 **Sheet No.** 1 **of** 1
Route No. 17 **County** Campbell
Project No. 0017-015-104, C503
FHWA No. None
Testing for Embankment
Model No. 3440 **Serial No.** 23456 **Calibration Date** 02/10/2015

STANDARD COUNT DATA

Density 2830 **Moisture** 701

Test No.			**1**	**2**	**3**	**4**
Location	Station ft. (m)		585+00			
of	Ref. to center line ft. (m)		at. C/L			
Test	Elevation		+8 / -4			
Compaction Depth of Lift in. (mm)			6”			
Method of Compaction			Sheepsfoot			
A. Wet Density (lbs/ft³), Wet Unit Mass (kg/m³)		=	133.3			
B. Moisture Unit Mass (lbs/ft³ or kg/m³)		=	12.8			
C. Dry Density (lbs/ft³), Dry Unit Mass (kg/m³) (A-B)		=	120.5			
D. Moisture Content (B ÷ C) x 100		=	10.6			
E. Maximum Dry Density (lbs/ft³), Dry Unit Mass (kg/m³) Lab Proctor or One Point Proctor		=	124.2			
F. Percent Optimum Moisture from Lab or One Point Proctor		=	10.7 8.6 – 12.8			
G. Percent of Pl		=				
H. Corrected M … kg/m³)		=				
I. Corrected O		=				
J. Percent Dry (C ÷ E) x 100		=	97.0			
K. Percent Mini		=	95.0			

Nuclear Gauge Display Panel

% PR = 97.0%

DD = 120.5
WD = 133.3

M = 12.8 M% = 10.6

Percent Density

Provided by Gauge (%PR = 97.0%)

Or

Manually Calculate

(Line C) ÷ (Line E) x 100

(120.5 ÷ 124.2) x 100 = 97.0%

Density Requirement

See Appendix C

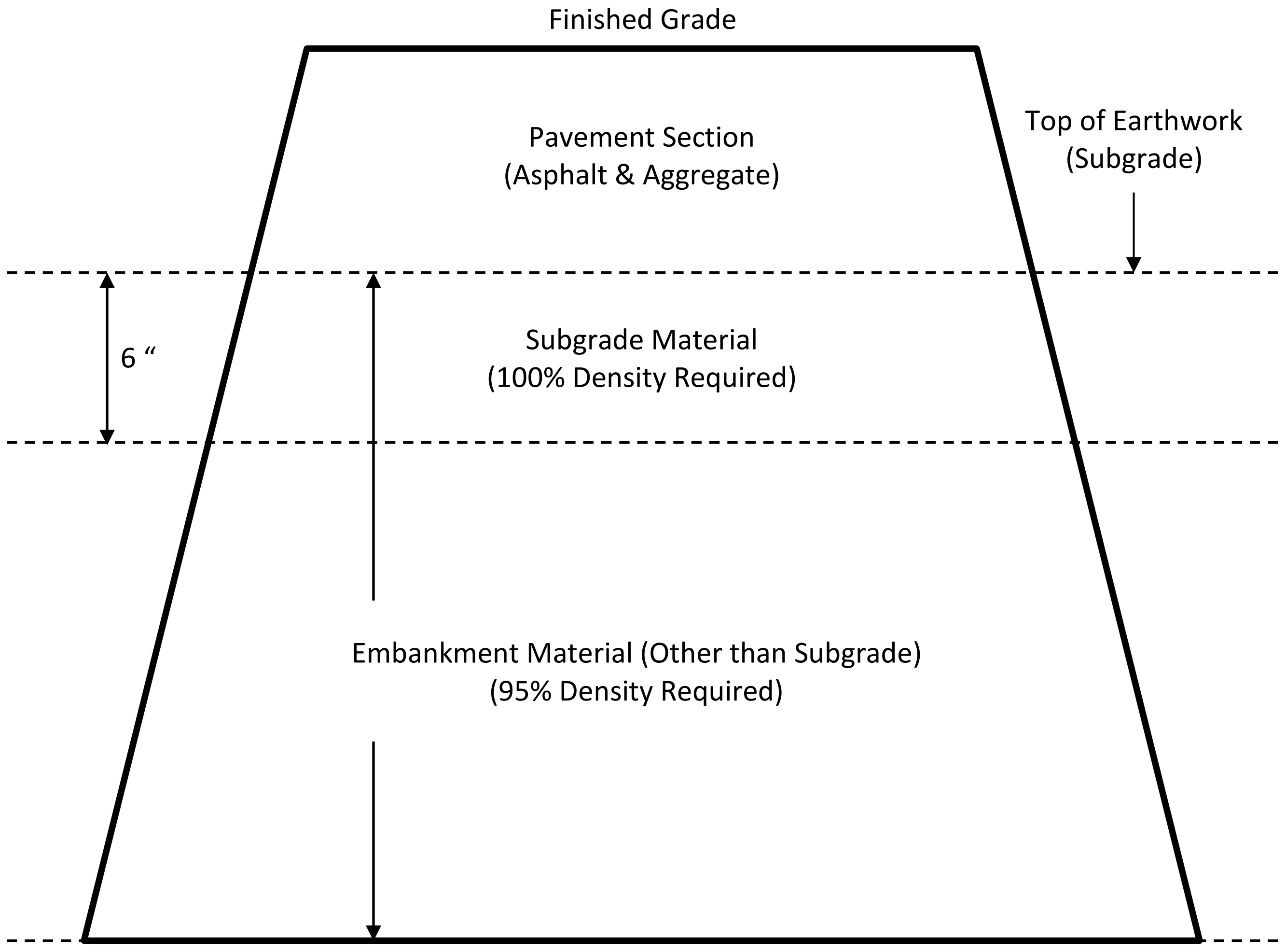
Comments:

BY: ____________________

TITLE: ____________________

Does the Material meet specification?

The actual density specification will vary with the vertical location of the material in the embankment and with the amount of +4 Material within the fill (see below).



CORRECTING FOR HIGH MOISTURE READINGS

As stated previously, the Nuclear Gauge is specifically designed to measure the moisture content and density of soils, aggregates, cement and lime treated materials. The gauge has an internal radioactive source (Americium–241: Beryllium) and it uses this source to determine moisture by releasing “fast” neutrons into the compacted material. These “fast” neutrons are then slowed down, or thermalized, when they interact with the nucleus of hydrogen, a key ingredient of the water molecule. However, some soils (i.e. micaceous soils) contain high-levels of naturally bound hydrogen, which increases the “thermalization” process. The gauge misinterprets this naturally bound hydrogen as “excessive” moisture content. Such errors in measurement can lead to a false Dry Density reading, which in turn may result in a false low or failing Percent Density value. When this situation arises, it is up to the technician to “correct” the moisture and density reading using the following process and standard calculations.

Example Problem:

A nuclear test conducted on a hydrogen-rich soil has produced false Moisture (M = 18.1, M% = 15.0) and Dry Density (DD = 120.9) readings. These false readings in turn have prompted a failing Percent Density value (%PR = 93.5%).

Maximum Dry Density = 129.3 lbs/ft^3
Optimum Moisture Content = 9.2%
Optimum Moisture Range (± 20%) = 7.4 – 11.0%
Minimum Density Required = 95.0%
Speedy Dial Reading = 8.9

Nuclear Gauge Display Panel

% PR = 93.5%

DD = 120.9
WD = 139.0

M = 18.1 M% = 15.0

Procedural Steps for Correcting the Moisture and Dry Density Readings (Form TL-124)

1) Conduct a Speedy Moisture Test to determine the correct Moisture Content (M%).

2) Adjust the Dry Density (Line C) by the dividing the original Wet Density (Line A) by the corrected Moisture Content (M%) plus 1. [DD = WD / (1 + M%)]

3) Adjust the Moisture Unit Mass (Line B) by subtracting the corrected Dry Density value from the original Wet Density value (Line A). [MM = WD – DD]

4) Adjust the Percent Density (Line J) by dividing the corrected Dry Density value by the Maximum Dry Density value (Line E) and then multiplying by 100. [%PR = (DD ÷ Max. DD) x 100]

Form TL-124 (Rev. 07/15)

CORRECTING FOR HIGH MOISTURE READINGS USING THE SPEEDY MOISTURE DEVICE

Report No. 1-21A-1 **Date** 06/22/2015 **Sheet No.** 1 **of** 1
Route No. 17 **County** Campbell
Project No. 0017-015-104, C503
FHWA No. None
Testing for Embankment
Model No. 3440 **Serial No.** 23456 **Calibration Date** 02/10/2015

STANDARD COUNT DATA

Density 2830 **Moisture** 701

Test No.			**1**	**2**	**3**	**4**
Location	Station ft. (m)		585+00			
of	Ref. to center line ft. (m)		at. C/L			
Test	Elevation		+8 / -4			
Compaction Depth of Lift in. (mm)			6”			
Method of Compaction			Sheepsfoot			
A. Wet Density (lbs/ft³), We		=	139.0			
B. Moisture Unit Mass (lbs/		=	18.1			
C. Dry Density (lbs/ft³), Dry Unit Mass (kg/m³) (A-B)		=	120.9			
D. Moisture Content (B ÷ C) x 100		=	15.0			
E. Maximum Dry Density (lbs/ft³), Dry Unit Mass (kg/m³) Lab Proctor or One Point Proctor		=	129.3			
F. Percent Optimum Moisture from Lab or One Point Proctor		=	9.2 7.4 – 11.0			
G. Percent of Plus #4, (plus 4.75 mm)		=				
H. Corrected Max. Dry De		=				
I. Corrected Optimum M		=				
J. Percent Dry Density (lb (C ÷ E) x 100 or (C ÷ H) x 100		=	93.5			
K. Percent Minimum Density Required		=	95.0			

Nuclear Gauge Display Panel

% PR = 93.5%

DD = 120.9
WD = 139.0

M = 18.1 **M% = 15.0**

Moisture Content is suspected to be incorrect due to soil properties or conditions

Failing Percent Density is suspected to be incorrect due to false high moisture readings

Comments:

BY: ____________________

TITLE: ____________________

Form TL-124 (Rev. 07/15)

CORRECTING FOR HIGH MOISTURE READINGS USING THE SPEEDY MOISTURE DEVICE

Report No. 1-21A-1 **Date** 06/22/2015 **Sheet No.** 1 **of** 1

Route No. 17 **County** Campbell

Project No. 0017-015-104, C503

FHWA No. None

Testing for Embankment

Model No. 3440 **Serial No.** 23456 **Calibration Date** 02/10/2015

STANDARD COUNT DATA

Density 2830 **Moisture** 701

			1	2	3	4
Location	ation ft. (m)		585+00			
of	r line ft. (m)		at. C/L			
Test	Elevation		+8 / -4			
Compaction Depth of Li			6"			
Method of Compaction			Sheepsfoot			
A. Wet Density (l		=	139.0			
B. Moisture Unit		=	~~18.1~~	12.4		
C. Dry Density (l		=	~~120.9~~	126.6		
D. Moisture Con		=	~~15.0~~	9.8		
E. Maximum Dry) Lab Proctor or One Point Proctor		=	129.3			
F. Percent Optimum		=	9.2 7.4 – 11.0			
G. Percent of Plus #4		=				
H. Corrected Max. Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3)		=				
I. Corrected Optimum Mois		=				
J. Percent Dry Density (lbs/ (C ÷ E) x 100 or (C ÷ H) x 1		=	~~93.5~~	97.9		
K. Percent Minimum Densit		=	95.0			

Step 1 – Conduct a Speedy Moisture Test to correct Moisture Content

Step 2 – Adjust Dry Density

DD = WD ÷ (1 + M%)

DD = 139.0 ÷ (1 + 0.098)

DD = 126.6 lbs/ft^3

Step 3 - Adjust Moisture Mass

MM = WD - DD

MM = 139.0 – 126.6

MM = 12.4 lbs/ft^3

Step 4 – Correct Percent Density

%PR = (DD ÷ Max. DD) x 100

%PR = (126.6 ÷ 129.3) x 100

%PR = 97.9%

Comments:

BY: ____________________

TITLE: ____________________

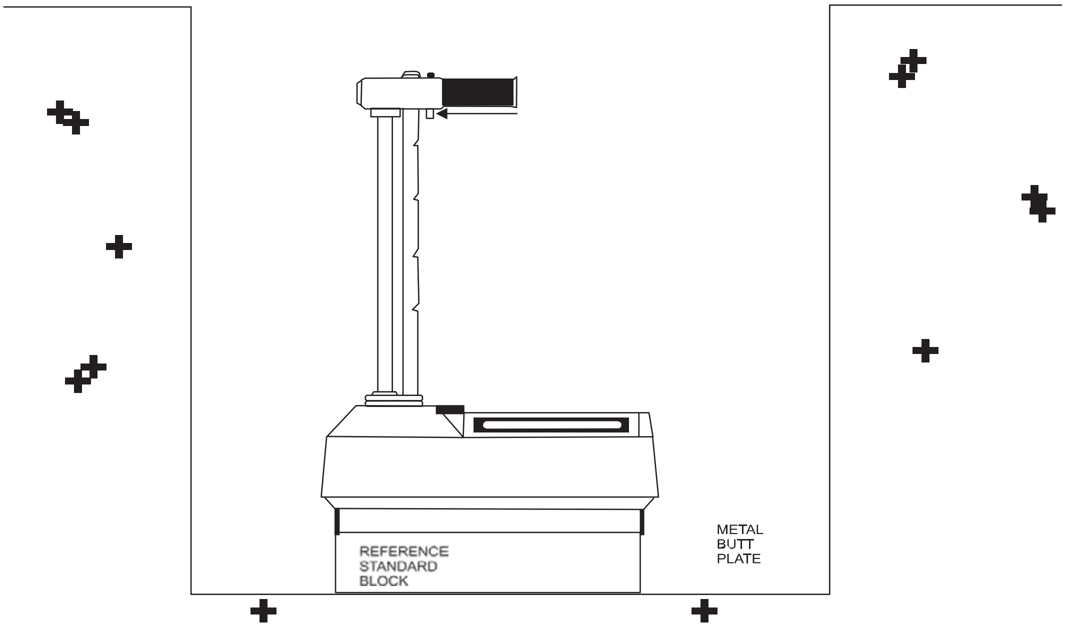
BACKGROUND CALCULATIONS FOR TRENCH AND SIDEWALL MOISTURE TESTING

When a 3440 Nuclear Gauge is operated within 24 inches of a vertical structure the density and moisture counts will be affected due to gamma photons and neutrons echoing off the walls of the structure. It is necessary to perform a trench offset when testing backfill material around pipe culverts, abutments, near a building, etc. This correction should be performed each day and when trench wall conditions (distance from wall, moisture content, material composition, etc.) vary.

The procedure to determine the background effect and apply the necessary correction is as follows:

1) Take the daily standard count with the gauge on the Standard Block outside the trench and record the density and moisture values.

2) Place the gauge on the Standard Block inside the trench in the testing area and press “OFFSET” on the display panel and select No. 3 “TRENCH OFF”. The gauge will show Trench Offset Disabled and ask if you want to use Trench Offset. Press “YES”. The gauge will show trench offset for moisture and density and ask if you want to change. Press “YES” to perform a new offset and “NO” to use the existing offset constants. If you selected yes, the gauge will prompt you to press “START” for 1 minute Standard Counts in the trench. Make sure to take counts the same distance from the wall as the anticipated test readings. The density and moisture trench offset constants will be calculated and stored. When the gauge is not to be used for trench measurements, disable the offset.

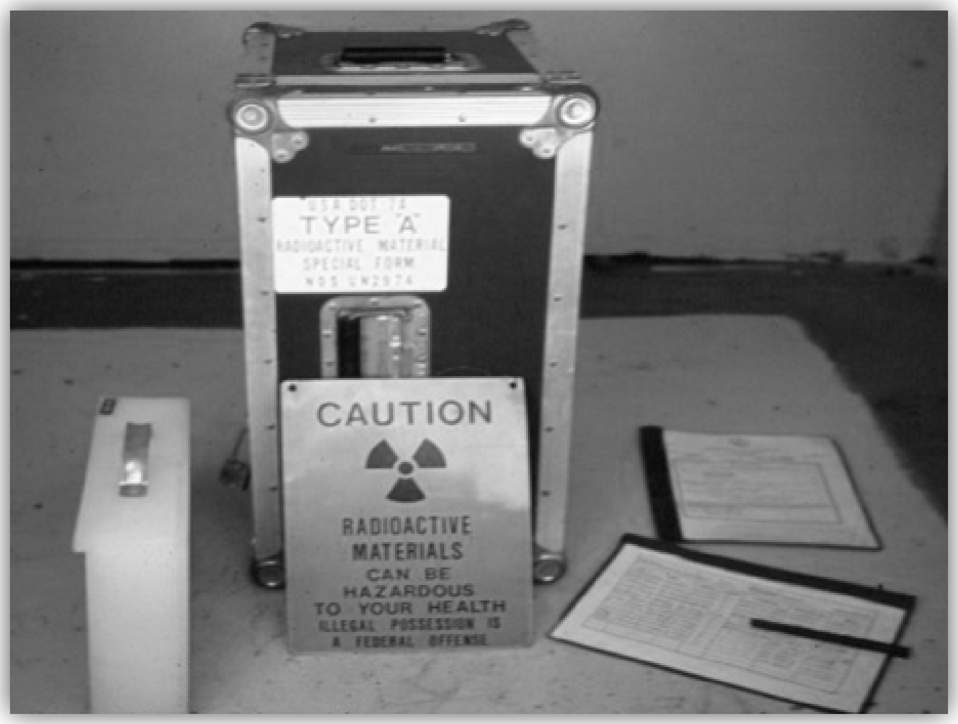


SELF REGULATIONS & THE VDOT LICENSE

VDOT has a Materials License issued by the Virginia Department of Health (VDH). The VDH is responsible for ensuring the safety of people who work with radioactive by-product materials and the security of such materials. To control the risks associated with the use of nuclear byproduct materials, the VDH sets strict health and safety standards for nuclear equipment, defines allowable limits for radiation exposure and frequently conducts inspections of nuclear products and facilities. The VDH enforces the Code of Federal Regulations (CFR) and all applicable state requirements governing the use of radioactive byproduct materials. The codes are Federal and state law and they are binding upon licensees to uphold.

In addition to the CFR, licensees are governed by the provisions outlined in the license authorizing the possession of byproduct material. The possession of a license obligates the Department to scrupulously perform the actions it stated it would perform to comply with the requirements of it license. This commitment is the condition under which the Department is able to receive and then retain the license. Failure to comply could mean a severe fine, loss of license, or both, together with the potential consequences of bad publicity. The provisions of the license are just as compelling as the CFR and govern nuclear safety.

Possession of a VDH license requires the licensee to adhere to safe practices and act as self-regulator in the enforcement of regulations. This Agency is compelled to report its own infraction of rules to the VDH. To enforce these safety regulations, periodic checks on the program to see that VDOT's employees are following the Department's instructions and radiation safety rules are an essential part of nuclear gauge safety and effective program management. VDOT has established a system of records covering the receipt and transfer of nuclear gauges. We must maintain records of radiation exposure of persons working in the program and surveys are conducted to evaluate the effectiveness of radiation safety programs.



NUCLEAR GAUGE STORAGE REQUIREMENTS

1) "Radioactive Material" signs shall be posted in the storage unit on the inside of the door in accordance with Virginia Department of Health Radiation Protection Regulations.

2) The Form "Notice to Employees," shall be posted on the project bulletin board where the nuclear gauge is assigned, in accordance with Virginia Department of Health Radiation Protection Regulations.

3) The radioactive source when not in use and when left unattended shall be stored and secured (locked, bolted, etc.) at all times against unauthorized removal from the storage place, in accordance with Virginia Department of Health Radiation Protection Regulations. The magenta and yellow "**FEDERAL OFFENSE**" sign shall be posted on the locked blue carrying case while the nuclear gauge is being stored. The intent of this sign is to discourage the theft of the gauge.

4) VDOT requires that an outside storage facility be used and that it be at least 10 feet from personnel's permanent workstation (desk). See Road and Bridge Specifications, Section 514.02 (c).

5) The nuclear gauge and TLD's (Film Badge) stored shall be at least 10 feet apart. Badges shall be stored in designated area inside project trailer.

6) The required records of transfer shall be completed when the nuclear gauge is in transit on the project site by using log sheet located in the storage facility on the project site, or moved from one assigned area to another or when transferred to another license.

NUCLEAR GAUGE CALIBRATIONS

The source decays at a rate of 2.2% per year and the electronics have a minor amount of drift from aging parts. Therefore, gauges are calibrated in the laboratory at least yearly under controlled conditions using the same methods of testing as in the field. The gauges are calibrated on a series of blocks of known density and moisture contents.

NUCLEAR GAUGE MAINTENANCE

The source rod in the 3400 Series is supported in linear bearings packed with Magnalube-G grease. The grease is retained within the bearings and the soil kept out by a system of wipers and seals at the top and bottom of the center post of the gauge. These bearings will require little or no service, unless the gauge is overhauled. Do not lubricate.

On the bottom surface of the gauge is a removable plate with a brass scraper ring mounted in it. This ring will remove most of the soil from the source rod. However, under some soil conditions, small amounts will be carried into the sliding shield assembly. If allowed to build up, this soil can cause wear in the shield cavity and can ultimately be forced into the bearings and ruin them.

Cleaning the cavity is relatively simple. Place the gauge on its side on a bench with the base away from the operator. The source rod should be latched in the SAFE position. Using a Phillips screwdriver, remove the four screws holding the bottom plate assembly in position and pry out the assembly using a flat blade screwdriver. Using the same tool, remove the sliding block and spring.

Using a rag, stiff brush and compressed air, if available, remove all soil and wipe clean the cavity, sliding block and bottom plate assembly. Inspect all items for excessive wear and replace if required. Check the scraper ring to insure that it is free to move in its groove. If the ring is damaged, it may be replaced or replace the assembly. The cleaning time will take no longer than five (5) minutes.

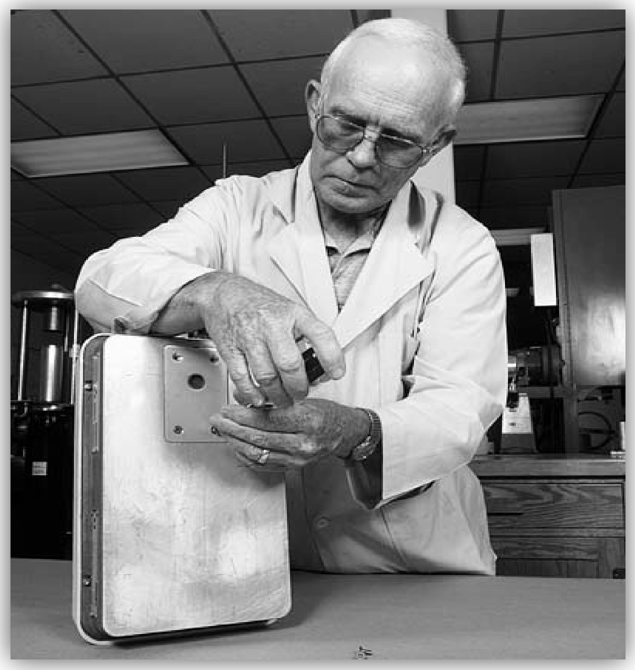
Nuclear Gauge Cleaning Procedures

1) Standing behind the gauge with the source rod pointing away from you, place the gauge on its end and remove the screws from the bottom plate.

2) Remove the bottom plate and the tungsten sliding block that shields the source rod.

3) Clean the area around the tungsten sliding block. Then, clean and polish the face of the block to remove all rough surfaces. Do not get hands near the source rod.

4) Replace the block and plate. Clean the gauge anytime that difficulty is encountered when trying to lower and/or raise the source rod.



Battery Charging for Model 3440

A fully charged battery will last approximately 8 weeks under normal working conditions (8 hours/day). The 3440 display panel will give you the hours remaining on the current charge and, when it is running low, the screen will display BATTERIES LOW! You still have a few hours left when this display occurs in order to finish the current testing. At the completion of the days testing however, the gauge needs to be plugged in overnight to fully recharge.

IMPORTANT: Only recharge when the gauge indicates that it is low. Needless recharging will shorten the battery life.

Alkaline Battery Use

Alkaline batteries may be used when recharging is not an option. The gauge has a separate battery case for this purpose. Refer to manual for further instructions.

CAUTION: Never mix alkaline and rechargeable batteries in the gauge. They may explode when charging!!!

INSTRUCTIONS TO FOLLOW IN THE EVENT OF AN ACCIDENT

DO NOT DISCUSS INCIDENT WITH ANYONE EXCEPT POLICE, STATE MATERIALS PERSONNEL, AND YOUR IMMEDIATE SUPERVISOR.

(The District Public Relations Specialist must address all news media questions)

1) Stop and detain all equipment or vehicles involved until the assessment can be made to determine if there is any contamination. If a vehicle is involved, notify the local and state police. Let them know that radioactive materials are involved. Segregate and detain all persons involved.

2) Assess and treat life-threatening injuries immediately. Do not delay advanced life support if victims cannot be moved. Move victims away from the radiation hazard area if possible, using proper patient transfer techniques to prevent further injury. Stay within the controlled area if contamination is suspected.

3) Prohibit eating, drinking, or smoking by persons while at the accident scene.

4) Locate the gauge and or source, see attached check list.

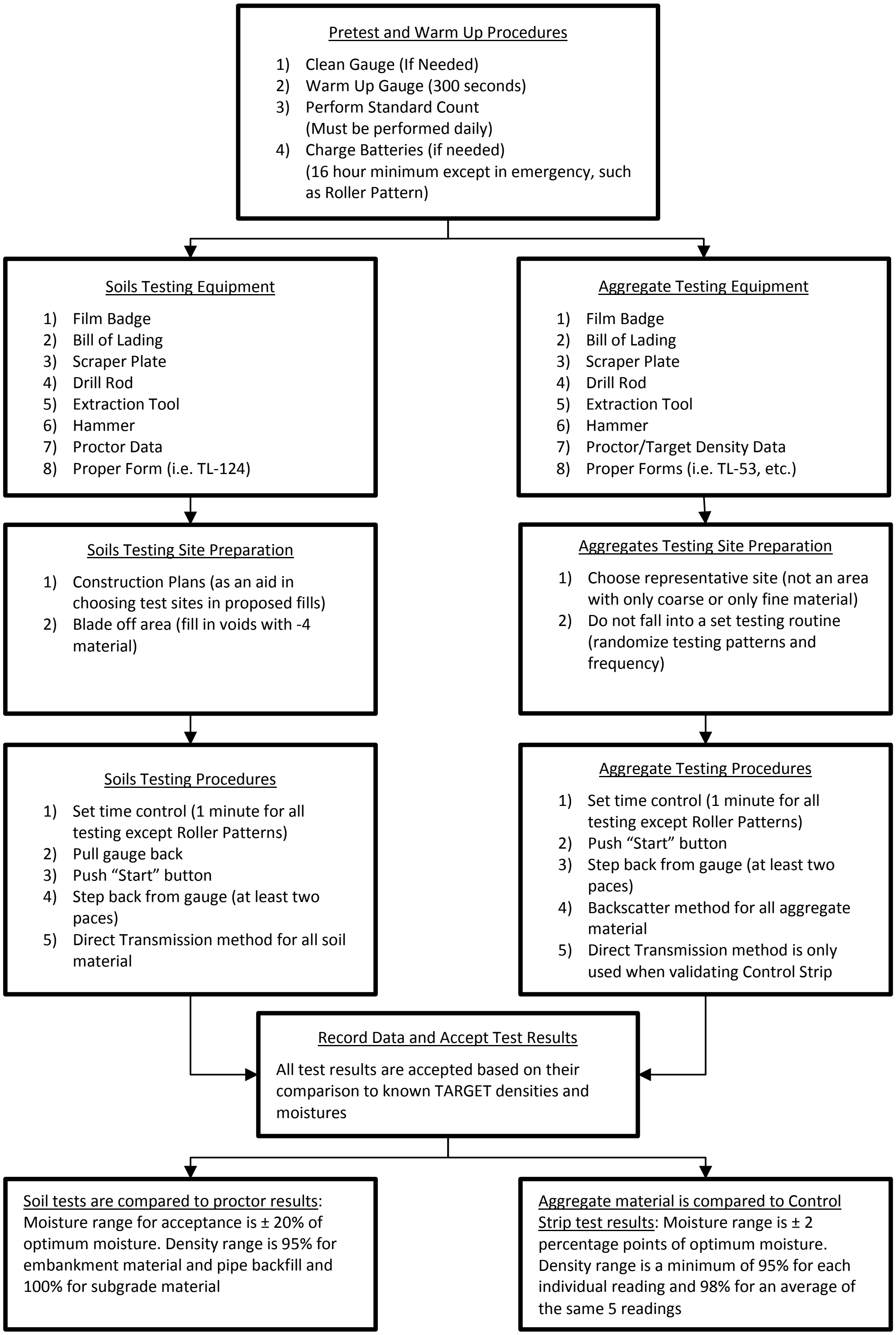
5) Immediately cordon off at least a 20 feet radius surrounding the gauge and parts, if any. Keep on-lookers and all unnecessary personnel at a safe distance, while caring for or rescuing any persons who are injured.

6) Notify the nearest Radiation Safety Officer of the license holder to come and monitor the device to determine if there is possible leakage. Give good directions as to location of accident.

7) Never let anyone remove the gauge, equipment or any articles that are involved in the accident until the area has been cleared by a monitoring team.

8) Complete the Nuclear Accident Checklist located in the Bill of Lading after the RSO or monitoring team has arrived and assessed the situation. The Emergency Notification List is also in the Bill of Lading.

NUCLEAR GAUGE TESTING FLOWCHART



Pretest and Warm Up Procedures

1) Clean Gauge (If Needed)
2) Warm Up Gauge (300 seconds)
3) Perform Standard Count (Must be performed daily)
4) Charge Batteries (if needed) (16 hour minimum except in emergency, such as Roller Pattern)

Soils Testing Equipment

1) Film Badge
2) Bill of Lading
3) Scraper Plate
4) Drill Rod
5) Extraction Tool
6) Hammer
7) Proctor Data
8) Proper Form (i.e. TL-124)

Aggregate Testing Equipment

1) Film Badge
2) Bill of Lading
3) Scraper Plate
4) Drill Rod
5) Extraction Tool
6) Hammer
7) Proctor/Target Density Data
8) Proper Forms (i.e. TL-53, etc.)

Soils Testing Site Preparation

1) Construction Plans (as an aid in choosing test sites in proposed fills)
2) Blade off area (fill in voids with -4 material)

Aggregates Testing Site Preparation

1) Choose representative site (not an area with only coarse or only fine material)
2) Do not fall into a set testing routine (randomize testing patterns and frequency)

Soils Testing Procedures

1) Set time control (1 minute for all testing except Roller Patterns)
2) Pull gauge back
3) Push “Start” button
4) Step back from gauge (at least two paces)
5) Direct Transmission method for all soil material

Aggregate Testing Procedures

1) Set time control (1 minute for all testing except Roller Patterns)
2) Push “Start” button
3) Step back from gauge (at least two paces)
4) Backscatter method for all aggregate material
5) Direct Transmission method is only used when validating Control Strip

Record Data and Accept Test Results

All test results are accepted based on their comparison to known TARGET densities and moistures

Soil tests are compared to proctor results: Moisture range for acceptance is ± 20% of optimum moisture. Density range is 95% for embankment material and pipe backfill and 100% for subgrade material

Aggregate material is compared to Control Strip test results: Moisture range is ± 2 percentage points of optimum moisture. Density range is a minimum of 95% for each individual reading and 98% for an average of the same 5 readings

TROUBLESHOOTING GUIDE FOR THE NUCLEAR GAUGE

Problem	Probable Cause	Solution
Gauge turns off after it is turned on or will not turn on at all	1. Gauge may be wet. DO NOT turn gauge on until it has dried. 2. Batteries are low.	1. Wait until gauge dries off. 2. Recharge batteries minimum of 16 hours (short and frequent charge drains battery life). If charge doesn't hold call District Materials Section.
Short Battery Life	1. Bad outlet. 2. Batteries are reaching end of cycle or charge isn't working.	1. Check outlet. 2. Call the District Materials Section.
Questionable Standard Counts	1. Gauge needs more warm-up time or isn't properly seated on the standard block. 2. Handle isn't in the safe position. 3. Background interference.	1. Check to see that the gauge isn't on the standard block backwards. Clean all dirt, gravel, etc. from the gauge standard or test block. Make sure these counts are taken exactly as all prior tests. 2. Check handle position. 3. Move away from any large structures.
Questionable Moisture Counts	1. Mica, asbestos, or other hydrogen-rich material is in the soil. 2. Background interference from large structure or trench wall if below ground level. 3. Internal tube failure. 4. Handle not locked in testing position notch.	1. Run a Speedy Moisture test. 2. Move test site away from structures or run background count if testing in a trench. 3. Run new standard count to check gauge. 4. Check handle position.
Questionable Density Counts	1. Presence of +4 Material. 2. Test isn't taken on soil represented by Proctor test result. 3. Internal tube failure. 4. Handle isn't locked into testing position.	1. Check for +4 material and take corrective action that applies to your District. 2. Run a Proctor test. 3. Run new standard counts. 4. Check the handle position.

CHAPTER 6 – STUDY QUESTIONS

1) Batteries should be charged ____.

2) True or False. The nuclear gauge should be warmed-up first thing in the morning before using it.

3) True or False. The only maintenance performed in the field is cleaning the nuclear gauge and charging the batteries.

4) When taking a standard count, the nuclear gauge should be a minimum of __________ ft. from any structure and __________ ft. from any other radioactive source.

5) True or False. Cesium-137 is located in the tip of the stainless steel rod which is used in taking moisture determinations and Americium-241:Beryllium is located inside the nuclear gauge and is used for density testing.

6) When taking Standard Counts the Reference Standard should be placed on what type of surface?

7) Three ways to limit exposure to radiation are __________, ____________, and ____________.

8) If the soil material fails a nuclear test because of excessive moisture, the first step taken is to __________________________.

9) A testing method for testing densities whereby the source rod is inserted into the material to be tested at a depth of 4, 6, or 8 inches is __________________________.

10) If, during construction, the density results either change suddenly, or simply don't make sense, you should ____.

11) If the moisture results from the nuclear test appear high, the ___________________________ could be used to check the moisture.

12) When a nuclear gauge is operated within 24" of a vertical structure, the _______________ and _______________ are influenced by the structure.

CHAPTER 6 – PRACTICE PROBLEMS

Nuclear Gauge Testing of Soil Material (Density and Moisture)

Transfer the information from each Practice Problem below to the Form TL-124 and then determine whether each test passes.

Practice Problem 1

Proctor Data
Maximum Dry Density = 114.6 lbs/ft^3
Optimum Moisture = 14.1%

Nuclear Gauge Display Panel

% PR = ______%

DD = 114.2
WD = 133.3

M = 19.1 M% = 16.7

Practice Problem 2

Proctor Data
Maximum Dry Density = 106.9 lbs/ft^3
Optimum Moisture = 17.6%

Nuclear Gauge Display Panel

% PR = ______%

DD = 105.7
WD = 123.6

M = 17.9 M% = 16.9

Practice Problem 3

Proctor Data
Maximum Dry Density = 112.1 lbs/ft^3
Optimum Moisture = 15.2%

Nuclear Gauge Display Panel

% PR = 97.8%

DD = 109.6
WD = 128.2

M = 18.6 M% = 17.0

Form TL-124 (Rev. 07/15)

VIRGINIA DEPARTMENT OF TRANPORTATION
MATERIALS DIVISION
REPORT ON NUCLEAR EMBANKMENT DENSITIES (UNIT MASSES)

Report No. 45 **Date** 06/22/2015 **Sheet No.** 1 **of** 1
Route No. 252 **County** Augusta
Project No. 0252-132-101, C501
FHWA No. None
Testing for Embankment
Model No. 3440 **Serial No.** 23456 **Calibration Date** 02/10/2015

STANDARD COUNT DATA

Density 2844 **Moisture** 701

Test No.			**1**	**2**	**3**	**4**
Location	Station ft. (m)		305+00	305+60	306+20	
of	Ref. to center line ft. (m)		at. C/L	10’ Lt.	7’ Lt.	
Test	Elevation		+10 / -7	+3 / -10	+3 / -3	
Compaction Depth of Lift in. (mm)			6”	6”	6”	
Method of Compaction			Sheepsfoot	Sheepsfoot	Sheepsfoot	
A. Wet Density (lbs/ft^3), Wet Unit Mass (kg/m^3)		=				
B. Moisture Unit Mass (lbs/ft^3 or kg/m^3)		=				
C. Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) (A-B)		=				
D. Moisture Content (B ÷ C) x 100		=				
E. Maximum Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) Lab Proctor or One Point Proctor		=				
F. Percent Optimum Moisture from Lab or One Point Proctor		=				
G. Percent of Plus #4, (plus 4.75 mm)		=				
H. Corrected Max. Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3)		=				
I. Corrected Optimum Moisture		=				
J. Percent Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) (C ÷ E) x 100 or (C ÷ H) x 100		=				
K. Percent Minimum Density Required		=				

Comments:

BY:

TITLE:

CHAPTER 6 – PRACTICE PROBLEMS

Nuclear Gauge Testing of Soil Material (Correcting for High Moisture)

Practice Problem 4

The nuclear density test reported on the Form TL-124 on the following page shows a false high moisture content, assumed to be caused by micaceous soil. Correct the test results using a Speedy Moisture Meter and record the results in the second column of the Form TL-124.

Speedy Dial Reading = 9.6

Form TL-124 (Rev. 07/15)

VIRGINIA DEPARTMENT OF TRANPORTATION
MATERIALS DIVISION
REPORT ON NUCLEAR EMBANKMENT DENSITIES (UNIT MASSES)

Report No. 1-17-1 **Date** 06/22/2015 **Sheet No.** 1 **of** 1
Route No. 17 **County** Campbell
Project No. 0017-015-104, C503
FHWA No. None
Testing for Embankment
Model No. 3440 **Serial No.** 23456 **Calibration Date** 02/10/2015

STANDARD COUNT DATA

Density 2830 **Moisture** 701

Test No.		**1**	**2**	**3**	**4**
Location	Station ft. (m)	85+00			
of	Ref. to center line ft. (m)	at. C/L			
Test	Elevation	+9 / -3			
Compaction Depth of Lift in. (mm)		6”			
Method of Compaction		Sheepsfoot			
A. Wet Density (lbs/ft^3), Wet Unit Mass (kg/m^3)	=	141.0			
B. Moisture Unit Mass (lbs/ft^3 or kg/m^3)	=	23.1			
C. Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) (A-B)	=	117.9			
D. Moisture Content (B ÷ C) x 100	=	19.6			
E. Maximum Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) Lab Proctor or One Point Proctor	=	132.4			
F. Percent Optimum Moisture from Lab or One Point Proctor	=	9.2 7.4 – 11.0			
G. Percent of Plus #4, (plus 4.75 mm)	=				
H. Corrected Max. Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3)	=				
I. Corrected Optimum Moisture	=				
J. Percent Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) (C ÷ E) x 100 or (C ÷ H) x 100	=	89.0			
K. Percent Minimum Density Required	=	95.0			

Comments:

BY:

TITLE:

7

CORRECTING DENSITY TEST RESULTS FOR MATERIAL RETAINED ON THE NO. 4 SIEVE

LEARNING OUTCOMES

- Understand how +4 material impacts the measurement of material moisture and density
- Understand the procedures for correcting target values and test results for +4 material in soils
- Understand the procedures for correcting target values and test results for dense graded aggregate

INTRODUCTION

A "*golden rule*" of compaction testing is: **The proctor used to calculate percent density must match the soil being tested**. This fact is restated here because it is the single most important factor why plus 4 corrections are necessary.

VTM-1 states when soil materials contain 10% or more material retained on the No. 4 sieve (3 or more dime size stones), it is necessary to correct the proctor results which are calculated on the minus 4 portion of the material. Basically, this is why: **Rocks are heavier than soil**. This sounds pretty simple, but this simple fact actually sets up a fairly complex relationship when +4 material is present in a soil.

Effects on Density Measurement

Since rocks are heavier than soil, the more present in a soil, the higher the maximum density. To calculate the corrected maximum density three figures are needed: the percentage of +4 material present; the material's specific gravity, and the maximum density of the minus 4 material.

Effects on Moisture Measurement

A very interesting thing happens with regard to moisture when +4 material is present in a soil. Think about this a moment: If we could separate the +4 from the minus 4 material, we would basically have a soil and some open graded aggregate. When working with aggregates we use the term absorption. This term is "kin" to optimum moisture because it represents Saturated Surface Dry (SSD) conditions. At SSD, aggregates neither add nor take water from whatever they're mixed with. Optimum moisture for +4 soil materials is generally between 1 and 3 percent. Compare that to the typical values for optimum moisture of soils, which often vary from as low as 6% to over 30%.

The optimum moisture for the total soil is a weighted average of the "optimums" for the two materials we've separated. Knowing the typical values for these optimums, we can understand why **the more +4 material present, the lower the optimum moisture**.

When these *corrected* values for maximum density and optimum moisture are applied to field densities, the relationships discussed here will be readily apparent as well as consistent.

This following information is included for your convenience (it is for instructional purposes only). For use outside this class, obtain the current VTM from the State Materials Engineer.

Laboratory Determination of Theoretical Maximum Density Optimum Moisture Content of Soils, Granular Subbase, and Base Materials.

Designation: VTM-1

AASHTO T 99 Method A shall be followed, except as modified below:

Moisture-Density Relationship

Note 12a: If there is 10% or greater material retained on the No. 4 sieve, use the following corrective procedure for determining the theoretical maximum dry density and optimum moisture content.

Material Containing Plus No. 4 Sieve Particles

AASHTO T 99 Method A procedure is applicable to soil that contains little or no material retained on the No. 4 sieve. Since the maximum density curve determined in the laboratory is obtained by utilizing only that material passing the No. 4 sieve, any appreciable amount of larger material contained in the embankment, which is being checked for compaction, will increase the apparent density, due to the higher specific gravity of the stone as compared to the bulk gravity of the compacted dry soil. At the same time, the optimum moisture content will be less, because some of the material passing the No. 4 sieve is replaced with coarser material (the void space is reduced and the total surface area is decreased).

(1) The theoretical maximum density, "D" of mixtures containing coarse aggregate larger than a No. 4 sieve will be determined by the formula:

$$\text{Total Density } (D_t) = \frac{D_f \times D_c}{(P_c \times D_f) + (P_f \times D_c)}$$

Where:

D_f = Maximum dry laboratory density of minus No. 4 material (by AASHTO Designation: T 99), in lb/ft^3

D_c = Maximum density of Plus No. 4 material (62.4 lb/ft^3 x bulk specific gravity by AASHTO Designation: T85 or as estimated by the Engineer), in lb/ft^3

P_c = Percent plus No. 4 material, expressed as a decimal, and

P_f = Percent minus No. 4 material, expressed as a decimal or by nomograph (see Figure 1).

(2) The optimum moisture for the total soil will be determined by the formula:

$$W_t = (P_c W_c + P_f W_f)100$$

Where:

W_t = Optimum moisture content for total soil,

W_c = Optimum moisture content (absorption), expressed as a decimal, for material retained on No. 4 sieve (estimated between 1% and 3%),

W_f = Optimum moisture content, expressed as a decimal, for material passing No. 4 sieve,

P_c = Percent, expressed as a decimal, of material retained on a No. 4 sieve, and

P_f = Percent, expressed as a decimal, of material passing a No. 4 sieve.

General Notes:

1. The density required in the work will be a variable percentage of the theoretical maximum density, "D", depending upon variations in the percentage of plus No. 4 material in the mixture and upon the position of the material in the work, and will be specified in the applicable section of the specifications.

2. The District Materials Engineer will inform the Inspector of the results of the compaction tests on the minus 4 material and the specific gravity of the +4 material. With this information, the Inspector can then prepare a chart showing the density of the total sample for varying percentages of the +4 material.

+4 CORRECTIONS FOR THE NUCLEAR GAUGE

It is worth noting here the difference between the presence of +4 material and a “rock fill”. Generally, nuclear density can be performed on compacted material with up to about 35% +4 material, as long as there are minimum large rocks present (i.e. > 8 inches).

When +4 material is encountered with the nuclear gauge, a number of trial test locations (4 to 5) may be necessary in order to find a suitable test site.

+4 Sampling

When using a nuclear gauge, it is extremely important that a representative sample be obtained. This is accomplished by taking the total soil sample from **directly beneath the location of the gauge where the density test was taken**. A minimum sample of 5.5 lb. is necessary.

The Form TL-124A

The Form TL-124A (Report of Nuclear Embankment Densities) contains spaces for both the Proctor data (Lines E & F), as well as a space for the Corrected Maximum Density (Line H) and Corrected Optimum Moisture (Line I).

Steps to Follow for +4 Calculations

1) Test and calculate the percent of +4 material
2) Calculate the corrected maximum density
3) Calculate the corrected optimum moisture and moisture limits
4) Apply corrected values to the field density test:
    a. Calculate the actual percent density
    b. Compare actual moisture to corrected moisture limits

Form TL-124 (Rev. 07/15)

VIRGINIA DEPARTMENT OF TRANPORTATION
MATERIALS DIVISION
REPORT ON NUCLEAR EMBANKMENT DENSITIES (UNIT MASSES)

Report No. 1-017-1 **Date** 06/22/2015 **Sheet No.** 1 **of** 1
Route No. 17 **County** Campbell
Project No. 0017-015-104, C503
FHWA No. None
Testing for Embankment
Model No. 3440 **Serial No.** 23456 **Calibration Date** 02/10/2015

STANDARD COUNT DATA

Density 2830 **Moisture** 701

Test No.			**1**	**2**	**3**	**4**
Location	Station ft. (m)		585+00			
of	Ref. to center line ft. (m)		At C/L			
Test	Elevation		+8 / -4			
Compaction Depth of Lift in. (mm)			6”			
Method of Compaction			Sheepsfoot			
A. Wet Density (lbs/ft^3), Wet Unit Mass (kg/m^3)		=	134.2			
B. Moisture Unit Mass (lbs/ft^3 or kg/m^3)		=	11.0			
C. Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) (A-B)		=	123.2			
D. Moisture Content (B ÷ C) x 100		=	8.9			
E. Maximum Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) Lab Proctor or One Point Proctor		=	118.2			
F. Percent Optimum Moisture from Lab or One Point Proctor		=	12.4 9.9 – 14.9			
G. Percent of Plus #4, (plus 4.75 mm)		=				
H. Corrected Max. Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3)		=				
I. Corrected Optimum Moisture		=				
J. Percent Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) (C ÷ E) x 100 or (C ÷ H) x 100		=	104.2			
K. Percent Minimum Density Required		=	95.0			

False “Low” Moisture

Proctor Values Based on the -4 Material

<u>False “High” Density</u>

Density = (123.2 ÷ 118.2) x 100
Density = 104.2%

Comments:

BY:

TITLE:

PROCEDURE FOR DETERMINING AMOUNT OF +4 MATERIAL IN TOTAL SOIL

(This Procedure is for Soil and Aggregates)

Testing Procedure

1) Obtain a representative sample (Use a minimum of 5.5 pounds from location of proposed nuclear test).
2) Dry the total sample.
3) Weigh the total dry sample.
4) Pass the dried material over the No. 4 Sieve.
5) Weigh the material retained on the No. 4 Sieve
6) Calculate the percent of +4 material:

Percent of +4 Material = (Weight of +4 Material ÷ Weight of total Sample) x 100

Note: Round answer to the nearest whole percent.

Example Problem

Step 1	Weight of Dry Soil + Dish		9.25	lbs.
	Weight of Dish Only	-	1.69	lbs.
	Total Weight of Dry Soil		7.56	lbs.
Step 2	Weight of +4 Material + Dish		3.20	lbs.
	Weight of Dish Only	-	1.69	lbs.
	Weight of +4 Material		1.51	lbs.

Step 3 Percent of +4 Material = (1.51 ÷ 7.56) x 100

= (0.199) x 100

= 19.9 or 20%

Step 4 Enter <u>20%</u> on Line G (Form TL-124)

CALCULATING THE TOTAL DENSITY OF SOILS WITH +4 MATERIAL

The equation for calculating the corrected total density of soils (D_t) containing +4 material may be expressed as follows:

$$\text{Total Density } (D_t) = \frac{D_f \times D_c}{(P_c \times D_f) + (P_f \times D_c)}$$

Needed Information:

P_c = Percent of +4 material expressed as a decimal = 0.2 (from sieve analysis)

D_c = Specific gravity of +4 material (2.68) x 62.4 lbs/ft^3 = 167.2 lbs/ft^3

P_f = Percent of -4 material expressed as a decimal = 0.8 (from sieve analysis)

D_f = Maximum Dry Density of the -4 material = 118.2 lbs/ft^3 (from proctor)

$$\text{Total Density } (D_t) = \frac{118.2 \times 167.2}{(0.2 \times 118.2) + (0.8 \times 167.2)}$$

$$\downarrow$$

$$\frac{19{,}763}{(23.6) + (133.8)}$$

$$\downarrow$$

$$\frac{19{,}763}{157.4}$$

$$\downarrow$$

$$\text{Total Density } (D_t) = 125.6 \text{ lbs/ft}^3$$

(Enter on Line H of TL-124)

CALCULATING THE OPTIMUM MOISTURE OF SOILS WITH +4 MATERIAL

The Optimum Moisture content for the total soil is expressed as follows:

$$\text{Optimum Moisture } (W_t) = [(P_cW_c + P_fW_f)] \text{ x } 100$$

Needed Information:

P_c = Percent of +4 material expressed as a decimal = 0.2 (from sieve analysis)

W_c = Absorption of +4 material expressed as a decimal = 0.02 (Materials Division)

P_f = Percent of -4 material expressed as a decimal = 0.8 (from sieve analysis)

W_f = Optimum Moisture of the -4 material expressed as a decimal = 0.124 (from proctor)

$$\text{Optimum Moisture } (W_t) = [(0.2 \text{ x } 0.02) + (0.8 \text{ x } 0.124)] \text{ x } 100$$

$$\downarrow$$

$$[(0.004) + (0.099)] \text{ x } 100$$

$$\downarrow$$

$$0.103 \text{ x } 100$$

$$\downarrow$$

$$\text{Optimum Moisture } (W_t) = 10.3\%$$

(Enter on Line I of TL-124)

CALCULATION #1

Amount of +4 Material in Total Soil

	Weight of Dry Soil + Dish	9.25	lb.	Weight of +4 Material + Dish	3.20	lb.
-	Weight of Dish Only	1.69	lb.	Weight of Dish Only	1.69	lb.
	Total Weight of Dry Soil	7.56	lb.	Total Weight of +4 Material	1.51	lb.

$$\frac{\text{Total Weight of +4 Material}}{\text{Total Weight of Dry Soil}} = \frac{\underline{1.51\text{ lbs.}}}{\underline{7.56\text{ lbs.}}} = \underline{0.199} \text{ x } 100 = \underline{20.0\%} \text{ (Enter on Line G)}$$

CALCULATION #2

Total Density of Soils with +4 Material

Needed Information:

P_c = Percent of +4 material expressed as a decimal = 0.20 (Taken from Sieve Analysis)

D_c = 2.68 Sp. Gr. of +4 Material x 62.4 lbs/ft^3 = 167.2 lbs/ft^3

P_f = Percent of -4 material expressed as a decimal = 0.80 (Taken from Sieve Analysis)

D_f = Maximum Dry Density of the -4 material = 118.2 (Taken from Proctor)

$$\frac{D_f \text{ x } D_c}{(P_c \text{ x } D_f) + (P_f \text{ x } D_c)} = \underset{\text{Step 1}}{\frac{\underline{118.2} \text{ x } \underline{167.2}}{(\underline{0.20} \text{ x } \underline{118.2}) + (\underline{0.80} \text{ x } \underline{167.2})}} = \underset{\text{Step 2}}{\frac{\underline{19{,}763}}{(\underline{23.6}) + (\underline{133.8})}} = \underset{\text{Step 3}}{\frac{\underline{19{,}763}}{\underline{157.4}}} = \underline{125.6\text{ lbs/ft}^3}$$

Maximum Dry Density of Total Soil = $\underline{125.6\text{ lbs/ft}^3}$ (Enter on Line H)

CALCULATION #3

Optimum Moisture Content of Soils with +4 Material

Needed Information:

P_c = Percent of +4 material expressed as a decimal = 0.20 (Taken from Sieve Analysis)

W_c =Absorption of the +4 Material expressed as a decimal = 0.02 (Taken from Material Division)

P_f = Percent of -4 material expressed as a decimal = 0.80 (Taken from Sieve Analysis)

W_f = Optimum Moisture of the -4 material expressed as a decimal = 0.124 (Taken from Proctor)

$$(P_cW_c + P_fW_f) \text{ x } 100 = \underset{\text{Step 1}}{[(\underline{0.20} \text{ x } \underline{0.02}) + (\underline{0.80} \text{ x } \underline{0.124})] \text{ x } 100} = \underset{\text{Step 2}}{[(\underline{0.004}) + (\underline{0.099})] \text{ x } 100} = \underset{\text{Step 3}}{(\underline{0.103}) \text{ x } 100} = \underline{10.3\%}$$

Optimum Moisture Content of Total Soil = $\underline{10.3\%}$ (Enter on Line I)

Form TL-124 (Rev. 07/15)

DENSITY AND MOISTURE OF TOTAL SOIL CORRECTED FOR +4 MATERIAL

Report No. 1-017-1 **Date** 06/22/2015 **Sheet No.** 1 **of** 1
Route No. 17 **County** Campbell
Project No. 0017-015-104, C503
FHWA No. None
Testing for Embankment
Model No. 3440 **Serial No.** 23456 **Calibration Date** 02/10/2015

STANDARD COUNT DATA

Density 2830 **Moisture** 701

Test No.			**1**	**2**	**3**	**4**
Location	Station ft. (m)		585+00			
of	Ref. to center line ft. (m)		At C/L			
Test	Elevation		+8 / -4			
Compaction Depth of Lift in. (mm)			6”			
Method of Compaction			Sheepsfoot			
A. Wet Density (lbs/ft^3), Wet Unit Mass (kg/m^3)		=	134.2			
B. Moisture Unit Mass (lbs/ft^3 or kg/m^3)		=	11.0			
C. Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) (A-B)		=	123.2			
D. Moisture Content (B ÷ C) x 100		=	8.9			
E. Maximum Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) Lab Proctor or One Point Proctor		=	118.2			
F. Percent Optimum Moisture from Lab or One Point Proctor		=	12.4 9.9 – 14.9			
G. Percent of Plus #4, (plus 4.75 mm)		=	20			
H. Corrected Max. Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3)		=	125.6			
I. Corrected Optimum Moisture		=	10.3 8.2 – 12.4			
J. Percent Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) (C ÷ E) x 100 or (C ÷ H) x 100		=	98.1			
K. Percent Minimum Density Required		=	95.0			

Percent +4 Material

Corrected Maximum Density

Corrected Optimum Moisture

Correct Percent Density

Density = (123.2 ÷ 125.6) x 100
Density = 98.1%

Comments:

BY: ____________________

TITLE: ____________________

DENSITY TESTING OF DENSE GRADED AGGREGATES

After placement of the embankment material and compaction and approval of the subgrade, the Contractor will apply the dense graded aggregate layer to the subgrade. After sufficient compactive effort has been applied to densify the aggregate, the inspector conducts field density tests to determine if the contractor’s operations have satisfactorily densified these materials.

The minimum rates of testing for these procedures are outlined in the Appendix.

Section 303.04(h) of the 2007 Road and Bridge Specification stipulates that all field density determinations are to be performed in accordance with the following testing procedures:

- AASHTO T310 - In-Place Density and Moisture Content of Soil-Aggregate by Nuclear Method (Shallow Depth)

- VTM-10 - Determining Percent of Moisture and Density of Soils and Asphalt (Nuclear Method)

Form TL-124 (Rev. 07/15)

VIRGINIA DEPARTMENT OF TRANPORTATION
MATERIALS DIVISION
REPORT ON NUCLEAR EMBANKMENT DENSITIES (UNIT MASSES)

Report No. 1-017-1 **Date** 06/22/2015 **Sheet No.** 1 **of** 1
Route No. 17 **County** Campbell
Project No. 0017-015-104, C503
FHWA No. None
Testing for Aggregate Base Type I (21A)
Model No. 3440 **Serial No.** 23456 **Calibration Date** 02/10/2015

STANDARD COUNT DATA

Density 2830 **Moisture** 701

Test No.			**1**	**2**	**3**	**4**
Location	Station ft. (m)		585+00			
of	Ref. to center line ft. (m)		5' Rt. C/L			
Test	Elevation					
Compaction Depth of Lift in. (mm)			6"			
Method of Compaction			Vibratory			
A. Wet Density (lbs/ft^3), Wet Unit Mass (kg/m^3)		=	145.2			
B. Moisture Unit Mass (lbs/ft^3 or kg/m^3)		=	7.0			
C. Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) (A-B)		=	138.2			
D. Moisture Content (B ÷ C) x 100		=	5.1			
E. Maximum Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) Lab Proctor or One Point Proctor		=	127.7			
F. Percent Optimum Moisture from Lab or One Point Proctor		=	8.5 6.5 – 10.5			
G. Percent of Plus #4, (plus 4.75 mm)		=				
H. Corrected Max. Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3)		=				
I. Corrected Optimum Moisture		=				
J. Percent Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) (C ÷ E) x 100 or (C ÷ H) x 100		=	108.2			
K. Percent Minimum Density Required		=	95.0			

False "Low" Moisture

Proctor Values Based on the -4 Material

False "High" Density

Density = (138.2 ÷ 127.7) x 100
Density = 108.2%

Comments:

BY: ____________________

TITLE: ____________________

PROCEDURE FOR DETERMINING AMOUNT OF +4 MATERIAL IN AGGREGATE

(This Procedure is for Soil and Aggregates)

1) Obtain a representative sample (Use a minimum of 5.5 pounds from location of proposed nuclear test).
2) Dry the total sample.
3) Weigh the total dry sample.
4) Pass the dried material over the No. 4 Sieve.
5) Weigh the material retained on the No. 4 Sieve
6) Calculate the percent of +4 material:

   Percent of +4 Material = (Weight of +4 Material ÷ Weight of total Sample) x 100

   Note: Round answer to the nearest whole percent.

Example Problem

Step 1	Weight of Dry Aggregate + Dish		9.22	lbs.
	Weight of Dish Only	-	2.54	lbs.
	Total Weight of Dry Aggregate		6.68	lbs.
Step 2	Weight of +4 Material + Dish		5.68	lbs.
	Weight of Dish Only	-	2.54	lbs.
	Weight of +4 Material		3.14	lbs.

Step 3 Percent of +4 Material = (3.14 ÷ 6.68) x 100
= (0.470) x 100
= 47.0%

Step 4 Enter <u>47%</u> on Line G (Form TL-124)

AGGREGATE DATA FROM PRODUCER (OR MATERIALS DIVISION)

Producer: Vulcan Materials, Shelton, NC

Density Data:

Bulk Specific Gravity = 2.63

Unit Weight of -4 Material = 127.7 lb.

Note: Use these values with the "Total Density Chart"
Enter the result on Line H of the Form TL-124

Moisture Data:

Absorption of +4 Material = 0.3 %

Optimum Moisture of -4 Material = 8.5 %

Note: Use these values for Optimum Moisture Calculation
Enter the result on Line I of the Form TL-124

CALCULATING THE TOTAL DENSITY OF AGGREGATE WITH +4 MATERIAL

The equation for calculating the corrected total density of aggregate (D_t) containing +4 material may be expressed as follows:

$$\text{Total Density } (D_t) = \frac{D_f \times D_c}{(P_c \times D_f) + (P_f \times D_c)}$$

Needed Information:

P_c = Percent of +4 material expressed as a decimal = 0.47 (from sieve analysis)

D_c = Specific gravity of +4 material (2.63) x 62.4 lbs/ft^3 = 164.1 lbs/ft^3

P_f = Percent of -4 material expressed as a decimal = 0.53 (from sieve analysis)

D_f = Maximum Dry Density of the -4 material = 127.7 lbs/ft^3 (from proctor)

$$\text{Total Density } (D_t) = \frac{127.7 \times 164.1}{(0.47 \times 127.7) + (0.53 \times 164.1)}$$

$$\downarrow$$

$$\frac{20{,}955.6}{(60.0) + (87.0)}$$

$$\downarrow$$

$$\frac{20{,}955.6}{147.0}$$

$$\downarrow$$

$$\text{Total Density } (D_t) = 142.6 \text{ lbs/ft}^3$$

(Enter on Line H of TL-124)

CALCULATING THE OPTIMUM MOISTURE OF AGGREGATE WITH +4 MATERIAL

The Optimum Moisture content for the aggregate is expressed as follows:

$$\text{Optimum Moisture } (W_t) = [(P_cW_c + P_fW_f)] \text{ x } 100$$

Needed Information:

P_c = Percent of +4 material expressed as a decimal = 0.47 (taken from sieve analysis)

W_c = Absorption of +4 material (+ 1) expressed as a decimal = 0.013 (Materials Division)

P_f = Percent of -4 material expressed as a decimal = 0.53 (from sieve analysis)

W_f = Optimum Moisture of the -4 material expressed as a decimal = 0.085 (from proctor)

$$\text{Optimum Moisture } (W_t) = [(0.47 \text{ x } 0.013) + (0.53 \text{ x } 0.085)] \text{ x } 100$$

$$\downarrow$$

$$[(0.006) + (0.045)] \text{ x } 100$$

$$\downarrow$$

$$0.051 \text{ x } 100$$

$$\downarrow$$

$$\text{Optimum Moisture } (W_t) = 5.1\%$$

(Enter on Line I of TL-124)

CALCULATION #1

Amount of +4 Material in Total Soil

	Weight of Dry Soil + Dish	9.22	lb.	Weight of +4 Material + Dish	5.68	lb.
-	Weight of Dish Only	2.54	lb.	Weight of Dish Only	2.54	lb.
	Total Weight of Dry Soil	6.68	lb.	Total Weight of +4 Material	3.14	lb.

$$\frac{\text{Total Weight of +4 Material}}{\text{Total Weight of Dry Soil}} = \frac{\underline{3.14\text{ lbs.}}}{\underline{6.68\text{ lbs.}}} = \underline{0.470} \text{ x } 100 = \underline{47.0\%} \text{ (Enter on Line G)}$$

CALCULATION #2

Total Density of Soils with +4 Material

Needed Information:

P_c = Percent of +4 material expressed as a decimal = 0.47 (Taken from Sieve Analysis)

D_c = 2.63 Sp. Gr. of +4 Material x 62.4 lbs/ft^3 = 164.1 lbs/ft^3

P_f = Percent of -4 material expressed as a decimal = 0.53 (Taken from Sieve Analysis)

D_f = Maximum Dry Density of the -4 material = 127.7 (Taken from Proctor)

$$\frac{D_f \text{ x } D_c}{(P_c \text{ x } D_f) + (P_f \text{ x } D_c)} = \underset{\text{Step 1}}{\frac{\underline{127.7} \text{ x } \underline{164.1}}{(\underline{0.47} \text{ x } \underline{127.7}) + (\underline{0.53} \text{ x } \underline{164.1})}} = \underset{\text{Step 2}}{\frac{\underline{20{,}955.6}}{(\underline{60.0}) + (\underline{87.0})}} = \underset{\text{Step 3}}{\frac{20{,}955.6}{\underline{146.9}}} = \underline{142.6 \text{ lbs/ft}^3}$$

Maximum Dry Density of Total Soil = <u>142.6 lbs/ft^3</u> (Enter on Line H)

CALCULATION #3

Optimum Moisture Content of Soils with +4 Material

Needed Information:

P_c = Percent of +4 material expressed as a decimal = 0.47 (Taken from Sieve Analysis)

W_c = Absorption of the +4 Material (+1) expressed as a decimal = 0.013 (Taken from Material Division)

P_f = Percent of -4 material expressed as a decimal = 0.53 (Taken from Sieve Analysis)

W_f = Optimum Moisture of the -4 material expressed as a decimal = 0.085 (Taken from Proctor)

$$(P_cW_c + P_fW_f) \text{ x } 100 = \underset{\text{Step 1}}{[(\underline{0.47} \text{ x } \underline{0.013}) + (\underline{0.53} \text{ x } \underline{0.085})] \text{ x } 100} = \underset{\text{Step 2}}{[(\underline{0.006}) + (\underline{0.045})] \text{ x } 100} = \underset{\text{Step 3}}{(\underline{0.051}) \text{ x } 100} = \underline{5.1\%}$$

Optimum Moisture Content of Total Soil = <u>5.1%</u> (Enter on Line I)

Form TL-124 (Rev. 07/15)

DENSITY AND MOISTURE OF AGGREGATE CORRECTED FOR +4 MATERIAL

Report No. 1-017-1 **Date** 06/22/2015 **Sheet No.** 1 **of** 1
Route No. 17 **County** Campbell
Project No. 0017-015-104, C503
FHWA No. None
Testing for Aggregate Base Type I (21A)
Model No. 3440 **Serial No.** 23456 **Calibration Date** 02/10/2015

STANDARD COUNT DATA

Density 2830 **Moisture** 701

Test No.			**1**	**2**	**3**	**4**
Location	Station ft. (m)		585+00			
of	Ref. to center line ft. (m)		5’ Rt. C/L			
Test	Elevation					
Compaction Depth of Lift in. (mm)			6”			
Method of Compaction			Vibratory			
A. Wet Density (lbs/ft^3), Wet Unit Mass (kg/m^3)		=	145.2			
B. Moisture Unit Mass (lbs/ft^3 or kg/m^3)		=	7.0			
C. Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) (A-B)		=	138.2			
D. Moisture Content (B ÷ C) x 100		=	5.1			
E. Maximum Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) Lab Proctor or One Point Proctor		=	127.7			
F. Percent Optimum Moisture from Lab or One Point Proctor		=	8.5 6.5 – 10.5			
G. Percent of Plus #4, (plus 4.75 mm)		=	47			
H. Corrected Max. Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3)		=	142.6			
I. Corrected Optimum Moisture		=	5.1 3.1 – 7.1			
J. Percent Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) (C ÷ E) x 100 or (C ÷ H) x 100		=	96.9			
K. Percent Minimum Density Required		=	95.0			

Percent +4 Material

Corrected Maximum Density

Corrected Optimum Moisture

Correct Percent Density

Density = (138.2 ÷ 142.6) x 100
Density = 96.9%

Comments:

BY: ____________________

TITLE: ____________________

CHAPTER 7 – PRACTICE PROBLEMS

Practice Problem Number 1
Nuclear Density Testing of Soils
(Correcting for +4 Material)

1) Complete the embankment density test (Form TL-124) using the calculation sheet and information provided below.

   Weight of Dry Soil and Dish = 9.29 lbs.
   Weight of Dish Only = 2.62 lbs.
   Weight of +4 Material and Dish = 3.63 lbs.

   Specific Gravity of +4 Material = 2.63
   Absorption of +4 Material = 3.0%

   Maximum Dry Density of -4 Material = 112.6 lbs/ft^3
   Optimum Moisture of -4 Material = 14.5%

Nuclear Gauge Display Panel

% PR = 102.0%

DD = 114.8
WD = 127.4

M = 12.6 M% = 11.0

2) Indicate in the remarks if the test passes or fails and why.

Form TL-124 (Rev. 07/15)

VIRGINIA DEPARTMENT OF TRANPORTATION
MATERIALS DIVISION
REPORT ON NUCLEAR EMBANKMENT DENSITIES (UNIT MASSES)

Report No. 1-117-1 **Date** 06/22/2015 **Sheet No.** 1 **of** 1
Route No. 117 **County** Roanoke
Project No. 0117-080-105, C501
FHWA No. None
Testing for Embankment
Model No. 3440 **Serial No.** 23456 **Calibration Date** 02/10/2015

STANDARD COUNT DATA

Density 2844 **Moisture** 701

Test No.			**1**	**2**	**3**	**4**
Location	Station ft. (m)		90+45			
of	Ref. to center line ft. (m)		6’ Rt. C/L			
Test	Elevation		+8 / -6			
Compaction Depth of Lift in. (mm)			6”			
Method of Compaction			Sheepsfoot			
A. Wet Density (lbs/ft^3), Wet Unit Mass (kg/m^3)		=				
B. Moisture Unit Mass (lbs/ft^3 or kg/m^3)		=				
C. Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) (A-B)		=				
D. Moisture Content (B ÷ C) x 100		=				
E. Maximum Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) Lab Proctor or One Point Proctor		=				
F. Percent Optimum Moisture from Lab or One Point Proctor		=				
G. Percent of Plus #4, (plus 4.75 mm)		=				
H. Corrected Max. Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3)		=				
I. Corrected Optimum Moisture		=				
J. Percent Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) (C ÷ E) x 100 or (C ÷ H) x 100		=				
K. Percent Minimum Density Required		=				

Comments:

BY: ____________________

TITLE: ____________________

CALCULATION #1

Amount of +4 Material in Total Soil

	Weight of Dry Soil + Dish	________ lb.	Weight of +4 Material + Dish	________ lb.
-	Weight of Dish Only	________ lb.	Weight of Dish Only	________ lb.
	Total Weight of Dry Soil	________ lb.	Total Weight of +4 Material	________ lb.

$$\frac{\text{Total Weight of +4 Material}}{\text{Total Weight of Dry Soil}} = \frac{\underline{\hspace{2em}}}{\underline{\hspace{2em}}} = \underline{\hspace{2em}} \text{ x } 100 = \underline{\hspace{2em}}$$ (Enter on Line G)

CALCULATION #2

Total Density of Soils with +4 Material

Needed Information:

P_c = Percent of +4 material expressed as a decimal = ________ (Taken from Sieve Analysis)

D_c = ________ Sp. Gr. of +4 Material x 62.4 lbs/ft^3 = ________ lbs/ft^3

P_f = Percent of -4 material expressed as a decimal = ________ (Taken from Sieve Analysis)

D_f = Maximum Dry Density of the -4 material = ________ (Taken from Proctor)

$$\frac{D_f \text{ x } D_c}{(P_c \text{ x } D_f) + (P_f \text{ x } D_c)} = \underset{\text{Step 1}}{\frac{\underline{\hspace{2em}} \text{ x } \underline{\hspace{2em}}}{(\underline{\hspace{2em}} \text{ x } \underline{\hspace{2em}}) + (\underline{\hspace{2em}} \text{ x } \underline{\hspace{2em}})}} = \underset{\text{Step 2}}{\frac{\underline{\hspace{3em}}}{(\underline{\hspace{2em}}) + (\underline{\hspace{2em}})}} = \underset{\text{Step 3}}{\frac{\underline{\hspace{3em}}}{\underline{\hspace{3em}}}} = \underline{\hspace{4em}}$$

Maximum Dry Density of Total Soil = ________ (Enter on Line H)

CALCULATION #3

Optimum Moisture Content of Soils with +4 Material

Needed Information:

P_c = Percent of +4 material expressed as a decimal = ________ (Taken from Sieve Analysis)

W_c =Absorption of the +4 Material expressed as a decimal = ________ (Taken from Material Division)

P_f = Percent of -4 material expressed as a decimal = ________ (Taken from Sieve Analysis)

W_f = Optimum Moisture of the -4 material expressed as a decimal = ________ (Taken from Proctor)

$$(P_cW_c + P_fW_f) \text{ x } 100 = \underset{\text{Step 1}}{[(\underline{\hspace{2em}} \text{ x } \underline{\hspace{2em}}) + (\underline{\hspace{2em}} \text{ x } \underline{\hspace{2em}})] \text{ x } 100} = \underset{\text{Step 2}}{[(\underline{\hspace{2em}}) + (\underline{\hspace{2em}})] \text{ x } 100} = \underset{\text{Step 3}}{(\underline{\hspace{2em}}) \text{ x } 100} = \underline{\hspace{3em}}$$

Optimum Moisture Content of Total Soil = ________ (Enter on Line I)

CHAPTER 7 – PRACTICE PROBLEMS

Practice Problem Number 2
Nuclear Density Testing of Soils
(Correcting for +4 Material)

1) Complete the embankment density test (Form TL-124) using the calculation sheet and information provided below.

   Weight of Dry Soil and Dish = 9.30 lbs.
   Weight of Dish Only = 2.62 lbs.
   Weight of +4 Material and Dish = 3.65 lbs.

   Specific Gravity of +4 Material = 2.70
   Absorption of +4 Material = 2.0%

   Maximum Dry Density of -4 Material = 110.5 lbs/ft^3
   Optimum Moisture of -4 Material = 14.3%

Nuclear Gauge Display Panel

% PR = 104.7%

DD = 115.7
WD = 127.9

M = 12.2 M% = 10.5

2) Indicate in the remarks if the test passes or fails and why.

Form TL-124 (Rev. 07/15)

VIRGINIA DEPARTMENT OF TRANPORTATION
MATERIALS DIVISION
REPORT ON NUCLEAR EMBANKMENT DENSITIES (UNIT MASSES)

Report No. 1-117-1 **Date** 06/22/2015 **Sheet No.** 1 **of** 1
Route No. 117 **County** Roanoke
Project No. 0117-080-105, C501
FHWA No. None
Testing for Embankment
Model No. 3440 **Serial No.** 23456 **Calibration Date** 02/10/2015

STANDARD COUNT DATA

Density 2844 **Moisture** 701

Test No.			**1**	**2**	**3**	**4**
Location	Station ft. (m)		90+45			
of	Ref. to center line ft. (m)		6’ Rt. C/L			
Test	Elevation		+8 / -6			
Compaction Depth of Lift in. (mm)			6”			
Method of Compaction			Sheepsfoot			
A. Wet Density (lbs/ft^3), Wet Unit Mass (kg/m^3)		=				
B. Moisture Unit Mass (lbs/ft^3 or kg/m^3)		=				
C. Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) (A-B)		=				
D. Moisture Content (B ÷ C) x 100		=				
E. Maximum Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) Lab Proctor or One Point Proctor		=				
F. Percent Optimum Moisture from Lab or One Point Proctor		=				
G. Percent of Plus #4, (plus 4.75 mm)		=				
H. Corrected Max. Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3)		=				
I. Corrected Optimum Moisture		=				
J. Percent Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) (C ÷ E) x 100 or (C ÷ H) x 100		=				
K. Percent Minimum Density Required		=				

Comments:

BY:

TITLE:

CALCULATION #1

Amount of +4 Material in Total Soil

Weight of Dry Soil + Dish ____________ lb.
\- Weight of Dish Only ____________ lb.
Total Weight of Dry Soil ____________ lb.

Weight of +4 Material + Dish ____________ lb.
Weight of Dish Only ____________ lb.
Total Weight of +4 Material ____________ lb.

$$\frac{\text{Total Weight of +4 Material}}{\text{Total Weight of Dry Soil}} = \frac{\_\_\_\_\_\_\_\_}{\_\_\_\_\_\_\_\_} = \_\_\_\_\_\_\_ \times 100 = \_\_\_\_\_\_\_\_ \text{ (Enter on Line G)}$$

CALCULATION #2

Total Density of Soils with +4 Material

Needed Information:

P_c = Percent of +4 material expressed as a decimal = ______________ (Taken from Sieve Analysis)
D_c = ______________ Sp. Gr. of +4 Material x 62.4 lbs/ft^3 = ______________ lbs/ft^3
P_f = Percent of -4 material expressed as a decimal = ______________ (Taken from Sieve Analysis)
D_f = Maximum Dry Density of the -4 material = ______________ (Taken from Proctor)

$$\frac{D_f \times D_c}{(P_c \times D_f) + (P_f \times D_c)} = \frac{\_\_\_\_\_ \times \_\_\_\_\_}{(\_\_\_\_\_ \times \_\_\_\_\_) + (\_\_\_\_\_ \times \_\_\_\_\_)} = \frac{\_\_\_\_\_\_\_\_}{(\_\_\_\_\_) + (\_\_\_\_\_)} = \frac{\_\_\_\_\_\_\_\_}{\_\_\_\_\_\_\_\_} = \_\_\_\_\_\_\_\_\_\_\_\_$$

Step 1 Step 2 Step 3

Maximum Dry Density of Total Soil = ____________ (Enter on Line H)

CALCULATION #3

Optimum Moisture Content of Soils with +4 Material

Needed Information:

P_c = Percent of +4 material expressed as a decimal = ______________ (Taken from Sieve Analysis)
W_c =Absorption of the +4 Material expressed as a decimal = ______________ (Taken from Material Division)
P_f = Percent of -4 material expressed as a decimal = ______________ (Taken from Sieve Analysis)
W_f = Optimum Moisture of the -4 material expressed as a decimal = ______________ (Taken from Proctor)

$$(P_cW_c + P_fW_f) \times 100 = [(\_\_\_\_ \times \_\_\_\_) + (\_\_\_\_ \times \_\_\_\_)] \times 100 = [(\_\_\_\_\_) + (\_\_\_\_\_)] \times 100 = (\_\_\_\_\_) \times 100 = \_\_\_\_\_\_$$

Step 1 Step 2 Step 3

Optimum Moisture Content of Total Soil = ___________ (Enter on Line I)

CHAPTER 7 – PRACTICE PROBLEMS

Practice Problem Number 3
Nuclear Density Testing of Soils
(Correcting for +4 Material)

1) Complete the embankment density test (Form TL-124) using the calculation sheet and information provided below.

   Weight of Dry Soil and Dish = 9.29 lbs.
   Weight of Dish Only = 2.62 lbs.
   Weight of +4 Material and Dish = 3.51 lbs.

   Specific Gravity of +4 Material = 2.68
   Absorption of +4 Material = 2.0%

   Maximum Dry Density of -4 Material = 109.9 lbs/ft^3
   Optimum Moisture of -4 Material = 13.9%

Nuclear Gauge Display Panel

% PR = 104.4%

DD = 114.7
WD = 127.5

M = 12.8 M% = 11.2

2) Indicate in the remarks if the test passes or fails and why.

Form TL-124 (Rev. 07/15)

VIRGINIA DEPARTMENT OF TRANPORTATION
MATERIALS DIVISION
REPORT ON NUCLEAR EMBANKMENT DENSITIES (UNIT MASSES)

Report No. 1-117-1 **Date** 06/22/2015 **Sheet No.** 1 **of** 1
Route No. 117 **County** Roanoke
Project No. 0117-080-105, C501
FHWA No. None
Testing for Embankment
Model No. 3440 **Serial No.** 23456 **Calibration Date** 02/10/2015

STANDARD COUNT DATA

Density 2844 **Moisture** 701

Test No.			**1**	**2**	**3**	**4**
Location	Station ft. (m)		90+45			
of	Ref. to center line ft. (m)		6’ Rt. C/L			
Test	Elevation		+8 / -6			
Compaction Depth of Lift in. (mm)			6”			
Method of Compaction			Sheepsfoot			
A. Wet Density (lbs/ft^3), Wet Unit Mass (kg/m^3)		=				
B. Moisture Unit Mass (lbs/ft^3 or kg/m^3)		=				
C. Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) (A-B)		=				
D. Moisture Content (B ÷ C) x 100		=				
E. Maximum Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) Lab Proctor or One Point Proctor		=				
F. Percent Optimum Moisture from Lab or One Point Proctor		=				
G. Percent of Plus #4, (plus 4.75 mm)		=				
H. Corrected Max. Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3)		=				
I. Corrected Optimum Moisture		=				
J. Percent Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) (C ÷ E) x 100 or (C ÷ H) x 100		=				
K. Percent Minimum Density Required		=				

Comments:

BY: ________________

TITLE: ________________

CALCULATION #1

Amount of +4 Material in Total Soil

Weight of Dry Soil + Dish ____________ lb.
\- Weight of Dish Only ____________ lb.
Total Weight of Dry Soil ____________ lb.

Weight of +4 Material + Dish ____________ lb.
Weight of Dish Only ____________ lb.
Total Weight of +4 Material ____________ lb.

$$\frac{\text{Total Weight of +4 Material}}{\text{Total Weight of Dry Soil}} = \frac{\_\_\_\_\_\_\_\_}{\_\_\_\_\_\_\_\_} = \_\_\_\_\_\_\_ \times 100 = \_\_\_\_\_\_\_\_$$

(Enter on Line G)

CALCULATION #2

Total Density of Soils with +4 Material

Needed Information:

P_c = Percent of +4 material expressed as a decimal = ______________ (Taken from Sieve Analysis)
D_c = ______________ Sp. Gr. of +4 Material x 62.4 lbs/ft^3 = ______________ lbs/ft^3
P_f = Percent of -4 material expressed as a decimal = ______________ (Taken from Sieve Analysis)
D_f = Maximum Dry Density of the -4 material = ______________ (Taken from Proctor)

$$\frac{D_f \times D_c}{(P_c \times D_f) + (P_f \times D_c)} = \underset{\text{Step 1}}{\frac{\_\_\_\_\_ \times \_\_\_\_\_}{(\_\_\_\_\_ \times \_\_\_\_\_) + (\_\_\_\_\_ \times \_\_\_\_\_)}} = \underset{\text{Step 2}}{\frac{\_\_\_\_\_\_\_\_}{(\_\_\_\_\_) + (\_\_\_\_\_)}} = \underset{\text{Step 3}}{\frac{\_\_\_\_\_\_\_\_}{\_\_\_\_\_\_\_\_}} = \_\_\_\_\_\_\_\_\_\_\_\_$$

Maximum Dry Density of Total Soil = ____________ (Enter on Line H)

CALCULATION #3

Optimum Moisture Content of Soils with +4 Material

Needed Information:

P_c = Percent of +4 material expressed as a decimal = ______________ (Taken from Sieve Analysis)
W_c =Absorption of the +4 Material expressed as a decimal = ______________ (Taken from Material Division)
P_f = Percent of -4 material expressed as a decimal = ______________ (Taken from Sieve Analysis)
W_f = Optimum Moisture of the -4 material expressed as a decimal = ______________ (Taken from Proctor)

$$(P_cW_c + P_fW_f) \times 100 = \underset{\text{Step 1}}{[(\_\_\_\_ \times \_\_\_\_) + (\_\_\_\_ \times \_\_\_\_\_)] \times 100} = \underset{\text{Step 2}}{[(\_\_\_\_\_) + (\_\_\_\_\_)] \times 100} = \underset{\text{Step 3}}{(\_\_\_\_\_) \times 100} = \_\_\_\_\_\_$$

Optimum Moisture Content of Total Soil = ___________ (Enter on Line I)

CHAPTER 7 – PRACTICE PROBLEMS

Practice Problem Number 4
Nuclear Density Testing of Aggregate
(Correcting for +4 Material)

1) Complete the embankment density test (Form TL-124) using the calculation sheet and information provided below.

Weight of Dry Soil and Dish = 5.41 lbs.
Weight of Dish Only = 1.61 lbs.
Weight of +4 Material and Dish = 3.01 lbs.

Specific Gravity of +4 Material = 2.73
Absorption of +4 Material = 0.3%

Maximum Dry Density of -4 Material = 124.4 lbs/ft^3
Optimum Moisture of -4 Material = 7.4%

Nuclear Gauge Display Panel

% PR = 107.0%

DD = 133.1
WD = 140.0

M = 6.9 M% = 5.2

2) Indicate in the remarks if the test passes or fails and why.

Form TL-124 (Rev. 07/15)

VIRGINIA DEPARTMENT OF TRANPORTATION
MATERIALS DIVISION
REPORT ON NUCLEAR EMBANKMENT DENSITIES (UNIT MASSES)

Report No. 1-21A-1 **Date** 06/22/2015 **Sheet No.** 1 **of** 1

Route No. 95 **County** Fairfax

Project No. 0095-029-F15, C502

FHWA No. None

Testing for Direct Transmission on Aggregate Base Type I (21A)

Model No. 3440 **Serial No.** 23456 **Calibration Date** 02/10/2015

STANDARD COUNT DATA

Density 2844 **Moisture** 701

Test No.			**1**	**2**	**3**	**4**
Location	Station ft. (m)		24+35			
of	Ref. to center line ft. (m)		5’ Rt. C/L			
Test	Elevation					
Compaction Depth of Lift in. (mm)			6”			
Method of Compaction			Vibratory			
A. Wet Density (lbs/ft^3), Wet Unit Mass (kg/m^3)		=				
B. Moisture Unit Mass (lbs/ft^3 or kg/m^3)		=				
C. Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) (A-B)		=				
D. Moisture Content (B ÷ C) x 100		=				
E. Maximum Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) Lab Proctor or One Point Proctor		=				
F. Percent Optimum Moisture from Lab or One Point Proctor		=				
G. Percent of Plus #4, (plus 4.75 mm)		=				
H. Corrected Max. Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3)		=				
I. Corrected Optimum Moisture		=				
J. Percent Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) (C ÷ E) x 100 or (C ÷ H) x 100		=				
K. Percent Minimum Density Required		=				

Comments:

BY: ____________________

TITLE: ____________________

CALCULATION #1

Amount of +4 Material in Total Soil

Weight of Dry Soil + Dish ____________ lb. Weight of +4 Material + Dish ____________ lb.
\- Weight of Dish Only ____________ lb. Weight of Dish Only ____________ lb.
Total Weight of Dry Soil ____________ lb. Total Weight of +4 Material ____________ lb.

$$\frac{\text{Total Weight of +4 Material}}{\text{Total Weight of Dry Soil}} = \frac{\_\_\_\_\_\_\_\_}{\_\_\_\_\_\_\_\_} = \_\_\_\_\_\_\_ \text{ x } 100 = \_\_\_\_\_\_\_\_$$ (Enter on Line G)

CALCULATION #2

Total Density of Soils with +4 Material

Needed Information:

P_c = Percent of +4 material expressed as a decimal = ______________ (Taken from Sieve Analysis)
D_c = ______________ Sp. Gr. of +4 Material x 62.4 lbs/ft^3 = ______________ lbs/ft^3
P_f = Percent of -4 material expressed as a decimal = ______________ (Taken from Sieve Analysis)
D_f = Maximum Dry Density of the -4 material = ______________ (Taken from Proctor)

$$\frac{D_f \text{ x } D_c}{(P_c \text{ x } D_f) + (P_f \text{ x } D_c)} = \underset{\text{Step 1}}{\frac{\_\_\_\_\_\_ \text{ x } \_\_\_\_\_\_\_}{(\_\_\_\_\_ \text{ x } \_\_\_\_\_) + (\_\_\_\_\_ \text{ x } \_\_\_\_\_)}} = \underset{\text{Step 2}}{\frac{\_\_\_\_\_\_\_\_}{(\_\_\_\_) + (\_\_\_\_)}} = \underset{\text{Step 3}}{\frac{\_\_\_\_\_\_\_\_}{\_\_\_\_\_\_\_\_}} = \_\_\_\_\_\_\_\_\_\_\_\_$$

Maximum Dry Density of Total Soil = ____________ (Enter on Line H)

CALCULATION #3

Optimum Moisture Content of Soils with +4 Material

Needed Information:

P_c = Percent of +4 material expressed as a decimal = ______________ (Taken from Sieve Analysis)
W_c = Absorption of the +4 Material (+1) expressed as a decimal = ______________ (Taken from Material Division)
P_f = Percent of -4 material expressed as a decimal = ______________ (Taken from Sieve Analysis)
W_f = Optimum Moisture of the -4 material expressed as a decimal = ______________ (Taken from Proctor)

$$(P_cW_c + P_fW_f) \text{ x } 100 = \underset{\text{Step 1}}{[(\_\_\_\_ \text{ x } \_\_\_\_\_) + (\_\_\_\_ \text{ x } \_\_\_\_\_)] \text{ x } 100} = \underset{\text{Step 2}}{[(\_\_\_\_\_) + (\_\_\_\_\_)] \text{ x } 100} = \underset{\text{Step 3}}{(\_\_\_\_\_\_) \text{ x } 100} = \_\_\_\_\_\_$$

Optimum Moisture Content of Total Soil = ___________ (Enter on Line I)

CHAPTER 7 – PRACTICE PROBLEMS

Practice Problem Number 5
Nuclear Density Testing of Aggregate
(Correcting for +4 Material)

1) Complete the embankment density test (Form TL-124) using the calculation sheet and information provided below.

Weight of Dry Soil and Dish = 8.43 lbs.
Weight of Dish Only = 1.61 lbs.
Weight of +4 Material and Dish = 5.71 lbs.

Specific Gravity of +4 Material = 2.81
Absorption of +4 Material = 0.3%

Maximum Dry Density of -4 Material = 134.6 lbs/ft^3
Optimum Moisture of -4 Material = 8.4%

Nuclear Gauge Display Panel

% PR = 111.6%

DD = 150.2
WD = 155.3

M = 5.1   M% = 3.4

2) Indicate in the remarks if the test passes or fails and why.

Form TL-124 (Rev. 07/15)

VIRGINIA DEPARTMENT OF TRANPORTATION
MATERIALS DIVISION
REPORT ON NUCLEAR EMBANKMENT DENSITIES (UNIT MASSES)

Report No. 1-21A-1 **Date** 06/22/2015 **Sheet No.** 1 **of** 1

Route No. 7 **County** Loudon

Project No. 0007-053-121, C501

FHWA No. None

Testing for Direct Transmission on Aggregate Base Type I (21A)

Model No. 3440 **Serial No.** 23456 **Calibration Date** 02/10/2015

STANDARD COUNT DATA

Density 2864 **Moisture** 709

Test No.			**1**	**2**	**3**	**4**
Location	Station ft. (m)		901+25			
of	Ref. to center line ft. (m)		3’ Lt. C/L			
Test	Elevation					
Compaction Depth of Lift in. (mm)			6”			
Method of Compaction			Vibratory			
A. Wet Density (lbs/ft^3), Wet Unit Mass (kg/m^3)		=				
B. Moisture Unit Mass (lbs/ft^3 or kg/m^3)		=				
C. Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) (A-B)		=				
D. Moisture Content (B ÷ C) x 100		=				
E. Maximum Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) Lab Proctor or One Point Proctor		=				
F. Percent Optimum Moisture from Lab or One Point Proctor		=				
G. Percent of Plus #4, (plus 4.75 mm)		=				
H. Corrected Max. Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3)		=				
I. Corrected Optimum Moisture		=				
J. Percent Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) (C ÷ E) x 100 or (C ÷ H) x 100		=				
K. Percent Minimum Density Required		=				

Comments:

BY: ____________________

TITLE: ____________________

CALCULATION #1

Amount of +4 Material in Total Soil

Weight of Dry Soil + Dish ____________ lb.
\- Weight of Dish Only ____________ lb.
Total Weight of Dry Soil ____________ lb.

Weight of +4 Material + Dish ____________ lb.
Weight of Dish Only ____________ lb.
Total Weight of +4 Material ____________ lb.

$$\frac{\text{Total Weight of +4 Material}}{\text{Total Weight of Dry Soil}} = \frac{\_\_\_\_\_\_\_\_}{\_\_\_\_\_\_\_\_} = \_\_\_\_\_\_\_\_ \text{ x } 100 = \_\_\_\_\_\_\_\_ \text{ (Enter on Line G)}$$

CALCULATION #2

Total Density of Soils with +4 Material

Needed Information:

P_c = Percent of +4 material expressed as a decimal = _______________ (Taken from Sieve Analysis)
D_c = _______________ Sp. Gr. of +4 Material x 62.4 lbs/ft^3 = _______________ lbs/ft^3
P_f = Percent of -4 material expressed as a decimal = _______________ (Taken from Sieve Analysis)
D_f = Maximum Dry Density of the -4 material = _______________ (Taken from Proctor)

$$\frac{D_f \text{ x } D_c}{(P_c \text{ x } D_f) + (P_f \text{ x } D_c)} = \frac{\_\_\_\_\_\_ \text{ x } \_\_\_\_\_\_}{(\_\_\_\_\_ \text{ x } \_\_\_\_\_) + (\_\_\_\_\_ \text{ x } \_\_\_\_\_)} = \frac{\_\_\_\_\_\_\_\_}{(\_\_\_\_) + (\_\_\_\_)} = \frac{\_\_\_\_\_\_\_\_}{\_\_\_\_\_\_\_\_} = \_\_\_\_\_\_\_\_\_\_\_$$

Step 1 Step 2 Step 3

Maximum Dry Density of Total Soil = ____________ (Enter on Line H)

CALCULATION #3

Optimum Moisture Content of Soils with +4 Material

Needed Information:

P_c = Percent of +4 material expressed as a decimal = _______________ (Taken from Sieve Analysis)
W_c = Absorption of the +4 Material (+1) expressed as a decimal = _______________ (Taken from Material Division)
P_f = Percent of -4 material expressed as a decimal = _______________ (Taken from Sieve Analysis)
W_f = Optimum Moisture of the -4 material expressed as a decimal = _______________ (Taken from Proctor)

$$(P_cW_c + P_fW_f) \text{ x } 100 = [(\_\_\_\_ \text{ x } \_\_\_\_\_) + (\_\_\_\_ \text{ x } \_\_\_\_\_)] \text{ x } 100 = [(\_\_\_\_\_) + (\_\_\_\_\_)] \text{ x } 100 = (\_\_\_\_\_\_) \text{ x } 100 = \_\_\_\_\_\_$$

Step 1 Step 2 Step 3

Optimum Moisture Content of Total Soil = ___________ (Enter on Line I)

CHAPTER 7 – PRACTICE PROBLEMS

Practice Problem Number 6
Nuclear Density Testing of Aggregate
(Correcting for +4 Material)

1) Complete the embankment density test (Form TL-124) using the calculation sheet and information provided below.

    Weight of Dry Soil and Dish = 8.40 lbs.
    Weight of Dish Only = 1.63 lbs.
    Weight of +4 Material and Dish = 4.75 lbs.

    Specific Gravity of +4 Material = 2.80
    Absorption of +4 Material = 0.6%

    Maximum Dry Density of -4 Material = 132.1 lbs/ft^3
    Optimum Moisture of -4 Material = 7.2%

Nuclear Gauge Display Panel

% PR = 109.1%

DD = 144.1
WD = 150.2

M = 6.1 **M% = 4.2**

2) Indicate in the remarks if the test passes or fails and why.

Form TL-124 (Rev. 07/15)

VIRGINIA DEPARTMENT OF TRANPORTATION
MATERIALS DIVISION
REPORT ON NUCLEAR EMBANKMENT DENSITIES (UNIT MASSES)

Report No. 1-21A-1 **Date** 06/22/2015 **Sheet No.** 1 **of** 1
Route No. 265 **County** Pittsylvania
Project No. 6265-071-102, G302
FHWA No. None
Testing for Direct Transmission on Aggregate Base Type I (21A)
Model No. 3440 **Serial No.** 23456 **Calibration Date** 02/10/2015

STANDARD COUNT DATA

Density 2844 **Moisture** 701

Test No.			**1**	**2**	**3**	**4**
Location	Station ft. (m)		609+10			
of	Ref. to center line ft. (m)		6’ Rt. C/L			
Test	Elevation					
Compaction Depth of Lift in. (mm)			6”			
Method of Compaction			Vibratory			
A. Wet Density (lbs/ft^3), Wet Unit Mass (kg/m^3)		=				
B. Moisture Unit Mass (lbs/ft^3 or kg/m^3)		=				
C. Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) (A-B)		=				
D. Moisture Content (B ÷ C) x 100		=				
E. Maximum Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) Lab Proctor or One Point Proctor		=				
F. Percent Optimum Moisture from Lab or One Point Proctor		=				
G. Percent of Plus #4, (plus 4.75 mm)		=				
H. Corrected Max. Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3)		=				
I. Corrected Optimum Moisture		=				
J. Percent Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) (C ÷ E) x 100 or (C ÷ H) x 100		=				
K. Percent Minimum Density Required		=				

Comments:

BY: ____________________

TITLE: ____________________

CALCULATION #1
Amount of +4 Material in Total Soil

	Weight of Dry Soil + Dish	________	lb.	Weight of +4 Material + Dish	________	lb.
-	Weight of Dish Only	________	lb.	Weight of Dish Only	________	lb.
	Total Weight of Dry Soil	________	lb.	Total Weight of +4 Material	________	lb.

$$\frac{\text{Total Weight of +4 Material}}{\text{Total Weight of Dry Soil}} = \frac{\underline{\qquad}}{\underline{\qquad}} = \underline{\qquad} \times 100 = \underline{\qquad}\ \text{(Enter on Line G)}$$

CALCULATION #2
Total Density of Soils with +4 Material

Needed Information:

P_c = Percent of +4 material expressed as a decimal = ________ (Taken from Sieve Analysis)

D_c = ________ Sp. Gr. of +4 Material x 62.4 lbs/ft^3 = ________ lbs/ft^3

P_f = Percent of -4 material expressed as a decimal = ________ (Taken from Sieve Analysis)

D_f = Maximum Dry Density of the -4 material = ________ (Taken from Proctor)

$$\frac{D_f \times D_c}{(P_c \times D_f) + (P_f \times D_c)} = \frac{\underline{\qquad} \times \underline{\qquad}}{(\underline{\quad} \times \underline{\quad}) + (\underline{\quad} \times \underline{\quad})} = \frac{\underline{\qquad}}{(\underline{\quad}) + (\underline{\quad})} = \frac{\underline{\qquad}}{\underline{\qquad}} = \underline{\qquad\qquad}$$

Step 1 Step 2 Step 3

Maximum Dry Density of Total Soil = ________ (Enter on Line H)

CALCULATION #3
Optimum Moisture Content of Soils with +4 Material

Needed Information:

P_c = Percent of +4 material expressed as a decimal = ________ (Taken from Sieve Analysis)

W_c = Absorption of the +4 Material (+1) expressed as a decimal = ________ (Taken from Material Division)

P_f = Percent of -4 material expressed as a decimal = ________ (Taken from Sieve Analysis)

W_f = Optimum Moisture of the -4 material expressed as a decimal = ________ (Taken from Proctor)

$$(P_cW_c + P_fW_f) \times 100 = [(\underline{\quad} \times \underline{\quad}) + (\underline{\quad} \times \underline{\quad})] \times 100 = [(\underline{\quad}) + (\underline{\quad})] \times 100 = (\underline{\quad}) \times 100 = \underline{\qquad}$$

Step 1 Step 2 Step 3

Optimum Moisture Content of Total Soil = ________ (Enter on Line I)

8

ROLLER PATTERNS, CONTROL STRIPS, AND TEST SECTIONS

LEARNING OUTCOMES

- Understand the procedures and methods for establishing the roller pattern
- Understand the procedures and methods for establishing the control strip
- Understand the procedures and methods for evaluating aggregate test sections

INTRODUCTION

In order to determine if maximum density in the field has been achieved, we must first establish a target density. The actual density tests are taken in the field and compared to that ideal or target density to determine whether the tests pass or fail. The following flow chart demonstrates the appropriate methods used to establish the targets and then the corresponding testing methods used to determine density in place for both soil and aggregate materials.

This chapter will discuss the establishment of a target density for aggregates by means of a roller pattern and control strip using the nuclear gauge method of testing.

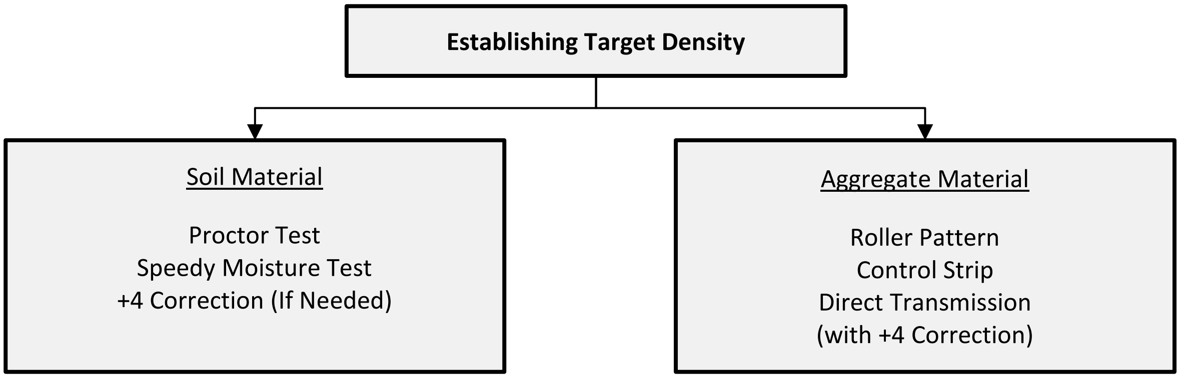


Figure 8.1: Testing Methods for Establishing Target Densities

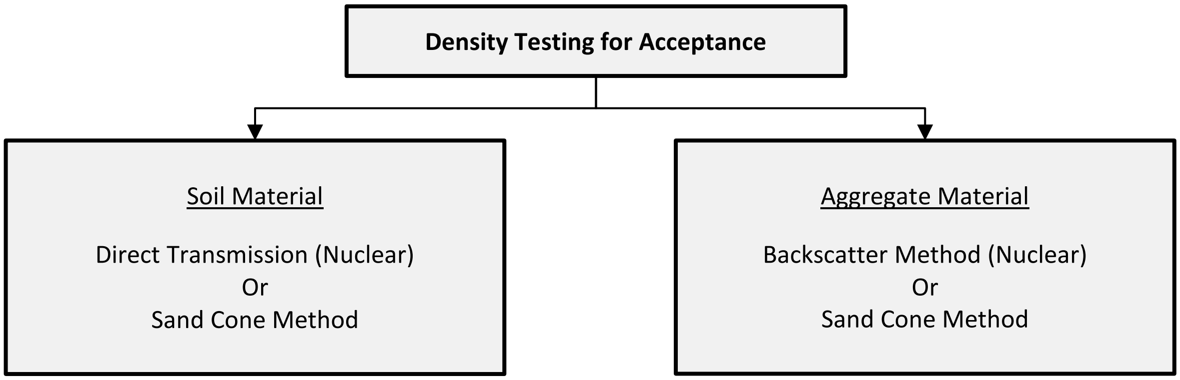


Figure 8.2: Testing Methods for Material Acceptance

TESTING PROCEDURES FOR AGGREGATE BASE, SUBBASE, AND SELECT MATERIALS

(Roller Pattern, Control Strip, Direct Transmission, and Acceptance Testing)

Before any acceptance testing can be performed on aggregate base, subbase, or select material, a roller pattern, control strip, and direct transmission test must be established. A roller pattern/control strip is a section of roadway on which the construction technique (placing, compacting, and shaping) of the material to be tested has been closely monitored and evaluated. A direct transmission test (VTM-10 Appendix D) is taken at the end of the control strip to compare its results to the Theoretical Maximum Density as established in accordance with VTM-1.

There are three requirements that must be met by the roller pattern/control strip/direct transmission test:

1) Roller Pattern – the establishment of a graphical comparison between roller passes and the density achieved; this gives the number of passes needed on the material to achieve the required density.

2) Control Strip – the determination of the average dry density of the control strip, which has been rolled according to the pattern established by the roller pattern; this provides the Control Values, which govern the acceptance of the Test Sections.

3) Direct Transmission Test – the comparison of the results of a direct transmission test to the Theoretical Maximum Density in accordance with VTM-1; this verifies that the Control Strip attained the maximum density achievable and therefore may be used to govern the Acceptance Test Sections.

Before the construction of a control strip, the Inspector and Contractor should be familiar with VDOT Specification Section 304. A copy of this Specification is located in Appendix C. If assistance is needed in setting up the roller pattern and control strip, contact the District Materials' Engineers office.

Initial Requirements:

A. A roller pattern must be established for each control strip. Before establishing these tests, communication with the contractor is fundamental to achieving accurate test results.

B. The results of the roller pattern are recorded on Form TL-53, the control strip on Form TL-54, the direct transmission test on Form TL-124 and the test section on Form TL-55.

C. All equipment should remain off the control strip until the material has been placed on the entire area.

D. After the material has been placed, the roller and water truck are the only two pieces of equipment allowed on the control strip until maximum density has been obtained.

ROLLER PATTERN CONSTRUCTION

Equipment needed:

- Portable Nuclear Moisture-Density Gauge
- 6 foot charger cord
- Reference Standard Block
- Leveling Plate/Drill Rod Guide
- Drill Rod with Extraction Tool
- Hammer
- Compaction Equipment (that is typical for the rest of the project)

The material used to construct the Roller Pattern must also be representative of the material that will be used for the Control Strip and Test Sections. A change in material will require a new roller pattern.

NOTE: For base, subbase and select material, the Backscatter method can be used.

Roller Pattern Procedure:

NOTE: A set of forms at the end of this chapter follows this procedure step by step through the readings and calculations.

1) Establish an area at least 10 feet from any structure and 33 feet from any other radioactive sources to take the Standard Counts. The area should be firm, such as a concrete or asphalt slab, or well compacted soil with a minimum density of 100 lbs/ft^3. Allow the 3440 gauge to complete a 4 minute count cycle with the gauge on the standard block. Be sure the standard counts you get a “P” next to each of them indicating they pass. These readings should be recorded on the top of the TL-53, TL-54, TL-55 and TL-124.

2) Select a level and uniform section of roadway that is large enough for the roller pattern (about 75 feet long for the typical application width – an area of at least 100 yd^2). Place the material on this section of roadway at the proper loose depth before any rolling is started. For shoulder material, the Roller Pattern should be sufficient length, so as to have an area of at least 100 yd^2. The material must be compacted uniformly from bottom to top and in the same manner as the remainder of the job.

   The moisture content of aggregates should be kept as near optimum as possible throughout the rolling operation. Water must be added when needed to maintain optimum moisture in accordance with

Section 308 and 309 of the Road and Bridge Specifications during the compaction process. Section 309.05 states after mixing and shaping each layer shall be compacted at optimum moisture within ± 2 percentage points of optimum.

3) Make passes with the roller over the entire surface of the roller pattern. One pass is counted each time the roller crosses the test site. Make sure the previous pass has been completed over the entire surface before the next pass is started. When testing aggregates, take a nuclear test for density and one for moisture in the 15-second mode, using the Backscatter Method. This test should be made at three randomly selected points with good surface conditions. Try to spread the 3 tests over most of the 75 foot section, making sure not to test any closer than 18" to an unsupported edge. Be sure to mark the exact location of each test. If paint is used to mark the test locations, be careful not to paint the gauge (use a template). Record the dry density and percent moisture on TL-53 and obtain the total and average for both moisture and density. Plot the average dry density versus the number of roller passes on the graph. All further tests for the roller pattern must be made in the same 3 locations, with the gauge source rod pointing in the same direction as the first test.

   Make 2 more passes with the roller over the entire surface of the Roller Pattern, and again take 3 density and moisture readings in the exact same location as the first test. Record these readings under Test No. 2 and plot this second result in the same manner as for Test No. 1.

4) Continue rolling and testing until the roller pattern reaches its maximum density before decreasing or until the graph levels off. To be sure this is a sufficient degree of compaction, make one additional roll over the entire surface and test again.

   NOTE: When the increase in dry density for a Roller Pattern on granular base is less than 1 lb/ft^3 to the maximum dry density, make one additional pass. If the density does not increase by 1 lb/ft^3 with the additional pass, the rolling should be discontinued.

There may be instances where a decrease in density rather than a small increase will occur. This usually is due to a false break where the density levels off well before maximum density is achieved. If this happens, examine the material and if no fracture of the material is visible, continue the rolling process until the maximum density can be obtained. Over-rolling can also cause a decrease in density. Consideration should be given to the number of passes already made and the materials involved – making certain that the break occurring in the Roller Pattern curve is not greater than 1.5 lbs/ft^3. If the break is greater than 1.5 lbs/ft^3, recompact the material to its maximum dry density based on the peak value of the Roller Pattern curve.

Criteria for Establishing a New Roller Pattern:

A new Roller Pattern should be established:

- Whenever there are multiple lifts of material Change in Source of material
- Change in compaction equipment
- Visual change in subsurface or subgrade conditions
- Change in gradation or type of material
- Change in depth of lift

Form TL-53 (Rev. 07/15)

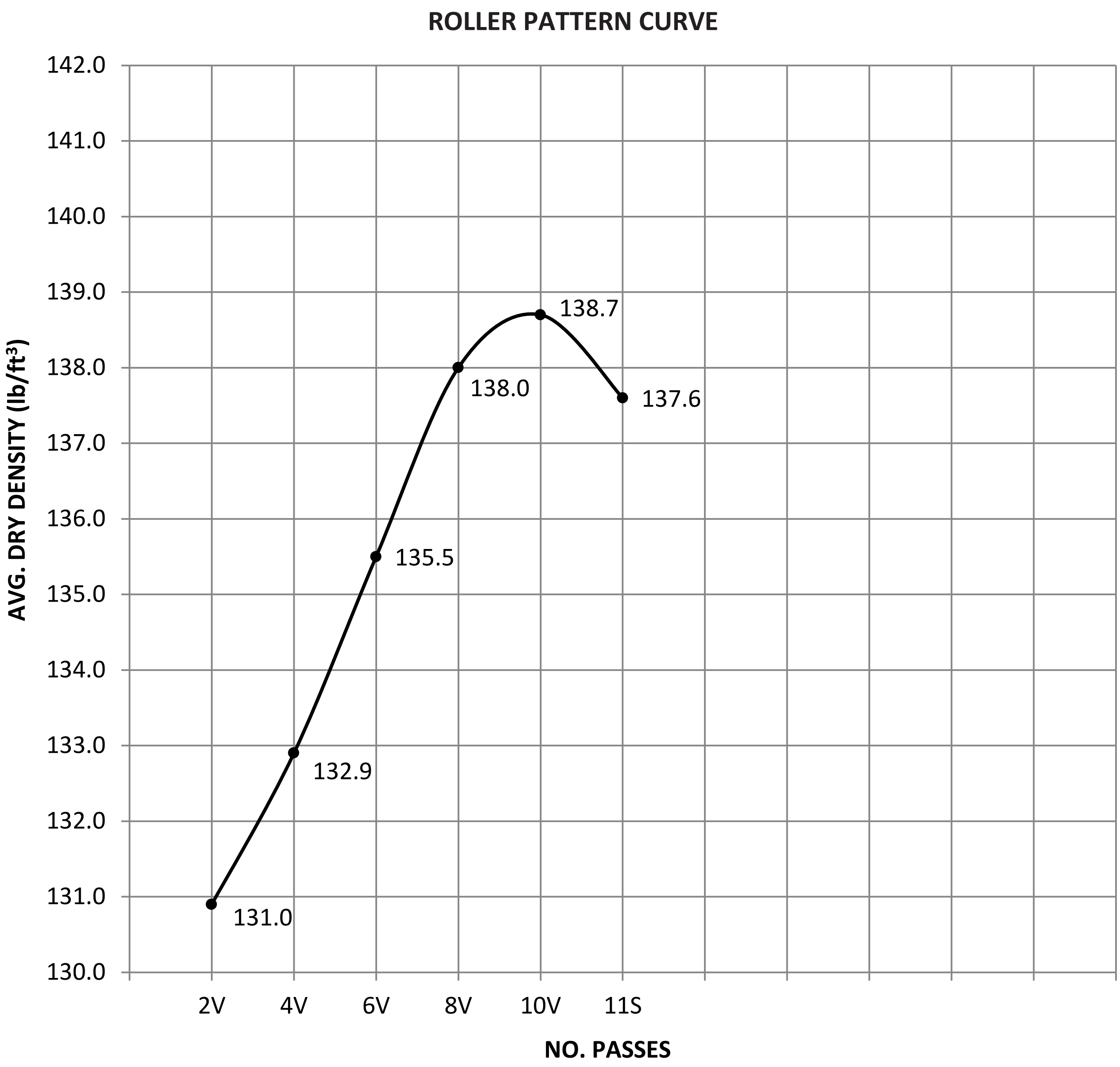
VIRGINIA DEPARTMENT OF TRANPORTATION
MATERIALS DIVISION
REPORT ON NUCLEAR ROLLER PATTERN

Report No. 1-21A-1 **Nuclear Gauge Model No.** 3440 **Serial No.** 23456
Date 06/22/2015 **Project No.** 0066-029-F19, C501 **Route No.** 66
FHWA No. IM-NH-66-1 **County** Fairfax
Section No. ______ **Station No.** 600+00 **ft. (m.) to Station** 600+75 **ft. (m.)**
Type Material Aggregate Base Type I (21A) **Width** 12 **ft. (m.)**
Optimum Moisture 5.2 **Optimum Moisture Range** 3.2 – 5.2
Remarks Roller Pattern #1 (“V” is for Vibratory and “S” is for Static)

STANDARD COUNT DATA

Density 2830 **Moisture** 701

TEST NO.	DRY DENSITY	MOISTURE	TEST NO.	DRY DENSITY	MOISTURE
Test No. 1 No. of Passes 2V			**Test No. 6 No. of Passes 11S**		
Sta. 600+00	137.2	4.4	**Sta. 600+00**	138.5	4.8
Sta. 600+40	131.8	5.3	**Sta. 600+40**	136.8	5.3
Sta. 600+75	123.9	4.4	**Sta. 600+75**	137.6	5.5
Total	392.9	14.1	**Total**	412.9	15.6
Average	131.0	4.7	**Average**	137.6	5.2
Test No. 2 No. of Passes 4V			**Test No. 7 No. of Passes**		
Sta. 600+00	137.4	4.8	**Sta.**		
Sta. 600+40	132.4	6.2	**Sta.**		
Sta. 600+75	128.9	4.9	**Sta.**		
Total	398.7	15.9	**Total**		
Average	132.9	5.3	**Average**		
Test No. 3 No. of Passes 6V			**Test No. 8 No. of Passes**		
Sta. 600+00	137.8	4.2	**Sta.**		
Sta. 600+40	134.2	5.8	**Sta.**		
Sta. 600+75	134.5	5.3	**Sta.**		
Total	406.5	15.3	**Total**		
Average	135.5	5.1	**Average**		
Test No. 4 No. of Passes 8V			**Test No. 9 No. of Passes**		
Sta. 600+00	138.6	4.6	**Sta.**		
Sta. 600+40	137.2	5.2	**Sta.**		
Sta. 600+75	138.3	4.6	**Sta.**		
Total	414.1	14.4	**Total**		
Average	138.0	4.8	**Average**		
Test No. 5 No. of Passes 10V			**Test No. 10 No. of Passes**		
Sta. 600+00	139.3	4.2	**Sta.**		
Sta. 600+40	137.3	5.0	**Sta.**		
Sta. 600+75	139.5	5.3	**Sta.**		
Total	416.1	14.5	**Total**		
Average	138.7	4.8	**Average**		



Comments:

By: ______________________

Title: ______________________

Form TL-53 (Rev. 07/15)

VIRGINIA DEPARTMENT OF TRANPORTATION
MATERIALS DIVISION
REPORT ON NUCLEAR ROLLER PATTERN

Report No. 1-21A-1 **Nuclear Gauge Model No.** 3440 **Serial No.** 23456
Date 06/22/2015 **Project No.** 0066-029-F19, C501 **Route No.** 66
FHWA No. IM-NH-66-1 **County** Fairfax
Section No. **Station No.** 600+00 **ft. (m.) to Station** 600+75 **ft. (m.)**
Type Material Aggregate Base Type I (21A) **Width** 12 **ft. (m.)**
Optimum Moisture 5. 3.2 – 5.2
Remarks Roller Pattern #1 (V is for Vib

Averages for Dry Density and Moisture must be calculated for each of the three (3) individual tests performed

Dry Density

1) 137.2 + 131.8 + 123.9 =392.9

2) 392.9 ÷ 3 = 131.0 lbs/ft^3 (Average)

Moisture

1) 4.4 + 5.3 + 4.4 = 14.1

2) 14.1 ÷ 3 = 4.7% (Average)

Density 2830 701

TEST NO.	**DRY DENSITY**			**DENSITY**	**MOISTURE**
Test No. 1 **No. of Passes 2V**					
Sta. 600+00	137.2	4.4	**Sta. 600+00**	138.5	4.8
Sta. 600+40	131.8	5.3	**Sta. 600+40**	136.8	5.3
Sta. 600+75	123.9	4.4	**Sta. 600+75**	137.6	5.5
Total	392.9	14.1	**Total**	412.9	15.6
Average	131.0	4.7	**Average**	137.6	5.2
Test No. 2 **No. of Passes 4V**			**Test No. 7** **No. of Passes**		
Sta. 600+00	137.4	4.8	**Sta.**		
Sta. 600+40	132.4	6.2	**Sta.**		
Sta. 600+75	128.9	4.9	**Sta.**		
Total	398.7	15.9	**Total**		
Average	132.9	5.3	**Average**		
Test No. 3 **No. of Passes 6V**			**Test No. 8** **No. of Passes**		
Sta. 600+00	137.8	4.2	**Sta.**		
Sta. 600+40	134.2	5.8	**Sta.**		
Sta. 600+75	134.5	5.3	**Sta.**		
Total	406.5	15.3	**Total**		
Average	135.5	5.1	**Average**		
Test No. 4 **No. of Passes 8V**					
Sta. 600+00	138.6				
Sta. 600+40	137.2				
Sta. 600+75	138.3	4.6	**Sta.**		
Total	414.1	14.4	**Total**		
Average	138.0	4.8	**Average**		
Test No. 5 **No. of Passes 10V**					
Sta. 600+00	139.3				
Sta. 600+40	137.3				
Sta. 600+75	139.5	[illegible]	**Sta.**		
Total	416.1	14.5	**Total**		
Average	138.7	4.8	**Average**		

Test 6 is < than Test 5

- **Break is < 1.5 lbs/ft^3**
- **Indicates an acceptable break**
- **Stop rolling operation**
- **Roller Pattern is 10 passes in vibratory mode (10V)**

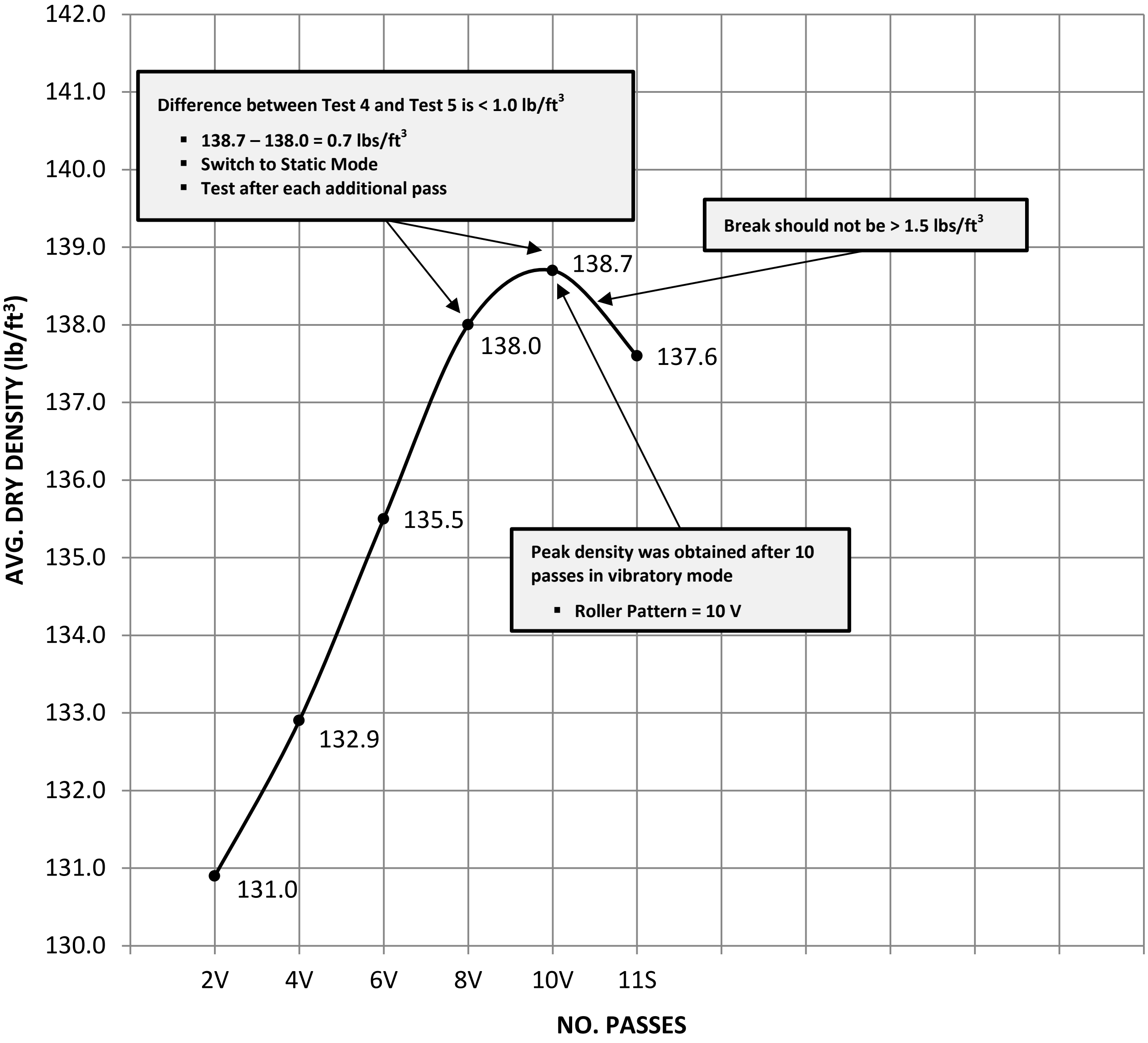
Difference between Test 3 and Test 4 is > 1.0 lb/ft^3

- **138.0 – 135.5 = 2.5 lbs/ft^3**
- **Continue making passes in Vibratory Mode**
- **Continue testing after two additional passes**

Difference between Test 4 and Test 5 is < 1.0 lb/ft^3

- **138.7 – 138.0 = 0.7 lbs/ft^3**
- **Switch to Static Mode**
- **Test after each additional pass**

ROLLER PATTERN CURVE



Difference between Test 4 and Test 5 is < 1.0 lb/ft^3

- **138.7 – 138.0 = 0.7 lbs/ft^3**
- **Switch to Static Mode**
- **Test after each additional pass**

Break should not be > 1.5 lbs/ft^3

Peak density was obtained after 10 passes in vibratory mode

- **Roller Pattern = 10 V**

Comments:

By: ______________________________

Title: ______________________________

THE CONTROL STRIP

Control Strip Procedure:

1) To prepare a Control Strip, place the material under the same conditions as outlined in Step 3 of the Roller Pattern, on an additional section of roadway approximately 300 feet in length and one travel lane in width. After placement, this area is to be rolled the number of passes determined in the Roller Pattern to achieve the peak density.

2) To determine the density of the Control Strip, use the Backscatter Method in the 1 minute mode. Take 10 nuclear readings for moisture and density over the entire section. The results are added and an average is obtained on Form TL-54. This dry density should be within 3.0 lbs/ft^3 of the Roller Pattern peak density. The control (target) values of 95% and 98% of the average dry density can now be determined. These are used to determine the acceptance of the Test Sections.

3) Direct Transmission – The dry density average that has been established from the Control Strip needs to meet two criteria in order to be acceptable for use with the remaining test sections.

    a) The average dry density from the control strip should be within 3.0 lbs/ft^3 of the Roller Pattern peak density.

    b) At the completion of the Control Strip, a verification test will be performed when testing aggregates using the direct transmission method with a nuclear moisture density gauge, or other methods approved by the Materials Engineer. At the completion of the test, the density of aggregate material shall be compared to the theoretical maximum density as determined in accordance with the requirements of VTM-1. The density shall conform to the following:

% Retained on No. 4 Sieve	% Minimum Density
0 – 50	95
51 – 60	90
61 – 70	85

NOTE: Percentages of material will be reported to the nearest whole number. The requirements for percent density referenced above, apply to the direct transmission method for aggregate only. See Chapter 7 for procedure. Record the results on the TL-124 Form.

4) Once the Control Strip dry density has been accepted – the remainder of the TL-54 can be completed.

5) After the direct transmission test passes and the Control Strip dry density has been accepted – the target values should be transferred to the TL-55 (Test Section).

Determining the Control (Target) Values from the Control Strip Testing:

The control (target) values for the rest of the density testing on a given project are set at 98% and 95% of the average dry density determined by the Control Strip.

Using the control values:

- The average of the five readings from the Test Section must be equal to or greater than 98% of the Control Strip dry density.
- Each individual reading from the Test Section must be equal to or greater than 95% of the Control Strip dry density.

For shoulder material:

- The average density must be 95% (± 2 percentage points) of the Control Strip dry density.
- Each individual density must be 95% (± 5 percentage points) of the Control Strip dry density.

Form TL-54 (Rev. 07/15)

VIRGINIA DEPARTMENT OF TRANPORTATION
MATERIALS DIVISION
REPORT ON NUCLEAR CONTROL STRIP

Report No. 1-21A-2 **Date** 06/22/2015
Route No. 66 **Project No.** 0066-029-F19, C501
FHWA No. IM-NH-66-1 **County** Fairfax
Type Material Aggregate Base Type I (21A) **Width** 12
Station No. 601+25 **ft. (m.) to Station** 604+25 **ft. (m.) to Nuclear Gauge**
Model No. 3440 **Serial No.** 23456
Remarks

STANDARD COUNT DATA

Density 2830 **Moisture** 701

	STATION	REFERENCE TO CENTER LINE FT. (M)	LANE	DRY DENSITY (LB/FT^3) DRY UNIT MASS (KG/M^3)	MOISTURE CONTENT
1	601+25	3 FT. RT.	EBL	138.0	4.9
2	601+50	9 FT. RT.	EBL	139.2	5.3
3	602+00	6 FT. RT.	EBL	138.5	4.8
4	602+25	9 Ft. Rt.	EBL	139.3	5.4
5	602+75	3 Ft. Rt.	EBL	138.7	4.9
6	603+00	6 Ft. Rt.	EBL	139.1	5.1
7	603+50	9 Ft. Rt.	EBL	139.0	4.7
8	603+75	6 Ft. Rt.	EBL	139.2	5.2
9	604+00	3 Ft. Rt.	EBL	139.0	4.6
10	604+25	9 Ft. Rt.	EBL	140.5	6.1
			TOTAL:	1390.5	
			AVERAGE:	139.1	

5.2 **OPTIMUM MOSTURE REQUIRED (From Producer or Materials Division)**

3.2 – 7.2 **OPTIMUM MOISTURE RANGE**

(139.1) x 0.95 = Dens. Avg. 132.1 **INDIVIDUAL DRY DENSITY (lbs/ft^3), DRY UNIT MASS (kg/m^3) REQUIREMENT FOR TEST SECTION**

(139.1) x 0.98 = Dens. Avg. 136.3 **AVERAGE DRY DENSITY (lbs/ft^3), DRY UNIT MASS (kg/m^3) REQUIREMENT FOR TEST SECTION**

BY:

TITLE:

Form TL-54 (Rev. 07/15)

VIRGINIA DEPARTMENT OF TRANPORTATION
MATERIALS DIVISION
REPORT ON NUCLEAR CONTROL STRIP

Report No. 1-21A-2 **Date** 06/22/2015
Route No. 66 **Project No.** 0066-029-F19, C501
FHWA No. IM-NH-66-1 **County** Fairfax
Type Material Aggregate Base Type I (21A) **Width** 12
Station No. 601+25 **ft. (m.) to Station** 604+25 **ft. (m.) to Nuclear Gauge**
Model No. 3440 **Serial No.** 23456
Remarks ______

An overall average Dry Density must be calculated from each of the ten (3) individual tests performed

1) **138.0 + 139.2 + 138.5 + 139.3 + 138.7 + 139.1 + 139.0 + 139.2 + 139.0 + 140.5 = 1390.5**
2) **1390.5 ÷ 10 = 139.1 lbs/ft^3**

Avg. Control Strip Density must within 3.0 lbs/ft^3 of Roller Patter Peak Density

oisture 701

				ENSITY (LB/FT^3) T MASS (KG/M^3)	**MOISTURE CONTENT**
1	601+25	3 FT. RT.	EBL	138.0	4.9
2	601+50	9 FT. RT.	EBL	139.2	5.3
3	602+00	6 FT. RT.	EBL	138.5	4.8
4	602+25	9 Ft. Rt.	EBL	139.3	5.4
5	602+75	3 Ft. Rt.	EBL	138.7	4.9
6	603+00	6 Ft. Rt.	EBL	139.1	5.1
7	603+50	9 Ft. Rt.	EBL	139.0	4.7
8	603+75	6 Ft. Rt.	EBL	139.2	5.2
9	604+00	3 Ft. Rt.	EBL	139.0	4.6
10	604+25	9 Ft. Rt.	EBL	140.5	6.1
			TOTAL:	1390.5	
			AVERAGE:	139.1	

Average Control Strip Density

5.2 **OPTIMUM MOSTURE REQUIRED (From Producer or Materials Division)**

The Optimum Moisture Required cannot be determined until after the +4 Correction for Optimum Moisture is made on the Form TL-124 (Report on Nuclear Embankment Densities)

3.2 – 7.2

(139.1) x 0.95 = Dens. Avg. 132.1 **INDIVIDUAL DRY DENSITY (lbs/ft^3), DRY UNIT MASS (kg/m^3) REQUIREMENT FOR TEST SECTION**

(139.1) x 0.98 = Dens. Avg. 136.3 **AVERAGE DRY DENSITY (lbs/ft^3), DRY UNIT MASS (kg/m^3) REQUIREMENT FOR TEST SECTION**

BY: ______

TITLE: ______

Form TL-124 (Rev. 07/15)

VIRGINIA DEPARTMENT OF TRANPORTATION
MATERIALS DIVISION
REPORT ON NUCLEAR EMBANKMENT DENSITIES (UNIT MASSES)

Report No. 1-21A-3 **Date** 06/22/2015 **Sheet No.** 1 **of** 1

Route No. 66 **County** Campbell

Project No. 0066-029-F19, C501

FHWA No. IM-NH-66-1

Testing for Aggregate Base Type I (21A)

Model No. 3440 **Serial No.** 23456 **Calibration Date** 02/10/2015

STANDARD COUNT DATA

Density 2830 **Moisture** 701

Test No.			**1**	**2**	**3**	**4**
Location	Station ft. (m)		603+00			
of	Ref. to center line ft. (m)		5’ Rt. C/L			
Test	Elevation					
Compaction Depth of Lift in. (mm)			6”			
Method of Compaction			Vibratory			
A. Wet Density (lbs/ft^3), Wet Unit Mass (kg/m^3)		=	140.9			
B. Moisture Unit Mass (lbs/ft^3 or kg/m^3)		=	7.0			
C. Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) (A-B)		=	133.9			
D. Moisture Content (B ÷ C) x 100		=	5.2			
E. Maximum Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) Lab Proctor or One Point Proctor		=	132.8			
F. Percent Optimum Moisture from Lab or One Point Proctor		=	10.7			
G. Percent of Plus #4, (plus 4.75 mm)		=	58.0			
H. Corrected Max. Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3)		=	145.4			
I. Corrected Optimum Moisture		=	5.2 3.2 – 7.2			
J. Percent Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) (C ÷ E) x 100 or (C ÷ H) x 100		=	92.1			
K. Percent Minimum Density Required		=	90.0			

Comments:

BY: ____________________

TITLE: ____________________

Form TL-124 (Rev. 07/15)

VIRGINIA DEPARTMENT OF TRANPORTATION
MATERIALS DIVISION
REPORT ON NUCLEAR EMBANKMENT DENSITIES (UNIT MASSES)

Report No. 1-21A-3 **Date** 06/22/2015 **Sheet No.** 1 **of** 1
Route No. 66 **County** Campbell
Project No. 0066-029-F19, C501
FHWA No. IM-NH-66-1
Testing for Aggregate Base Type I (21A)
Model No. 3440 **Serial No.** 23456 **Calibration Date** 02/10/2015

STANDARD COUNT DATA

Density 2830 **Moisture** 701

Test No.			**1**	**2**	**3**	**4**
Location	Station ft. (m)		603+00			
of	Ref. to center line ft. (m)		5’ Rt. C/L			
Test	Elevation					
Compaction Depth of Lift in. (mm)			6”			
Method of Co			Vibratory			
A. Wet Densi		=	140.9	**Gauge**		
B. Moisture U		=	7.0	**Gauge**		
C. Dry Densit	-B)	=	133.9	**Gauge**		
D. Moisture Content (B ÷ C) x 100		=	5.2	**Gauge**		
E. Maximum Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) Lab Procto		=	132.8	**Materials**		
F. Percent Op	oint Proctor	=	10.7	**Materials**		
G. Percent of Plus #4, (plus 4.75 mm)		=	58.0	**Materials**		
H. Corrected Max. Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3)		=	145.4	**See Page 8-15 & 8-16**		
I. Corrected Optimum Moisture		=	5.2 3.2 – 7.2	**See Page 8-15 & 8-16**		
J. Percent Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) (C ÷ E) x 100 or (C ÷ H) x 100		=	92.1	**See Page 8-15 & 8-16**		
K. Percent Minimum Density Required		=	90.0	**Appendix C**		

Nuclear Gauge Display Panel

% PR = 100.8%

DD = 133.9
WD = 140.9

M = 7.0 M% = 5.2

Determined by Proctor on the Fine (– 4) Material

Comments:

BY: ______________________

TITLE: ______________________

Form TL-124 (Rev. 07/15)

VIRGINIA DEPARTMENT OF TRANPORTATION
MATERIALS DIVISION
REPORT ON NUCLEAR EMBANKMENT DENSITIES (UNIT MASSES)

Report No. 1-21A-3 **Date** 06/22/2015 **Sheet No.** 1 **of** 1
Route No. 66 **County** Campbell
Project No. 0066-029-F19, C501
FHWA No. IM-NH-66-1
Testing for Aggregate Base Type I (21A)
Model No. 3440 **Serial No.** 23456 **Calibration Date** 02/10/2015

STANDARD COUNT DATA

Density 2830 **Moisture** 701

Test No.			**1**	**2**	**3**	**4**
Location	Station ft. (m)		603+00			
of	Ref. to center line ft. (m)		5' Rt. C/L			
Test	Elevation					
Compaction Depth of Lift in. (mm)			6"			
Method of Compaction			Vibratory			
A. V		=	140.9			
B.		=	7.0			
C.		=	133.9			
D.		=	5.2			
E. m³)		=	132.8			
F. Proctor		=	10.7			
G. Percent of Plus #4, (plus 4.75 mm)		=	58.0			
H. ss (kg/m³)		=	145.4			
I.		=	5.2 3.2 – 7.2			
J. ³)		=	92.1			
K.		=	90.0	**Appendix C**		

Corrected Dry Density for +4 Aggregate

$$\frac{D_f \times D_c}{(P_c \times D_f) + (P_f \times D_c)}$$

$$\frac{132.8 \times 156.0}{(0.58 \times 132.8) + (0.42 \times 156.0)}$$

$$\frac{20{,}716}{77.0 + 65.5} = \frac{20{,}716}{142.5} = 145.4 \text{ lbs/ft}^3$$

Corrected Moisture for +4 Aggregate

$$(P_cW_c + P_fW_f) \times 100$$

$$[(0.58 \times 0.012) + (0.42 \times 0.107)] \times 100$$

$$[(0.007) + (0.045)] \times 100$$

$$[0.052] \times 100 = 5.2\%$$

Corrected Percent Density

(Dry Density ÷ Corrected +4 Density) x 100

(133.9 ÷ 145.4) x 100

(0.9209) x 100

% Density = 92.1%

Comments:

BY: __________

TITLE: __________

Calculations for Direct Transmission Test take within the Control Strip

Information from Quarry or Materials Division:

A. Total Percent Passing the No. 4 Sieve = 42% (This is the -4 Material) **(P_f = 0.42)**
Therefore: 100 – 42 = 58% (This is the +4 Material) **(P_c = 0.58)**

B. Specific Gravity of the +4 Material = 2.50
Therefore: 2.50 x 62.4 = 156.0 lbs/ft^3 **(D_c = 156.0)**

C. Absorption Rate of the +4 Material = 0.2%
Therefore: 0.2 + 1 = 1.2% **(W_c = 0.012)**

D. Lab Proctor Information
Maximum Dry Density of the -4 Material = 132.8 lbs/ft^3 **(D_f = 132.8)**
Optimum Moisture of the -4 Material = 10.7% **(W_f = 0.107)**

Maximum Dry Density (+4 Material)		**Optimum Moisture (+4 Material)**
$\frac{D_f \times D_c}{(P_c \times D_f) + (P_f \times D_c)}$	Formula	$[(P_cW_c) + (P_fW_f)] \times 100$
↓		↓
$\frac{132.8 \times 156.0}{(0.58 \times 132.8) + (0.42 \times 156.0)}$	Step 1	$[(0.58 \times 0.012) + (0.42 \times 0.107)] \times 100$
↓		↓
$\frac{20{,}716.8}{(77.0) + (65.5)}$	Step 2	$[(0.007) + (0.045)] \times 100$
↓		↓
$\frac{20{,}716.8}{142.5}$	Step 3	0.052×100
↓		↓
Corrected Dry Density = 145.4 lbs/ft^3		Corrected Optimum Moisture = 5.2%

Form TL-54 (Rev. 07/15)

VIRGINIA DEPARTMENT OF TRANPORTATION
MATERIALS DIVISION
REPORT ON NUCLEAR CONTROL STRIP

Report No. 1-21A-2 **Date** 06/22/2015
Route No. 66 **Project No.** 0066-029-F19, C501
FHWA No. IM-NH-66-1 **County** Fairfax
Type Material Aggregate Base Type I (21A) **Width** 12
Station No. 601+25 **ft. (m.) to Station** 604+25 **ft. (m.) to Nuclear Gauge**
Model No. 3440 **Serial No.** 23456
Remarks

STANDARD COUNT DATA

Density 2830 **Moisture** 701

	STATION	**REFERENCE TO CENTER LINE FT. (M)**	**LANE**	**DRY DENSITY (LB/FT^3) DRY UNIT MASS (KG/M^3)**	**MOISTURE CONTENT**
1	601+25	3 FT. RT.	EBL	138.0	4.9
2	601+50	9 FT. RT.	EBL	139.2	5.3
3	602+00	6 FT. RT.	EBL	138.5	4.8
4	602+25	9 Ft. Rt.	EBL	139.3	5.4
5	602+75	3 Ft. Rt.	EBL	138.7	4.9
6	603+00	6 Ft. Rt.	EBL	139.1	5.1
7	603+50	9 Ft. Rt.	EBL	139.0	4.7
8	603+75	6 Ft. Rt.	EBL	139.2	5.2
9	604+00	3 Ft. Rt.	EBL	139.0	4.6
10	604+25	9 Ft. Rt.	EBL	140.5	6.1

The Optimum Moisture Required (corrected for the +4 material) can now be transferred from the Form TL-124 (Line I) to the Form TL-54 (Report on Nuclear Control Strip)

- **Once complete, the Optimum Moisture values can then be transferred to the Form TL-55 (Report on Nuclear Test Section)**

5.2

3.2 – 7.2 **OPTIMUM MOISTURE RANGE**

(139.1) x 0.95 = Dens. Avg. 132.1 **OR**

(139.1) x 0.98 = Dens. Avg. 136.3 **R TEST**

Now that the Direct Transmission Test has passed and validated the control strip, the 95% and 98% control (target) values can also be transferred to the Form TL-55 (Report on Nuclear Test Section)

- **These values will be used to evaluate the Test Sections for acceptance**

BY:

TITLE:

TEST SECTIONS

1) Next will be the testing of the Test Sections. Each test sect ion for aggregate base, subbase, and select materials will be 0.5 miles (2640 ft.) in length per application width.

   The length of test sections for shoulders will be the same as the mainline, if possible test alternating sides.

2) The test section is rolled the number of passes determined by the Control Strip. Five (5) readings will be made in the one minute mode on each test section for both density and moisture using the same method of test used on the Roller Pattern and Control Strip. These values are recorded on the TL-55. Each individual reading must be at least 95% of the Control Strip dry density and the average of the five readings must be at least 98% of the Control Strip dry density and the moisture readings must fall within the optimum moisture range.

   For aggregate shoulder material, an average density of 95% (± 2 percentage points) of the Control Strip dry density, with individual densities within 95% (± 5 percentage points) of the Control Strip dry density is required. No other test will be required, unless specified by the Engineer.

   NOTE: If test section readings are significantly above or below the target values by more than 8 lbs/ft^3, another control strip (and target density) should be established.

Form TL-55 (Rev. 07/15)

VIRGINIA DEPARTMENT OF TRANPORTATION
MATERIALS DIVISION
REPORT ON NUCLEAR TEST SECTION

Report No. 1-21A-2 **Date** 06/22/2015
Route No. 66 **Project No.** 0066-029-F19, C501
FHWA No. IM-NH-66-1 **County** Fairfax
Type Material Aggregate Base Type I (21A) **Width** 12
Section No. 1 **Station No.** 604+25 **ft. (m.) to Station** 630+65 **ft. (m.)**
Model No. 3440 **Serial No.** 23456
Remarks ______

STANDARD COUNT DATA

Density 2830 **Moisture** 701

5.2 **OPTIMUM MOISTURE REQUIRED % (From Producer or Materials Division)**

3.2 – 7.2 **OPTIMUM MOISTURE RANGE**

132.1 **INDIVIDUAL DRY DENSITY (lbs/ft^3), DRY UNIT MASS (kg/m^3) REQUIRED (95% of Control Strip Density from TL-54A)**

136.3 **AVERAGE DRY DENSITY (lbs/ft^3), DRY UNIT MASS (kg/m^3) REQUIRED (98% of Control Strip Density from TL-54A)**

Test No.	Station ft. (m)	Lane	Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3)	Moisture Content	Pass (P) Fail (F)
1	606+26	EBL	138.3	5.3	P
2	610+89	EBL	139.7	5.0	P
3	615+59	EBL	139.0	5.3	P
4	620+18	EBL	138.9	5.2	P
5	626+66	EBL	139.2	5.4	P
Average			139.0		P

Comments:

BY: ______

TITLE: ______

Form TL-55 (Rev. 07/15)

VIRGINIA DEPARTMENT OF TRANPORTATION
MATERIALS DIVISION
REPORT ON NUCLEAR TEST SECTION

Report No. 1-21A-2 **Date** 06/22/2015
Route No. 66 **Project No.** 0066-029-F19, C501
FHWA No. IM-NH-66-1 **County** Fairfax
Type Material Aggregate Base Type I (21A) **Width** 12
Section No. 1 **Station No.** 604+25 **ft. (m.) to Station** 630+65 **ft. (m.)**
Model No. 3440 **Serial No.** 23456
Remarks

Density 2830

All Optimum Moisture and Density Control (Target) Values have been transferred from the bottom of the Form TL-54 (Report on Nuclear Control Strip)

5.2 **OPTIMUM MOISTURE REQUIRED % (From Producer or Materials Division)**

3.2 – 7.2 **OPTIMUM MOISTURE RANGE**

132.1 **INDIVIDUAL DRY DENSITY (lbs/ft^3), DRY UNIT MASS (kg/m^3) REQUIRED (95% of Control Strip Density from TL-54A)**

136.3 **AVERAGE DRY DENSITY (lbs/ft^3), DRY UNIT MASS (kg/m^3) REQUIRED (98% of Control Strip Density from TL-54A)**

Each individual Dry Density must be at least 132.1 lbs/ft^3

An overall average Dry Density must be calculated from each of the five (5) individual tests performed

1. **138.3 + 139.7 + 139.0 + 138.9 + 139.2 = 695.1**
2. **695.1 ÷ 5 = 139.0 lbs/ft^3**

Test No.	Station ft. (m)	Lane	Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3)	Moisture Content	Pass (P) Fail (F)
			138.3	5.3	P
			139.7	5.0	P
			139.0	5.3	P
			138.9	5.2	P
5	626+66	EBL	139.2	5.4	P
Average			139.0		P

Comments:

The average Dry Density must be at least 136.3 lbs/ft^3

Each individual Moisture reading must fall within the 3.2 to 7.2 range

For the test section to pass, the following conditions must be met:

- **Each individual Dry Density reading must be at least 132.1 lbs/ft^3**
- **The average Dry Density must be at least 136.3 lbs/ft^3**
- **Each individual Moisture reading must fall within the 3.2 to 7.2 range**

If any test section readings are significantly above or below the control (target) values by more than 8 lbs/ft^3, another Control Strip should be established

BY:

TITLE:

RANDOM SAMPLING OF CONSTRUCTION MATERIALS

This section provides guidelines for the selection of random locations or times at which samples or tests of construction materials are to be taken. Highway construction materials are typically accepted or rejected based on the test results of small representative samples. Consequently, acceptance or rejection of materials is highly dependent on how well a small sample represents a larger quantity of material. If the samples are not truly representative of the larger quantity, acceptable material could be rejected, or substandard material accepted. Correct sampling methods are critical to the validity of the sample test results. Sampling performed incorrectly will lead to test results that do not reflect the true characteristics of the material or product being tested.

The actions required to obtain a good sample (such as how to take the sample, where to take it, what tools to use and the size of sample) are covered in the appropriate materials control program and guidelines specified by the agency for use on the project. Reference should be made to these instructions on sampling requirements.

When a sample is not representative or random, it is said to be biased. Examples of biased sampling that should not be used include sampling an embankment at a given interval, such as every 500 cubic yards (yd^3); sampling borrow material at a given frequency, such as every fifth truckload; or taking samples at a given time frequency, such as every hour on the hour. Random sampling is used to eliminate bias in selecting a location or time for sampling. A random sample is any sample which has an equal chance of being selected from a large quantity. In other words, there is an equal chance for all locations and all fractions of a large quantity of material to be sampled.

Random unbiased samples must represent the true nature of the material. Samples should not be obtained on a predetermined basis or based on the quality of the material in a certain area. If sampling is not performed on a random basis, the quality of the sample can be artificially modified causing the sample to no longer be representative of the larger quantity. Specifications will identify lot size, location and frequencies for sampling and testing. A lot is defined as a given quantity of material that is to be sampled. The lot is a predetermined unit which may represent a day's production, a specified quantity of material, a specified number of truckloads, or an interval of time. Agencies will usually specify the lot size and sampling frequency. Although these frequencies may appear to be a violation of random sampling, they are given as a minimum amount of sampling, not as a specific frequency. Lots are often divided into sublots. The number of sublots used to represent the lot will be determined by the agency and specifications. It may be necessary to take multiple samples and combine them to represent a unit. For example, three samples may be taken from a borrow source and combined to form a composite sample. Several composite samples will then be tested to determine the compliance of a sublot or lot to the specifications. The use of random samples from sublots is referred to as stratified random sampling. Stratified random sampling assures that samples are taken throughout the entire lot and are not concentrated in one area of the lot (see Figure 1.18).

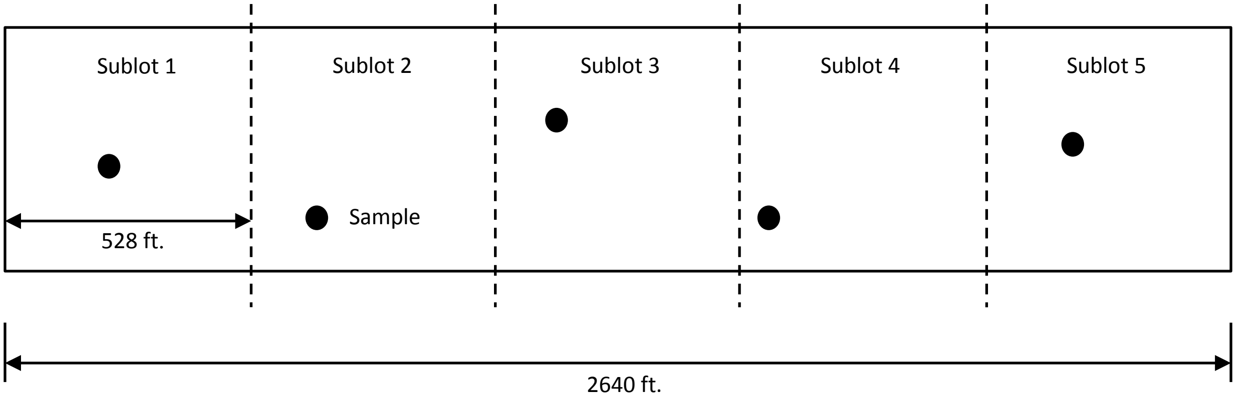


Figure 1.3: Illustration of Random Test Site Locations

Quality control/quality assurance specifications are developed based on statistical theory, which is valid only when random sampling is performed. QC/QA specifications are statistically based on a normal distribution (bell curve) of material production. If samples are biased or not random, the test results will not fit in the normal distribution, and the QC/QA specification will no longer be valid.

Random sampling is usually accomplished with the use of random number generators or tables of random numbers. Most calculators and computers contain a random number generator that merely requires the operator to hit a button. The automated random number generators use programmed tables of random numbers similar to the tables included later. A random numbers table is simply a random arrangement of numbers.

ASTM D 3665 is a method for determining random locations or time intervals for sampling and testing. Individual states within the Mid-Atlantic Region have developed various random numbers tables that are much easier to use and less time consuming. The Table on page 8-26 is an example of a table used for selecting test locations on aggregate subbase or base. It is not important which table or method is used as long as random numbers are incorporated into the selection process.

A Test Section for aggregate subbase or base is half a mile per paver width. Each test section is divided into 5 sublots of 528 feet (2640 feet ÷ 5 = 528 feet). One reading is taken in each sublot.

To use the table, select a random starting point on the table by tossing a pencil upon the page or blindly pointing out a location with the finger. Since you will need five sets of numbers, use the location selected and the next four beneath it. The column to the left is used to determine the distance from the beginning of each sublot and the corresponding columns to the right are used to determine the offset distance from the reference line based on the paver width.

RANDOM NUMBER TABLE

Distance from Start of Sublot (ft.)	Distance from Reference Line						
	Paver Width						
	8 feet	9 feet	10feet	11 feet	12 feet	13 feet	14 feet
201	2	4	5	5	8	9	12
136	4	4	7	8	11	5	8
78	4	6	8	5	3	4	6
9	5	2	5	9	11	4	8
129	5	4	3	9	4	10	12
106	5	3	7	8	8	10	9
27	2	3	7	6	3	4	7
140	2	5	3	8	3	10	2
182	2	2	8	5	10	5	10
156	3	3	7	6	3	6	10
22	5	5	8	2	5	3	7
232	4	3	4	2	7	6	8
57	5	4	3	2	7	8	10
201	2	2	7	5	9	3	8
136	6	5	8	7	7	4	11
78	6	4	2	2	5	5	3
9	3	2	6	3	6	9	11
129	3	5	3	8	3	4	4
244	3	3	3	3	8	2	6
189	2	7	3	9	5	2	5
208	4	5	4	5	10	9	5
128	5	7	8	6	4	4	5
98	3	3	8	8	9	2	10
200	2	4	5	6	10	2	8
78	3	4	8	6	3	6	11
185	4	5	2	6	7	10	3
3	2	4	7	7	3	6	12
96	6	3	7	3	9	8	11
17	4	6	8	9	8	8	8
228	3	7	6	5	2	5	4
230	5	4	8	6	5	10	10
73	2	5	8	6	5	6	9
109	4	4	4	4	6	8	11
181	3	6	6	9	3	9	4
252	4	3	4	3	3	9	11
96	4	4	2	2	2	9	11
43	4	7	5	7	6	3	11
71	4	6	5	6	4	4	12
9	3	3	3	9	6	10	11
157	5	5	7	9	6	9	12

Example Problem:

The contractor has applied the dense graded aggregate layer to the right lane of a two lane roadway beginning at Station 604+25 with a paver width of 12 feet. The right side will be used to measure the offset distances. Five (5) sets of numbers are needed to determine where the tests will be performed.

Random numbers from Random Number Table (Block One):

Distance from Start of Sublot	Distance from Reference Line
201	8
136	11
78	3
9	11
129	4

Determine the Station Number at the beginning of each sublot. Remember, the Test Section is half a mile per paver with and is divided into five (5) sublots of 528 feet in length.

Beginning Station Number of Sublot 1:		604+25	
	+	5 28	← Length of Sublot (ft)
Beginning Station Number of Sublot 2:		609+53	
	+	5 28	
Beginning Station Number of Sublot 3:		614+81	
	+	5 28	
Beginning Station Number of Sublot 4:		620+09	
	+	5 28	
Beginning Station Number of Sublot 5:		625+37	
	+	5 28	
Ending Station Number of Sublot 5:		630+65	

To determine the test locations, add the Distance from Start of Sublot selected from the Random Number Table to the beginning station number of each sublot. Use the numbers from the Random Number Table under Distance from Reference Line to measure the offset from the right side of the sublot.

Station No. at Beginning of Each Sublot	+	Distance from Start of Sublot	=	Station No. of Each Test Location	Distance from Reference Line (ft)
604+25	+	201	=	606+26	8
609+53	+	136	=	610+89	11
614+81	+	78	=	615+59	3
620+09	+	9	=	620+18	11
625+37	+	129	=	626+66	4

CHAPTER 8 – STUDY QUESTIONS

1) True or False. Before a Roller Pattern can be set the subgrade must be approved, compaction equipment must be approved and material to be tested must be placed at uniform depth.

2) ____________________ compares compactive effort vs. density.

3) When must a new Roller Pattern be set up?

4) __________________________ is the testing method in which the gauge is placed on the surface of the material to be tested and the source rod is lowered to the first notch.

5) When taking a nuclear reading near an unsupported edge, ____________________ is the minimum distance from the edge that an accurate nuclear reading can be taken.

6) A _________________________ is taken at the end of the control strip to verify the results.

7) The control strip dry density must be within ____________________ of the roller pattern peak density.

8) A roller pattern on aggregate covers ____________________, a control strip covers ____________________ and a test section covers ____________________ per paver width.

9) The Contractor has applied the dense graded aggregate layer to the right lane of a two-lane roadway beginning at Station 25 + 25. Using the numbers from the Random Number Table given below, calculate and determine the test location for each density and moisture reading for this test section, which is 12 feet wide. Remember not to test any closer than 18 inches to an unsupported edge.

Distance from Start of Sublot	Distance from Reference Line
181	3
252	3
96	2
43	6
71	4

There are 5,280 feet in a mile. A Test Section is _________ mile per paver width or _________ feet. _________ tests will be performed in the test section. __________ ÷ __________ = __________.

Beginning Station No. 25+25

Sublot 1 __________ Feet

Station No. ____________

Sublot 2 __________ Feet

Station No. ____________

Sublot 3 __________ Feet

Station No. ____________

Sublot 4 __________ Feet

Station No. ____________

Sublot 5 __________ Feet

Ending Station No. ____________

Test No.	Station No. at Start of Each Sublot	+	Distance from Start of Sublot	=	Station No. of Each Test Location	Distance from Reference Line (ft)
		+		=		
		+		=		
		+		=		
		+		=		
		+		=		

CHAPTER 8 – PRACTICE PROBLEMS

NOTE: Each Practice Problem contains 4 Parts

Practice Problem Number 1
Nuclear Density Testing of Aggregates
Step 1 – Roller Pattern

A. Given the following information, complete the following worksheet (Form TL-53)

Station Numbers for Test Locations	21+00
	21+35
	21+75

Test 1		Test 4	
2V Passes		8V Passes	
Density	Moisture	Density	Moisture
125.4	5.1	134.7	5.5
124.9	5.2	133.7	4.9
125.3	5.6	134.8	5.1

Test 2		Test 5	
4V Passes		?? Passes	
Density	Moisture	Density	Moisture
128.4	5.4	135.5	5.2
127.5	5.1	135.0	5.1
128.5	4.9	135.4	4.9

Test 3		Test 6	
6V Passes		?? Passes	
Density	Moisture	Density	Moisture
131.8	5.1	134.0	4.9
131.0	5.0	133.5	5.0
132.1	4.9	134.1	5.1

B. How many passes should be made for Test 5? Why?

How many passes should be made for Test 6? Why?

C. Should this be considered an acceptable Roller Pattern? Why?

Form TL-53 (Rev. 07/15)

VIRGINIA DEPARTMENT OF TRANPORTATION
MATERIALS DIVISION
REPORT ON NUCLEAR ROLLER PATTERN

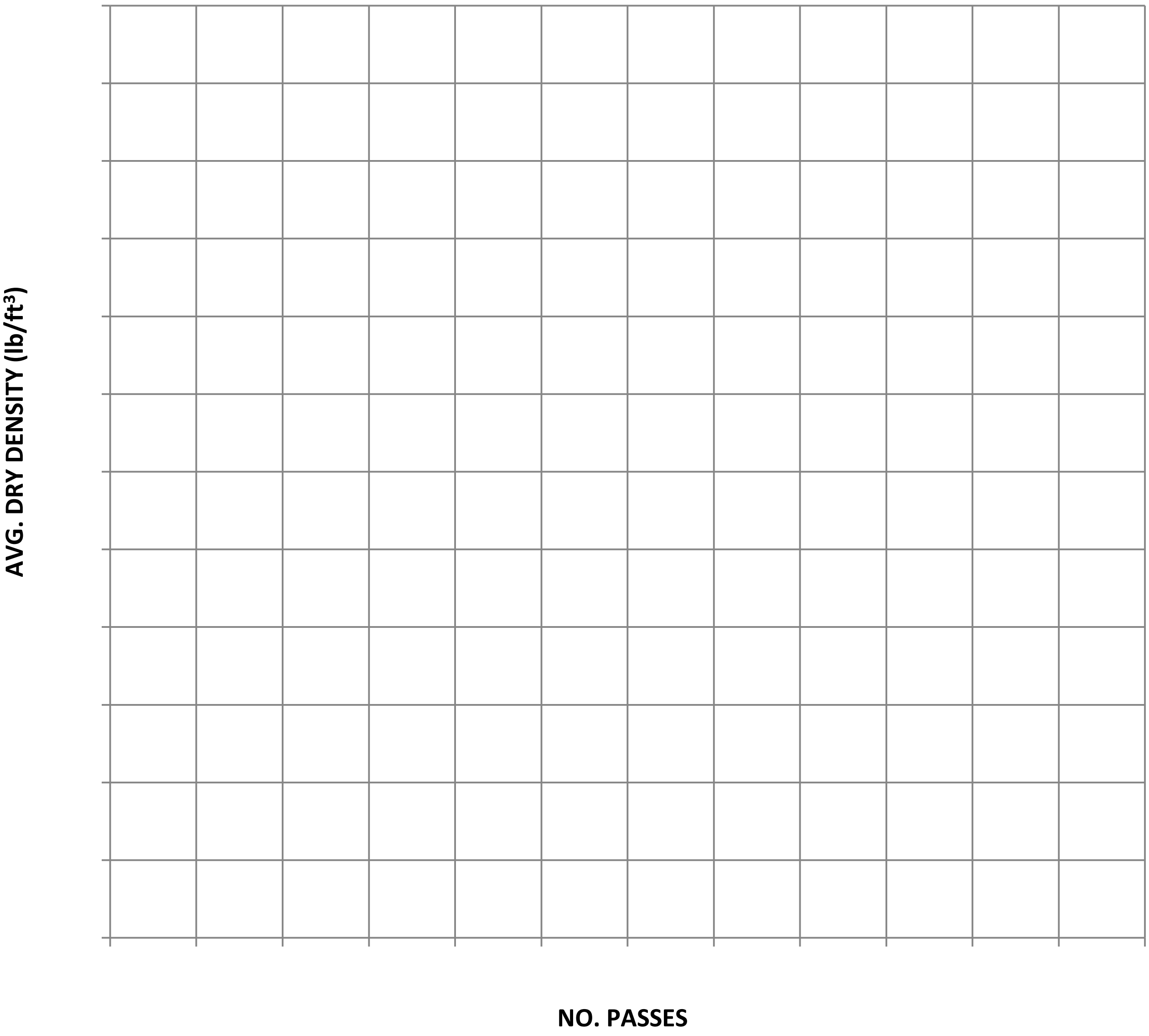
Report No. 1-21A-1 **Nuclear Gauge Model No.** 3440 **Serial No.** 23456
Date 06/22/2015 **Project No.** 0095-029-F14, C502 **Route No.** 95
FHWA No. NH (95) - 1 **County** Fairfax
Section No. 1 **Station No.** 21+00 **ft. (m.) to Station** 21+75 **ft. (m.)**
Type Material Aggregate Base Type I (21A) **Width** 12 **ft. (m.)**
Optimum Moisture ______ **Optimum Moisture Range** ______
Remarks ______

STANDARD COUNT DATA

Density 2847 **Moisture** 695

TEST NO.	DRY DENSITY	MOISTURE	TEST NO.	DRY DENSITY	MOISTURE
Test No. 1 No. of Passes			Test No. 6 No. of Passes		
Sta.			Sta.		
Sta.			Sta.		
Sta.			Sta.		
Total			Total		
Average			Average		
Test No. 2 No. of Passes			Test No. 7 No. of Passes		
Sta.			Sta.		
Sta.			Sta.		
Sta.			Sta.		
Total			Total		
Average			Average		
Test No. 3 No. of Passes			Test No. 8 No. of Passes		
Sta.			Sta.		
Sta.			Sta.		
Sta.			Sta.		
Total			Total		
Average			Average		
Test No. 4 No. of Passes			Test No. 9 No. of Passes		
Sta.			Sta.		
Sta.			Sta.		
Sta.			Sta.		
Total			Total		
Average			Average		
Test No. 5 No. of Passes			Test No. 10 No. of Passes		
Sta.			Sta.		
Sta.			Sta.		
Sta.			Sta.		
Total			Total		
Average			Average		

ROLLER PATTERN CURVE



Comments:

By: ____________________

Title: ____________________

Practice Problem Number 1
Nuclear Density Testing of Aggregates
Step 2 – Control Strip

A. Complete the following worksheet (Form TL-54) using the data below and answer the following questions.

B. How many roller passes were required to attain the maximum density on the Control Strip (Use the information from Step 1 – Form TL-53)

____

C. Does the test pass the moisture criteria?

____

D. Is the Control Strip within tolerance of the Roller Pattern?

____

Test No.	Density Readings	Moisture Readings
1	134.8	5.4
2	135.2	5.3
3	135.6	5.4
4	135.5	5.4
5	135.3	5.4
6	135.3	5.1
7	135.2	5.5
8	135.8	5.4
9	135.3	5.1
10	134.7	5.0

Form TL-54 (Rev. 07/15)

VIRGINIA DEPARTMENT OF TRANPORTATION
MATERIALS DIVISION
REPORT ON NUCLEAR CONTROL STRIP

Report No. 1-21A-2 **Date** 06/22/2015
Route No. 95 **Project No.** 0095-029-F14, C502
FHWA No. NH(95)-1 **County** Fairfax
Type Material Aggregate Base Type I (21A) **Width** 12
Station No. 22+25 **ft. (m.) to Station** 25+25 **ft. (m.) to Nuclear Gauge**
Model No. 3440 **Serial No.** 23456
Remarks ______

STANDARD COUNT DATA

Density 2847 **Moisture** 695

	STATION	**REFERENCE TO CENTER LINE FT. (M)**	**LANE**	**DRY DENSITY (LB/FT^3) DRY UNIT MASS (KG/M^3)**	**MOISTURE CONTENT**
1	22+25	3 FT. RT.	WBL		
2	22+65	9 FT. RT.	WBL		
3	23+00	6 FT. RT.	WBL		
4	23+35	9 Ft. Rt.	WBL		
5	23+70	3 Ft. Rt.	WBL		
6	24+00	9 Ft. Rt.	WBL		
7	24+35	6 Ft. Rt.	WBL		
8	24+70	9 Ft. Rt.	WBL		
9	25+00	6 Ft. Rt.	WBL		
10	25+25	3 Ft. Rt.	WBL		
			TOTAL:		
			AVERAGE:		

______ **OPTIMUM MOSTURE REQUIRED (From Producer or Materials Division)**

______ **OPTIMUM MOISTURE RANGE**

(_____) x 0.95 = ______ **INDIVIDUAL DRY DENSITY (lbs/ft^3), DRY UNIT MASS (kg/m^3) REQUIREMENT FOR TEST SECTION**
Dens. Avg.

(_____) x 0.98 = ______ **AVERAGE DRY DENSITY (lbs/ft^3), DRY UNIT MASS (kg/m^3) REQUIREMENT FOR TEST SECTION**
Dens. Avg.

BY: ______

TITLE: ______

Practice Problem Number 1
Nuclear Density Testing of Aggregates
Step 3 – Control Strip (Direct Transmission Test)

A. Use the information below to complete the following worksheet (Form TL-124) and answer the following questions.

Information from Quarry or Materials Lab:

Percent Passing the No. 4 Sieve = 46%
Therefore, the percent of +4 Material = __________

Specific Gravity of the +4 Material = 2.40
Therefore, the density of the +4 Material = __________

Absorption Rate of the +4 Material = 0.2%

Lab Proctor Information
Maximum Dry Density of the -4 Material = 133.0 lbs/ft^3
Optimum Moisture of the -4 Material = 10.1%

Nuclear Gauge Display Panel

% PR = 97.9%

DD = 130.2
WD = 137.1

M = 6.9   M% = 5.3

B. What is the minimum density required?

____

C. Does the test pass?

____

D. Does this test validate the Roller Pattern and Control Strip Target Density?

____

Form TL-124 (Rev. 07/15)

VIRGINIA DEPARTMENT OF TRANPORTATION
MATERIALS DIVISION
REPORT ON NUCLEAR EMBANKMENT DENSITIES (UNIT MASSES)

Report No. 1-21A-3 **Date** 06/22/2015 **Sheet No.** 1 **of** 1
Route No. 95 **County** Fairfax
Project No. 0095-029-F14, C502
FHWA No. NH(95)-1
Testing for Aggregate Base Type I (21A)
Model No. 3440 **Serial No.** 23456 **Calibration Date** 02/10/2015

STANDARD COUNT DATA

Density 2847 **Moisture** 695

Test No.			**1**	**2**	**3**	**4**
Location	Station ft. (m)		22+25			
of	Ref. to center line ft. (m)		2’ Rt. C/L			
Test	Elevation					
Compaction Depth of Lift in. (mm)			6”			
Method of Compaction			Vibratory			
A. Wet Density (lbs/ft^3), Wet Unit Mass (kg/m^3)		=				
B. Moisture Unit Mass (lbs/ft^3 or kg/m^3)		=				
C. Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) (A-B)		=				
D. Moisture Content (B ÷ C) x 100		=				
E. Maximum Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) Lab Proctor or One Point Proctor		=				
F. Percent Optimum Moisture from Lab or One Point Proctor		=				
G. Percent of Plus #4, (plus 4.75 mm)		=				
H. Corrected Max. Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3)		=				
I. Corrected Optimum Moisture		=				
J. Percent Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) (C ÷ E) x 100 or (C ÷ H) x 100		=				
K. Percent Minimum Density Required		=				

Comments:

BY:

TITLE:

Practice Problem Number 1
Nuclear Density Testing of Aggregates
Step 4 – Test Section

A. Transfer the Optimum Moisture, Optimum Moisture Range, Individual Dry Density Requirement, and Average Dry Density Requirement from the Control Strip (Form TL-54) to the proper place on the Test Section worksheet (Form TL-55).

B. Given the following nuclear density and moisture readings, complete the Form TL-55.

Test 1

Nuclear Gauge Display Panel

% PR = _____%

DD = 136.4
WD = 144.1

M = 7.7   M% = 5.1

Test 2

Nuclear Gauge Display Panel

% PR = _____%

DD = 135.0
WD = 142.3

M = 7.3   M% = 5.4

Test 3

Nuclear Gauge Display Panel

% PR = _____%

DD = 136.5
WD = 143.8

M = 7.3   M% = 5.0

Test 4

Nuclear Gauge Display Panel

% PR = _____%

DD = 133.2
WD = 140.2

M = 7.0   M% = 5.3

Test 5

Nuclear Gauge Display Panel

% PR = _____%

DD = 136.0
WD = 142.9

M = 6.9   M% = 5.1

C. Does this test pass? Why?

D. If the test does not pass, what corrective action should be taken?

E. What are the beginning and ending station numbers of the first Test Section?

Form TL-55 (Rev. 07/15)

VIRGINIA DEPARTMENT OF TRANPORTATION
MATERIALS DIVISION
REPORT ON NUCLEAR TEST SECTION

Report No. 1-21A-4 **Date** 06/22/2015
Route No. 95 **Project No.** 0095-029-F14, C502
FHWA No. NH(95)-1 **County** Fairfax
Type Material Aggregate Base Type I (21A) **Width** 12
Section No. 1 **Station No.** 25+25 **ft. (m.) to Station** 51+65 **ft. (m.)**
Model No. 3440 **Serial No.** 23456
Remarks ______

STANDARD COUNT DATA

Density 2830 **Moisture** 701

______ **OPTIMUM MOISTURE REQUIRED % (From Producer or Materials Division)**

______ **OPTIMUM MOISTURE RANGE**

______ **INDIVIDUAL DRY DENSITY (lbs/ft^3), DRY UNIT MASS (kg/m^3) REQUIRED (95% of Control Strip Density from TL-54A)**

______ **AVERAGE DRY DENSITY (lbs/ft^3), DRY UNIT MASS (kg/m^3) REQUIRED (98% of Control Strip Density from TL-54A)**

Test No.	Station ft. (m)	Lane	Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3)	Moisture Content	Pass (P) Fail (F)
1	27+06	WBL			
2	33+05	WBL			
3	36+77	WBL			
4	41+52	WBL			
5	47+08	WBL			
Average					

Comments:

BY: ______

TITLE: ______

CHAPTER 8 – PRACTICE PROBLEMS

Practice Problem Number 2
Nuclear Density Testing of Aggregates
Step 1 – Roller Pattern

A. Given the following information, complete the following worksheet (Form TL-53)

Report No: 3-21ACTA-1
Nuclear Gauge Model No: 3440
Nuclear Gauge Serial No: 23456
Date: Use today's date
Route: 0007
Project No: 0007-053-121, C501
FHWA No: None
County: Loudon
Section No: 1

Station No: 900+00 to 900+75
Type Material: Aggregate Base Type I (21A)
Pavement Width: 12
Optimum Moisture: 5.1
Optimum Moisture Range: Must be calculated
Remarks: 1st Lift 6" Compacted Depth, Roller Pattern No. 3, Vibratory Roller
Standard Counts: Density – 2864
Moisture – 709

Station Numbers for Test Locations 900+00, 900+35, and 900+75

Test 1 – After 2V Passes

Density	Moisture
115.4	5.3
114.6	5.1
116.1	4.9

Test 2 – After 4V Passes

Density	Moisture
118.9	5.3
118.6	5.2
119.1	5.3

Test 3 – After 6V Passes

Density	Moisture
121.9	5.1
121.0	4.9
122.9	5.3

Test 4 – After 8V Passes

Density	Moisture
129.2	5.5
128.1	4.8
130.2	5.0

Test 5 – After 10V Passes

Density	Moisture
132.1	5.3
131.6	4.3
132.6	5.9

Test 6 – After 12V Passes

Density	Moisture
132.2	5.2
131.7	5.0
132.7	5.2

Test 7 – After 13 (1S) Passes

Density	Moisture
131.8	4.4
131.7	5.2
131.8	5.8

B. Should this be considered an acceptable Roller Pattern? Why?

Form TL-53 (Rev. 07/15)

VIRGINIA DEPARTMENT OF TRANPORTATION
MATERIALS DIVISION
REPORT ON NUCLEAR ROLLER PATTERN

Report No. ____________ **Nuclear Gauge Model No.** ____________ **Serial No.** ____________

Date ____________ **Project No.** ____________ **Route No.** ____________

FHWA No. ____________ **County** ____________

Section No. ____________ **Station No.** ____________ **ft. (m.) to Station** ____________ **ft. (m.)**

Type Material ____________ **Width** ____________ **ft. (m.)**

Optimum Moisture ____________ **Optimum Moisture Range** ____________

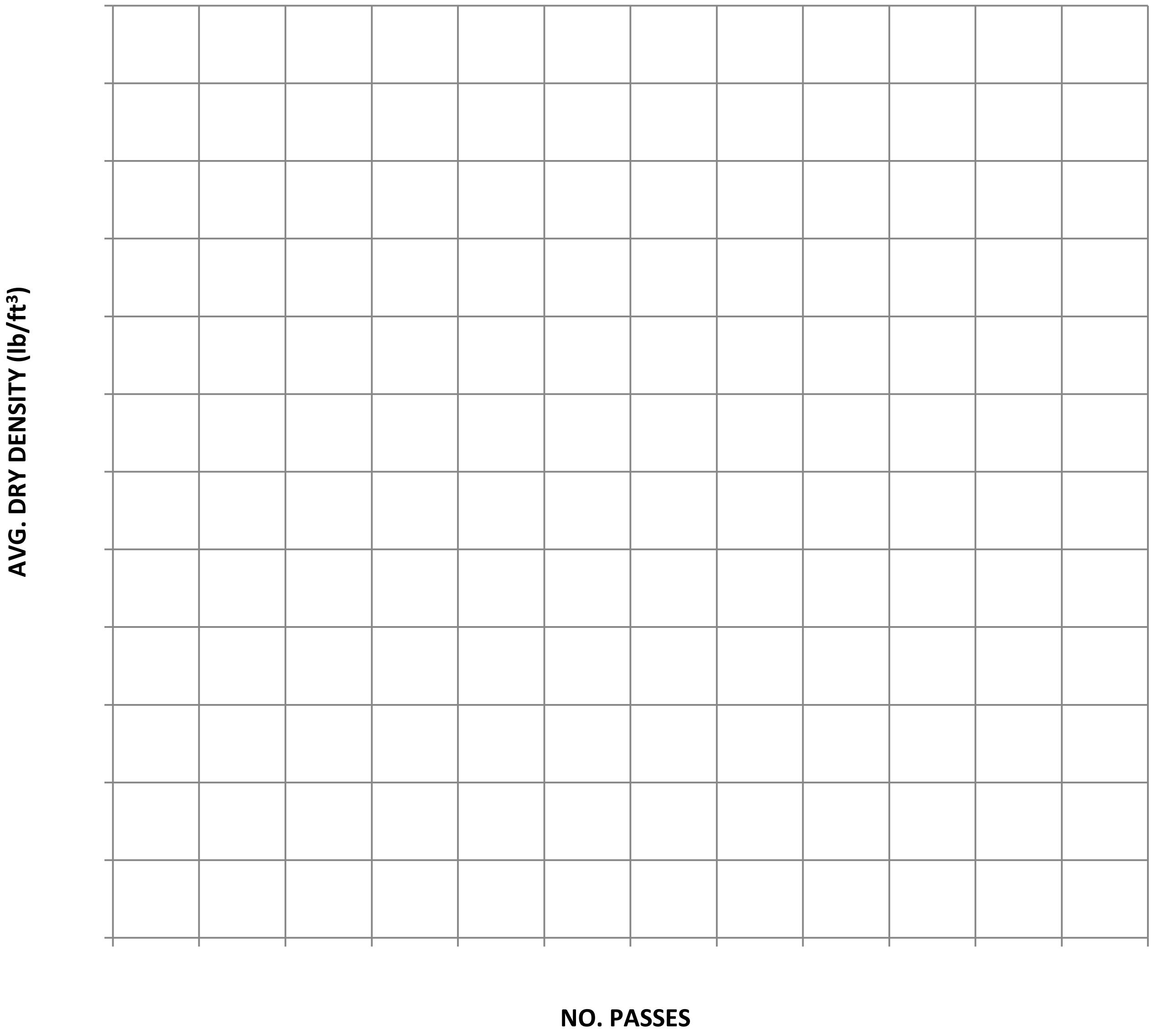
Remarks ____________

STANDARD COUNT DATA

Density ____________ **Moisture** ____________

TEST NO.	DRY DENSITY	MOISTURE	TEST NO.	DRY DENSITY	MOISTURE
Test No. 1 No. of Passes			Test No. 6 No. of Passes		
Sta.			Sta.		
Sta.			Sta.		
Sta.			Sta.		
Total			Total		
Average			Average		
Test No. 2 No. of Passes			Test No. 7 No. of Passes		
Sta.			Sta.		
Sta.			Sta.		
Sta.			Sta.		
Total			Total		
Average			Average		
Test No. 3 No. of Passes			Test No. 8 No. of Passes		
Sta.			Sta.		
Sta.			Sta.		
Sta.			Sta.		
Total			Total		
Average			Average		
Test No. 4 No. of Passes			Test No. 9 No. of Passes		
Sta.			Sta.		
Sta.			Sta.		
Sta.			Sta.		
Total			Total		
Average			Average		
Test No. 5 No. of Passes			Test No. 10 No. of Passes		
Sta.			Sta.		
Sta.			Sta.		
Sta.			Sta.		
Total			Total		
Average			Average		

ROLLER PATTERN CURVE



Comments:

By: ______________________________

Title: ______________________________

Practice Problem Number 2
Nuclear Density Testing of Aggregates
Step 2 – Control Strip

A. Using the same “header” information in Step 1, as well as the given below, complete the Control Strip (Form TL-54) and Direct Transmission (Form TL-124) worksheets.

Report No: 3-21ACTA-2 (Form TL-54)
Station No: 901+25 to 904+25
Report No: 3-21ACTA-3 (Form TL-124)
Station No. for Direct Transmission Test: 902+70 (Offset 9 Ft. Lt.)
Gauge Calibration Date: 12/10/2015

B. How many roller passes were required to attain the maximum density on the Control Strip (Use the information from Step 1 – Form TL-53)

____

C. Does the test pass the moisture criteria?

____

D. Is the Control Strip within tolerance of the Roller Pattern?

____

E. Does the Direct Transmission Test validate the Control Strip Dry Density? (See Page 8-49)

____

Test No.	Station No.	Ref. To C/L	Lane	Density Readings	Moisture Readings
1	901+25	3 Ft. Lt.	WBL	132.8	5.6
2	901+75	9 Ft. Lt.	WBL	132.7	5.7
3	902+00	6 Ft. Lt.	WBL	132.9	5.6
4	902+30	3 Ft. Lt.	WBL	132.6	5.8
5	902+70	6 Ft. Lt.	WBL	133.0	5.2
6	903+00	9 Ft. Lt.	WBL	132.5	5.7
7	903+35	9 Ft. Lt.	WBL	132.7	5.1
8	903+70	3 Ft. Lt.	WBL	132.7	5.8
9	904+00	6 Ft. Lt.	WBL	132.5	5.2
10	904+25	9 Ft. Lt.	WBL	132.8	5.5

Form TL-54 (Rev. 07/15)

VIRGINIA DEPARTMENT OF TRANPORTATION
MATERIALS DIVISION
REPORT ON NUCLEAR CONTROL STRIP

Report No. ____________ **Date** ____________
Route No. ____________ **Project No.** ____________
FHWA No. ____________ **County** ____________
Type Material ____________ **Width** ____________
Station No. ____________ **ft. (m.) to Station** ____________ **ft. (m.) to Nuclear Gauge**
Model No. ____________ **Serial No.** ____________
Remarks ____________

STANDARD COUNT DATA

Density ____________ **Moisture** ____________

	STATION	REFERENCE TO CENTER LINE FT. (M)	LANE	DRY DENSITY (LB/FT^3) DRY UNIT MASS (KG/M^3)	MOISTURE CONTENT
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
			TOTAL:		
			AVERAGE:		

____________ **OPTIMUM MOSTURE REQUIRED (From Producer or Materials Division)**

____________ **OPTIMUM MOISTURE RANGE**

(_____) x 0.95 =
Dens. Avg. ____________ **INDIVIDUAL DRY DENSITY (lbs/ft^3), DRY UNIT MASS (kg/m^3) REQUIREMENT FOR TEST SECTION**

(_____) x 0.98 =
Dens. Avg. ____________ **AVERAGE DRY DENSITY (lbs/ft^3), DRY UNIT MASS (kg/m^3) REQUIREMENT FOR TEST SECTION**

BY: ____________

TITLE: ____________

Practice Problem Number 2
Nuclear Density Testing of Aggregates
Step 3 – Control Strip (Direct Transmission Test)

A. Use the information below to complete the following worksheet (Form TL-124) and answer the following questions.

Information from Quarry or Materials Lab:

Percent Passing the No. 4 Sieve = 43%
Therefore, the percent of +4 Material = __________

Specific Gravity of the +4 Material = 2.50
Therefore, the density of the +4 Material = __________

Absorption Rate of the +4 Material = 0.3%

Lab Proctor Information
Maximum Dry Density of the -4 Material = 133.0 lbs/ft^3
Optimum Moisture of the -4 Material = 10.1%

Nuclear Gauge Display Panel

% PR = 100.5%

DD = 133.6
WD = 140.8

M = 7.2   M% = 5.4

B. What is the minimum density required?

C. Does the test pass?

Form TL-124 (Rev. 07/15)

VIRGINIA DEPARTMENT OF TRANPORTATION
MATERIALS DIVISION
REPORT ON NUCLEAR EMBANKMENT DENSITIES (UNIT MASSES)

Report No. ____________ **Date** ____________ **Sheet No.** 1 **of** 1

Route No. ____________ **County** ____________

Project No. ____________

FHWA No. ____________

Testing for ____________

Model No. ____________ **Serial No.** ____________ **Calibration Date** ____________

STANDARD COUNT DATA

Density ____________ **Moisture** ____________

Test No.			**1**	**2**	**3**	**4**
Location	Station ft. (m)					
of	Ref. to center line ft. (m)					
Test	Elevation					
Compaction Depth of Lift in. (mm)						
Method of Compaction						
A. Wet Density (lbs/ft^3), Wet Unit Mass (kg/m^3)		=				
B. Moisture Unit Mass (lbs/ft^3 or kg/m^3)		=				
C. Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) (A-B)		=				
D. Moisture Content (B ÷ C) x 100		=				
E. Maximum Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) Lab Proctor or One Point Proctor		=				
F. Percent Optimum Moisture from Lab or One Point Proctor		=				
G. Percent of Plus #4, (plus 4.75 mm)		=				
H. Corrected Max. Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3)		=				
I. Corrected Optimum Moisture		=				
J. Percent Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) (C ÷ E) x 100 or (C ÷ H) x 100		=				
K. Percent Minimum Density Required		=				

Comments:

BY: ____________

TITLE: ____________

Practice Problem Number 2
Nuclear Density Testing of Aggregates
Step 4 – Test Section

A. Testing at the minimum frequency: With the Test Section beginning at Station No. 904+25 and having a paving width 12 feet, choose five (5) test site location using the following random numbers.

Distance from Start of Sublot	Distance from Reference Line
101	4
106	8
27	3
140	3
182	10

There are 5,280 feet in a mile. A Test Section is ________ mile per paver width or ________ feet. ________ tests will be performed in the test section. __________ ÷ __________ = __________.

Beginning Station No. _____________

Sublot 1 __________ Feet

Station No. _____________

Sublot 2 __________ Feet

Station No. _____________

Sublot 3 __________ Feet

Station No. _____________

Sublot 4 __________ Feet

Station No. _____________

Sublot 5 __________ Feet

Ending Station No. _____________

Test No.	Station No. at Start of Each Sublot	+	Distance from Start of Sublot	=	Station No. of Each Test Location	Distance from Reference Line (ft)
		+		=		
		+		=		
		+		=		
		+		=		
		+		=		

B. Transfer the Optimum Moisture, Optimum Moisture Range, Individual Dry Density Requirement, and Average Dry Density Requirement from the Control Strip (Form TL-54) to the proper place on the Test Section worksheet (Form TL-55).

C. Given the following nuclear density and moisture readings, complete the Form TL-55 using the same header information from the preceding problems (except use the correct Report Number: 3-21ACTA-4).

Test 1

Nuclear Gauge Display Panel

% PR = _____%

DD = 132.3
WD = 139.8

M = 7.5 M% = 5.7

Test 2

Nuclear Gauge Display Panel

% PR = _____%

DD = 131.2
WD = 138.4

M = 7.2 M% = 5.5

Test 3

Nuclear Gauge Display Panel

% PR = _____%

DD = 130.6
WD = 137.4

M = 6.8 M% = 5.2

Test 4

Nuclear Gauge Display Panel

% PR = _____%

DD = 131.3
WD = 138.0

M = 6.7 M% = 5.1

Test 5

Nuclear Gauge Display Panel

% PR = _____%

DD = 129.6
WD = 137.4

M = 7.8 M% = 6.0

D. Does this test pass? Why?

E. At what station is Test 4 to be taken from?

F. At what station does Sublot 2 begin?

G. How many feet from the reference line is Test 5 to be taken?

Form TL-55 (Rev. 07/15)

VIRGINIA DEPARTMENT OF TRANPORTATION
MATERIALS DIVISION
REPORT ON NUCLEAR TEST SECTION

Report No. ______________________ **Date** ______________________

Route No. ______________________ **Project No.** ______________________

FHWA No. ______________________ **County** ______________________

Type Material ______________________ **Width** ______________________

Section No. ______________ **Station No.** __________ **ft. (m.) to Station** __________ **ft. (m.)**

Model No. ______________________ **Serial No.** ______________________

Remarks ____

STANDARD COUNT DATA

Density ______________ **Moisture** ______________

______________ **OPTIMUM MOISTURE REQUIRED % (From Producer or Materials Division)**

______________ **OPTIMUM MOISTURE RANGE**

______________ **INDIVIDUAL DRY DENSITY (lbs/ft^3), DRY UNIT MASS (kg/m^3) REQUIRED**
(95% of Control Strip Density from TL-54A)

______________ **AVERAGE DRY DENSITY (lbs/ft^3), DRY UNIT MASS (kg/m^3) REQUIRED**
(98% of Control Strip Density from TL-54A)

Test No.	Station ft. (m)	Lane	Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3)	Moisture Content	Pass (P) Fail (F)
1					
2					
3					
4					
5					
Average					

Comments:

BY: ______________________

TITLE: ______________________

APPENDIX A

MINIMUM TESTING FREQUENCIES

MINIMUM TESTING FREQUENCIES
Manual of Instructions Section 314.01(d)

Embankment (Below Subgrade) – One test for each 2,500 cubic yards of material placed plus:

> For fills from 500 to 2000 feet in length: two density tests will be required for each 6 inch layer within the top 5 feet of fill.
>
> For fills less than 500 feet in length – One density test will be required for every other 6 inch layer from bottom to top of the fill starting with the second lift.
>
> > NOTE: The terms “embankment” and “fill” as used here are intended to encompass the entire roadway in width, under construction between right-of-way lines, regardless of whether the roadway is single or dual lane. For example, a dual lane fill would be considered as a single fill. However, each separate linear embankment or fill will be considered as a separate item and tested at the above specified rate, separately and independently of adjoining fills. Location of test run is to be staggered, so that the entire length, width, and depth of the fill is covered by tests. The top, bottom and middle of fills, and any necessary points in between, shall each be tested. When testing is not being conducted, the Inspector is to visually observe lifts being placed to ensure that proper placement and compaction procedures are being used.

Finished subgrade both cut and fill sections – a minimum of one test shall be made for each 2000 feet of subgrade for each roadway (full width)

Soil Cement or Soil-Lime Stabilized Subgrade (Material-in-Place or Imported Material, other than Aggregate Base, Subbase, or Select Material) – One density test per ½ mile per paver application width.

Treated Aggregate Base, Subbase, and Select Material (Regardless of where material is used in pavement structure) – Average of 5 readings (location of which shall be at randomly selected sites) per ½ mile per paver (mixer) application width for each layer of material placed, using the Backscatter, Control Strip Method of testing. A Roller Pattern and Control Strip must be set up for each layer of lift placed.

Untreated Select Material, Base and Subbase – Same as Item 3b

Shoulder Material – A Roller Pattern and Control Strip must be set up for each layer/ lift placed in order to establish the density requirements.

Aggregate – Average of 5 readings per ½ mile per paver application width per layer of material on alternating sides of the road, using the Backscatter Method of testing.

Pipes – One test per lift on alternating sides of pipe for each 300 linear feet of pipe or portion thereof. Test pattern is to begin after first compactive layer above structures bedding and continue to 1 foot above top of pipe.

Drop Inlets – One test every other lift around the perimeter of the structure. Test pattern is to begin after the first 4” compacted layer above the bedding and continue to the top of the structure. Stagger tests to ensure consistent compactive effort has been achieved throughout.

Manholes – One test every fourth compacted layer around the perimeter of the structure. Test pattern is to begin after first 4” compacted layer above the bedding and continue to 5 feet below top of structure. In the top 5 feet, minimum of one test every other lift around the perimeter of structure and continue to top of structure.

APPENDIX B

MINIMUM DENSITY REQUIREMENTS

DENSITY REQUIREMENTS

For soil embankments, the minimum allowable density is 95 percent of the theoretical maximum dry density (R&B Sec.303.04(h)).

For rock fills, the rock should be placed and manipulated in uniform layers, however the density requirements are waived (R&B Sec.303.04(h)).

At the subgrade area (R&B Sec.305.03(a)), the top 6 inches is scarified for a distance of 2 feet beyond the outer edges of the pavement and recompacted. The minimum percentage density of the recompacted soil is as follows:

Percentage + No. 4 Sieve Material	Min Percent Density
0 - 50	100
51 - 60	95
61 - 70	90

When density control strips are utilized for compaction control of the roadway, the density of each test section will be evaluated based upon the results of 5 readings performed at randomly selected sites within the test section. The mean density obtained for the 5 readings in each test section shall be at least 98 percent of the average density obtained in the approved control strip. In addition, each individual test value obtained within a test section shall be at least 95 percent of the average density obtained in the approved control strip (R&B Sec.304.05(a)).

When density control strips are utilized for compaction control of shoulders, the density of each test section of select or aggregate material used to construct the shoulder will be evaluated based on 5 readings conducted at randomly selected sites within the test section. The average density obtained for these 5 sites in each section shall be within 95 ± 2 percentage points of the average density determined by the approved control strip. In addition, the individual tests in the section shall be within 95 ± 5 percentage points of the average density determined by the approved control strip (R&B Sec.304.05(b)).

When shoulders are constructed with aggregate other than aggregate material No. 18 (R&B Sec.305.03(e)), the minimum densities are as follows:

Percentage + No. 4 Sieve Material	Min Percent Density
0 - 50	95
51 - 60	90
61 - 70	85

When shoulders are constructed with aggregate material No. 18 (which is quite common in hydraulic cement concrete pavement), the density shall not be less than 90 percent, nor more than 95 percent of the theoretical maximum dry density (R&B Sec.305.03(e)).

Aggregate placed in the guardrail section of embankments should be compacted to a minimum of 90 percent of the theoretical maximum density (R&B Sec.305.03(e)).

For lime stabilized subgrades, compaction should be to a density of not less than 95 percent of the theoretical maximum density (R&B Sec.306.03(f)).

For hydraulic cement stabilized subgrades, compaction should be to a density of not less than 100 percent of the theoretical maximum density (R&B Sec.307.05(c)).

For aggregate base (R&B Sec.309.05) and subbase layers (cement stabilized or untreated) (R&B Sec.308.03), the minimum densities are as follows:

Percentage + No. 4 Sieve Material	Min Percent Density
0 - 50	100
51 - 60	95
61 - 70	90

When testing aggregate using direct transmission (VTM-10) the minimum densities are as follows:

Percentage + No. 4 Sieve Material	Min Percent Density
0 - 50	95
51 - 60	90
61 - 70	85

APPENDIX C

ROAD AND BRIDGE SPECIFICATIONS

SECTION 301--CLEARING AND GRUBBING

301.01--Description.

This work shall consist of clearing, grubbing, removing, and disposing of vegetation, debris, and other objects within the construction limits except for vegetation and objects that are designated to be preserved, protected, or removed in accordance with the requirements of other provisions of these specifications.

301.02--Procedures.

If approved by the Engineer, the Contractor may clear and grub to accommodate construction equipment within the right of way up to 5 feet beyond the construction limits at his own expense. The Contractor shall install erosion and siltation control devices prior to beginning clearing and grubbing operations and such devices shall be functional before upland land-disturbing activities take place.

The surface area of earth material exposed by grubbing, stripping topsoil, or excavation shall be limited to that necessary to perform the next operation within a given area. Grubbing of root mat and stumps shall be confined to the area which excavation shall be performed within 15 days following grubbing.

Stumps, roots, other perishable material, and nonperishable objects that will be less than 5 feet below the top of earthwork within the area directly beneath the pavement and shoulders shall be removed. However, such material and objects that will be 5 feet or more than 5 feet below the top of earthwork within the area directly beneath the pavement and shoulders and all such material and objects beneath slopes of embankments shall be left in place unless removal is necessary for installation of a structure. The top of stumps left in place shall be not more than 6 inches above the existing ground surface or low water level.

Branches of trees that overhang the roadway or reduce sight distance and that are less than 20 feet above the elevation of the finished grade shall be trimmed using approved tree surgery practices in accordance with the requirements of Section 601.03(b).

Vegetation, structures, or other items outside the construction limits shall not be damaged. Trees and shrubs in ungraded areas shall not be cut without the approval of the Engineer.

Combustible cleared and grubbed material shall be disposed of in accordance with the following:

(a) **Trees, limbs, and other timber having a diameter of 3 inches and greater** shall be disposed of as saw logs, pulpwood, firewood, or other usable material; however, treated timber shall not be disposed of as firewood. Not more than 2 feet of trunk shall be left attached to grubbed stumps.

When specified that trees or other timber is to be reserved for the property owner, such material shall be cut in the lengths specified and piled where designated, either within the limits of the right of way or not more than 100 feet from the right-of-way line. When not reserved for the property owner, such material shall become the property of the Contractor.

(b) **Material less than 3 inches in diameter** shall be used to form brush silt barriers when located within 500 feet of the source of such material when specified on the plans or where directed by the Engineer. Material shall be placed approximately 5 feet beyond the toe of fill in a strip approximately 10 feet wide to form a continuous barrier on the downhill side of fills. Where selective clearing has been done, material shall be piled, for stability, against trees in the proper location. On the uphill side of fills, brush shall be stacked against fills at approximately 100 foot intervals in piles approximately 5 feet high and 10 feet wide. Any such material not needed to form silt barriers shall be processed into chips having a thickness of not more than 3/8 inch and an area of not more than 6 square inches and may be stockpiled out of sight of any public highway for use as mulch.

(c) **Stumps and material less than 3 inches in diameter** that are not needed to form silt barriers and that are not processed into wood chips shall be handled in accordance with the requirements of Sections 106 and 107.

301.03--Measurement and Payment.

Clearing and grubbing will be measured and paid for in accordance with one of the following methods, as specified:

(a) **Lump sum basis:** No measurement of the area to be cleared and grubbed will be made.

(b) **Acre basis:** The work to be paid for will be the number of acres, computed to the nearest 0.1 of an acre, actually cleared and grubbed. Areas within the limits of any existing roadway or local material pit will not be measured.

(c) **Unit basis:** The work to be paid for will be determined by the actual count of trees, stumps, structures, or other obstructions removed.

These prices shall include disposing of cleared and grubbed material.

When clearing and grubbing is not a pay item, the cost thereof shall be included in the price for other appropriate pay items. Allowance will not be made for clearing and grubbing borrow pits or other local material pits.

Payment will be made under:

Pay Item	Pay Unit
Clearing and grubbing	Lump sum, acre, or unit

SECTION 302--DRAINAGE STRUCTURES

302.01--Description.

This work shall consist of installing pipe culverts, endwalls, box culverts, precast concrete and metal arches, storm drains, drop inlets, manholes, spring boxes, junction boxes, and intake boxes and removing and replacing existing structures in accordance with the requirements of these specifications and in reasonably close conformity with the lines and grades shown on the plans or as established by the Engineer.

302.02--Materials.

(a) **Pipe** shall conform to the requirements of Section 232 and shall be furnished in accordance with the diameter, wall thickness, class, and strength or corrugation specified for the maximum height of fill to be encountered along the length of the pipe culvert, storm drain, or sewer.

(b) **End sections** shall conform to the applicable requirements of Section 232. End sections used with rigid pipe shall be concrete. End sections used with asphalt- coated or paved pipe shall not be asphalt coated or paved.

(c) **Pipe fittings, such as tees, elbows, wyes, and bends**, shall conform to the applicable requirements of Section 232. Fittings shall be of the same type, class, thickness, gage, and strength as the line in which they are used.

(d) **Steel grates, steel frames and structural steel** shall conform to the requirements of Section 226 and shall be galvanized in accordance with the requirements of Section 233.

(e) **Concrete blocks** shall conform to the requirements of Section 222 for masonry blocks.

(f) **Brick** shall conform to the requirements of Section 222.

(g) **Hydraulic cement mortar** shall conform to the requirements of Section 218.

(h) **Cast-in-place concrete** shall conform to the requirements of Section 217 for Class A3.

(i) **Bedding material** shall conform to the requirements of Section 205.

(j) **Joint material and gaskets** shall conform to the requirements of Section 212.

(k) **Gray-iron castings** shall conform to the requirements of Section 224.

(l) **Reinforcing steel** shall conform to the requirements of Section 223, Grade 40 or 60.

(m) **Curing materials** shall conform to the requirements of Section 220.

302.03--Procedures.

Excavation and backfill operations shall be performed in accordance with the requirements of Section 303.

Foundation exploration shall be performed in accordance with the requirements of Section 401 unless otherwise provided herein. Concrete construction shall conform to the requirements of Section 404. Reinforcing steel placement shall conform to the requirements of Section 406. Bearing pile operations shall be performed in accordance with the requirements of Section 403. When specified on the plans or directed by the Engineer, a temporary diversion channel shall be constructed to facilitate installation of a pipe or box culvert.

The Contractor shall be responsible for anticipating and locating underground utilities and obstructions in accordance with the requirements of Section 105.08.

When construction appears to be in close proximity to existing utilities, the trench(es) shall be opened a sufficient distance ahead of the work or test pits made to verify the exact locations and inverts of the utility to determine if changes in line or grade are required for the new work.

When lift holes are provided in concrete pipe or precast box culverts, the Contractor shall install a lift hole plug furnished by the manufacturer in accordance with the requirements of Section 232.02(a)1. After pipe installation and prior to backfilling, plugs shall be installed from the exterior of the pipe or box culvert and snugly seated.

(a) **Pipe Culverts:** Not more than one type of pipe shall be used in any one pipe line. When the proposal indicates that all types of pipe of one size are combined into one bid item, one bid price shall be submitted for each size of pipe to be used.

When field cutting corrugated metal pipe is permitted by the Engineer, damaged areas of the protective coating shall be repaired in accordance with the requirements of Section 233 for galvanized pipe and in accordance with the manufacturer’s recommended procedures for all other metallic or polymer coatings.

1. **Jack and bore method:** The Contractor shall submit to the Engineer a complete plan and schedule for jack and bore pipe installation prior to beginning such work. The submission shall include complete details for dewatering; soil stabilization; jacking and receiving pits; jacks; reaction block; boring equipment; sheeting, shoring, and bracing for protecting the roadbed; installation sequence; materials; and equipment. The Contractor shall not proceed with pipe installation until the plan has been reviewed and accepted by the Engineer.

The jack and bore method shall be applicable for installing concrete pipe 12 through 108 inches in diameter and smooth-wall steel pipe 12 3/4 through 48 inches in diameter.

Pipe shall have a design strength and wall thickness sufficient to withstand the jacking operation and maximum height of fill to be encountered along the length of the pipe.

Construction shall be performed in such a manner that the ground surface above the pipe line will not settle. The hole shall be bored mechanically with a suitable boring assembly designed to produce a smooth, straight shaft and so operated that the completed shaft shall be at the established line and grade. The size of the bored hole shall be of such diameter to provide ample clearance for bells or other joints. The holes shall be bored mechanically. The boring shall be done by using either a pilot hole or a dry bore method.

In operating jacks, even pressure shall be applied to all jacks used. Suitable bracing between jacks and the jacking head shall be provided so that pressure shall be applied to the pipe uniformly around the ring of the pipe. The jacking head shall be of such weight and dimensions that it shall not bend or deflect when full pressure is applied to the jack. The jacking head shall be provided with an opening for the removal of excavated material as the jacking proceeds. The pipe to be jacked shall be set on guides that are straight and securely braced together in such manner as to support the section of pipe and to direct it in the proper line and grade.

Installation of the pipeline shall immediately follow heading or tunneling excavation. Voids occurring behind the pipe during installation shall be filled with hydraulic cement grout, placed under pressure, upon completion of the jack and bore operation.

Joint sealant material on concrete pipe shall be placed ahead of the jacking frame. The Contractor shall replace or repair, as directed by the Engineer, pipe that is damaged during jacking operations at his own expense. Joints of steel pipe shall be butt welded, watertight, as installation progresses.

When work is stopped, the heading shall be bulkheaded.

When the contractor encounters an obstruction during the jacking and boring operation that stops the forward progress of the work for more than 60 minutes, the following procedure shall be followed:

a. The Contractor shall notify the Engineer immediately upon encountering an obstruction that stops the forward progress of the work. The Engineer shall verify that an obstruction has stopped the forward progress of the work in excess of 60 minutes and that the Contractor’s efforts to remove or bore through the obstruction have been deliberately and diligently pursued.

b. The Contractor shall consult with the Engineer and offer appropriate options for consideration. Upon authorization by the Engineer, the Contractor shall proceed with removal of the obstruction by other methods on a force account basis in accordance with the requirements of Section 109.05. Such alternative methods may include tunneling. In the event tunneling is determined to be necessary by the Engineer, the Contractor shall detail a plan for such an operation including all necessary safety and health precautions for workers as required by local, state, and federal regulations as required by the work being performed. Work shall not commence until this plan is received and authorized by the Engineer. The Contactor shall notify the Engineer before resuming work and afford the Engineer the opportunity to witness all work performed by the Contractor. Payment for obstruction removal shall be from the start of removal operations until the successful removal of the obstruction.

c. Upon removal of the obstruction, the Engineer shall make a determination as to the method to use to proceed with the pipe installation.

2. **Open trench method:**

   a. **Foundation:** The foundation shall be explored below the bottom of the excavation to determine the type and condition of the foundation. However, explorations need not be made for routine entrance or crossover pipe 12 through 30 inches in diameter that is to be installed under fills 15 feet or less in height. Foundation exploration shall extend to a depth equal to ½ inch per foot of fill height or 8 inches, whichever is greater. The Contractor shall report the findings of the foundation exploration to the Engineer for approval prior to placing pipe.

Where unsuitable foundation is encountered at the established grade, as determined by the Engineer, such material shall be removed and replaced.

Backfill for areas where unsuitable material has been removed shall be placed and compacted in accordance with the requirements of Section 303.04(g).

b. **Bedding:** Bedding material for culvert foundations, including foundations in soft, yielding or otherwise unsuitable material, shall be aggregate No. 25 or 26 conforming to the requirements of Section 205. Where standing or running water is present in the pipe foundation excavation, pipe bedding material shall be aggregate No. 57 for the depth specified on the plans or as directed by the Engineer, capped with 4 inches of aggregate No. 25 or 26. Where such conditions are discovered in the field and the Contractor is directed by the Engineer to use No. 57 stone, No. 57 stone will be paid for at the existing contract until price, or if not in the contract, in accordance with Section 109.05.

Pipe bedding shall be lightly and uniformly compacted and shall be carefully shaped so that the lower section of the pipe exterior is in contact with the bedding material for at least ten percent of the overall height of the pipe. Bedding material shall be shaped to accommodate the bell when bell and spigot pipe is used. The depth of bedding material shall be at least 4 inches or as specified on the plans.

c. **Placing pipe:** Pipe shall be placed beginning at the downstream end of the pipe line. The lower segment of pipe shall be in contact with the shaped bedding for its entire length. Bell or groove ends of rigid pipe shall be placed facing upstream.

Paved or partially lined pipe shall be placed so that the longitudinal center line of the paved segment coincides with the flow line.

Pipe will be inspected before backfill is placed. Pipe found to be out of alignment, unduly settled, or damaged shall be taken up and reinstalled or replaced.

d. Joining pipe:

(1) **Rigid pipe:** The method of joining pipe sections shall be such that ends are fully entered and inner surfaces are reasonably flush and even so as to permit sealing as specified herein.

Joints shall be sealed with any one or combination of the following to form a leak-resistant joint: rubber, preformed plastic, or mastic gaskets from the Department’s approved list; oakum and mortar; oakum and joint compound; or cold-applied pipe joint sealer.

Rubber ring gaskets shall be installed to form a flexible, leak- resistant seal. Where oakum is used, the joint shall be caulked with this material and then sealed with mortar or joint compound.

(2) **Flexible pipe:** Flexible pipe sections shall be aligned and firmly joined by approved coupling bands to form a leak-resistant joint.

e. **Structural plate pipe, pipe arches, and arches:** Erection shall be in accordance with the manufacturer's assembly diagrams and instruction sheets. Splices in the haunch areas of structural plate pipe arches shall be constructed using the reverse shingle method or the side plates shall be provided without longitudinal seams in the haunch areas. The complete line shall be assembled before backfill is placed. Bolts shall be tightened to a torque of 150 to 250 foot-pounds. If spiraling occurs during installation, bolts shall be loosened and the pipe assembly adjusted to the correct position.

f. **Arch substructures:** Each side of an arch shall rest in a groove formed into the masonry or on a galvanized angle or channel securely anchored to or embedded in the substructure. Where the span of the arch is more than 15 feet or the skew angle is more than 20 degrees, a metal bearing surface having a width at least equal to the depth of the corrugation shall be provided.

Metal bearings for arches shall be cold-formed galvanized channel conforming to the requirements of ASTM A569 at least 3/16 inch in thickness, with the horizontal leg securely anchored to the substructure at points spaced on centers of not more than 24 inches. When the metal bearing is not embedded in a groove in the substructure, one vertical leg shall be punched to allow bolting to the bottom row of plates.

g. **Backfilling:** Class I backfill shall be crusher run aggregate size No. 25 or 26, aggregate base material size 21A or 21B, flowable fill, or crushed glass conforming to the size requirements for crusher run aggregate size No. 25 and 26.

Regular backfill material outside of the neatlines of the Class I areas shown on the Standard PB-1 drawings shall be regular excavation conforming to Section 303. Regular and classified backfill shall be placed in uniform layers not more than 6 inches in thickness, loose measurement, before compaction. Each layer of Class I and regular backfill material shall be thoroughly compacted as specified in Section 303.04(g) with the exception that Class I backfill material shall be placed and compacted at a moisture content of optimum to plus 2 percentage points of optimum. Class I backfill material shall be thoroughly compacted under the haunches of pipe culverts. Each layer of Class I and regular backfill material shall be compacted by rolling, tamping with mechanical rammers, or hand tamping with heavy metal tampers with a face of at least 25 square inches. If vibratory rollers are used in the backfill operations, vibratory motors shall not be activated until at least 3 feet of backfill has been placed and compacted over the pipe. Backfill and compaction shall be advanced simultaneously on both sides of the pipe. The fill above the top of the regular backfill shall be installed and completed as specified for embankment construction.

Field density determinations will be performed in accordance with the requirements of VTM-1, VTM-10 or other methods approved by the Engineer.

Concrete pipe with a height of cover greater than that shown in the Standard PC-1 drawings, table for Class V pipe, shall be special design pipe with Method "A" bedding and backfill in accordance with the requirements of Standard PB-1.

Puddling will not be permitted. Rock more than 2 inches in its greatest dimension shall not be placed within 12 inches of pipe.

Backfill and compaction shall be advanced simultaneously on both sides of the pipe. The fill above the top of the pipe shall be completed as specified for embankment construction unless the induced trench method of installation is used.

3. **Tunneling operations:** The jacked tunneling method shall be applicable for installing concrete pipe 30 through 108 inches in diameter and smooth-wall steel pipe 30 through 48 inches in diameter. Where the plans specifically identify tunneling as the means of pipe installation, tunneling shall be performed by the Contractor as follows:

   The tunnel shall be excavated in such a manner and to such dimensions that shall permit placing of the proper supports necessary to protect the excavation. The Contractor shall take the proper precautions to avoid excavating earth or rock or shattering rock beyond the limits of excavation necessary for the safe and proper installation of the pipe. Damage from excavating and blasting, either to surface or subsurface structures, shall be repaired or replaced by the Contractor at his own expense. Adequate provisions shall be made for the safety and health of the workers required by the work being performed.

   No pipe shall be placed until the foundation is in a condition satisfactory to the Engineer. Tunnel dimensions shown on the plans are minimum dimensions. Any excess excavation and subsequent backfill, concrete or grout fill shall be at the Contractor's expense. The pipe shall be laid in the tunnel true to line and grade. If required by the plans or if required for safety, suitable steel or timber sheeting, shoring, and bracing shall be used to support the sides and roof of the excavation. Supports may be left in place provided they clear the encasement or carrier pipe. No separate payment shall be made for supports left in place. Installation of the pipeline shall immediately follow tunneling excavation.

   If indicated or specified, the entire void between the outside of the pipe and the tunnel walls or the inside face of the tunnel lining shall be grouted in accordance with ASTM C476 unless the permanent sheeting, bottom, sides, and roof of the tunnel are in a condition satisfactory to the Engineer. The minimum thickness of grout backfill shall be maintained throughout. Grout required for backfill in excess of the excavation tolerances specified herein shall be at the Contractor's expense.

   Any pipe damaged during construction operations shall be repaired, if approved by the Engineer, or removed and replaced by the Contractor at his expense.

   If corrugated galvanized metal pipe is used, joints may be made by field bolting or by connecting bands, whichever is feasible. When reinforced concrete pipe 24 inches and larger in diameter with tongue-and-groove joints is used for the encasement pipe, the interior joints for the full circumference shall be sealed, packed with mortar, and finished smooth and even with the adjacent section of pipe.

(b) **Precast Drainage Structures:** Submittal of designs for precast items included in the standard drawings will not be required provided fabrication is in accordance with the standard details. Submittal of designs for precast box culverts on the Department's approved list will not be required provided the Contractor submits a certification that the item will be fabricated in accordance with the preapproved design drawings.

Requests for approval of a precast design shall include detailed plans and supporting computations that have been reviewed and approved by a registered Professional Engineer having at least 5 years of experience in structural design of the type of precast structures or components proposed and licensed in the Commonwealth. Concrete shall conform to Section 217 unless otherwise specified and have a design strength at 28 days of at least 4000 pounds per square inch and an air content of 6 ± 2 percent. The design of the concrete mixture and the method of casting, curing, handling, and erecting shall be subject to review by the Engineer. Precast units may be shipped after reaching 85 percent of the design strength as determined by control cylinders tested in accordance with the requirements of Section 404. However, units shall retain their structural integrity during shipment and shall be subject to inspection at the job site. Approval to use precast units shall not be construed as waiving the size and weight hauling limitations specified in Section 107.21.

1. **Standard precast drainage units** shall conform to the material requirements of AASHTO M199 and the following:

    a. If the grade on the adjacent gutter is less than 1.5 percent, the grade on the invert of the throat section of the inlet shall be at least 1.5 percent. Precast throats having flat inverts will be permitted in sag locations provided the total length of the required throat opening does not exceed 6 feet.

    b. Pipe openings in precast drainage units shall not exceed the outside cross sectional dimensions of the pipes by more than a total of 8 inches regardless of the placement of the pipes, the angles of intersection, or the shapes of the pipes. Pipe openings shall be formed, drilled, or neatly cut.

    c. The Contractor shall use brick, masonry block, other standard masonry units, or clean, durable, and sound local stone in conjunction with mortar to fill the void between the pipe culverts and the precast drainage structures. Stone or masonry units, areas of the pipe openings, and exterior walls of pipe shall be thoroughly wetted and then bonded with mortar by standard masonry practice in such a manner as to provide a contiguous masonry connection between the precast drainage structures and the pipe culverts. The remaining exterior and interior voids shall be filled with mortar and shaped to the contour of the precast structure.

    d. When precast units are to be located adjacent to the subbase or base course, units with chambers shall be provided with weep holes 3 inches in diameter and hardware cloth and shall be located to drain the subbase or base.

e. Precast units located adjacent to cast-in-place concrete items, such as flumes, ditches, and gutters, shall be connected to the adjacent unit by means of No. 4 smooth steel dowels spaced on approximately 12 inch centers throughout the contact length and extending at least 4 inches into both the precast unit and the cast-in-place item. If holes to receive the dowels are provided in the precast unit, they shall be not more than 5/8 inch in diameter. Other methods of providing the connection, such as keyed joints, shall be approved by the Department prior to fabrication.

f. The chamber section shall be installed in the plumb position. The throat and top sections shall have positive restraints, such as adjacent concrete, pavement, or soil on all sides to prevent displacement and shall have a positive interlock, such as dowels, with the chamber section. The throat and top sections shall be installed to conform with the normal slope of the finished grade, and may be canted up to a maximum grade of 10%. The chamber may be built up a maximum of 12 inches at any point to provide for complete and uniform bearing of the throat and top sections on the chamber flat slab top or other approved top section. The built up section shall be constructed using whole concrete spacer units where feasible, and partial and whole sections of concrete block or brick with high strength grout and mortar. High strength grout shall be used to provide the final grade adjustment and uniform bearing. The width of the built up section shall match the wall thickness of the chamber section. The concrete block and brick shall be thoroughly bonded with mortar and the inside and outside of the built-up section shall be plastered with mortar except that the concrete spacer unit shall not be plastered.

2. **Precast arches** shall conform to the applicable requirements of AASHTO's Standard Specifications for Highway Bridges with the following modifications:

   a. **Combination of loads:** For service load design: E: vertical loads: 1.00; lateral loads: 1.00 and 0.5 (check both loadings).

      For load factor design: E: vertical loads: 1.00; lateral loads: 1.30 and 0.5 (check both loadings).

   b. **Protection against corrosion:** The concrete cover of reinforcement shall be at least 1 ½ inches.

      In corrosive or marine environments or other severe exposure conditions, reinforcement shall be epoxy coated in accordance with the requirements of Section 223.

      Exposed reinforcing bars, inserts, and plates intended for bonding with future extensions shall be protected from corrosion as directed by the Engineer.

      Reinforcement shall be designed and detailed in consideration of fabrication and construction tolerances so that the minimum required cover and proper positioning of reinforcement shall be maintained.

   c. **Anchorage:** Sufficient anchorage shall be provided at the terminus of lines of precast units. Anchorage may consist of a cast-in-place end section at least 3 feet in length with a headwall or collar around the precast unit(s) provided adequate connection can be made between the collar and units.

   d. **Joints:** Joints between units shall be sealed by preformed plastic or mastic gaskets or grout. When preformed gaskets are used, they shall be of a type listed on the Department’s approved products list.

   e. **Pipe openings:** Pipe openings will not be allowed in the precast arch but may be provided through the wingwalls. When required, openings shall conform to the requirements of 1.b. herein.

3. **Precast box culverts** shall conform to the applicable requirements of AASHTO M259 or M273 and AASHTO’s Standard Specifications for Highway Bridges with the following modifications:

   a. Combination of loads: For service load design or load factor design: E: new reinforced concrete boxes: vertical loads: 1.00; lateral loads: 1.00 and 0.5 (check both loadings).

   b. Protection against corrosion: The following minimum concrete cover shall be provided for reinforcement: For boxes with more than 2 feet of fill over the top slab: 1 ½ inches. For boxes with less than 2 feet of fill over the top slab: top reinforcement of top slab: 2 ½ inches; bottom reinforcement of top slab: 2 inches; all other reinforcement: 1 ½ inches.

      The minimum cover for reinforcement may be reduced by not more than ½ inch, provided the reinforcement having reduced cover is epoxy coated or the concrete surfaces adjacent to the reinforcement are coated in accordance with the requirements of Section 416.

      Reinforcing steel for box culverts used in 0 to 2 foot fills, used in corrosive or marine environments or used in other severe exposure conditions shall be epoxy coated. When epoxy coated reinforcing steel is required due to these conditions, the minimum cover specified shall not be reduced.

   c. The type of sealant used in joints between units shall be from the Department’s approved list of preformed plastic or mastic gaskets.

      Where double or greater lines of precast units are used, a buffer zone of 3 to 6 inches between lines shall be provided. This buffer zone shall be backfilled with porous backfill conforming to the requirements of Section 204. The porous backfill shall be drained by a 3 inch diameter weep hole, formed by non-rigid tubing, located at the top of the bottom haunch, centered in the outlet end section and at approximately 50 foot intervals along the length of the box. Weep holes shall be covered with a 3 foot square section of filter barrier cloth firmly attached to the outside of the box. A 3 foot width of filter barrier cloth shall also be centered over the buffer zone for the entire length of the structure after placement of the porous backfill material. Filter barrier cloth shall conform to the requirements of Section 245.

Forming weep holes and furnishing and placing of the filter barrier cloth shall be included in the price bid per linear foot for the Precast Box Culvert.

d. At the terminus of precast units, sufficient anchorage shall be provided. This anchorage may consist of a cast-in-place end section at least 3 feet in length with a headwall and curtain wall or a collar cast-in-place around the units provided adequate connection can be made between the collar and units.

   When the ends of precast units are skewed, the end section shall be cast monolithically. The skew may be provided by forming, saw cutting, or other methods approved by the Engineer. Regardless of the method used, the variation in the precast unit from the exact skew shall be not greater than 1 ½ inches at any point.

e. Pipe openings shall conform to the requirements of 1.b. herein.

f. Bedding shall be at least 6 inches in thickness.

(c) **Drop Inlets, Manholes, Spring Boxes, Intake Boxes, and Endwalls:** Masonry construction shall not be initiated when the air temperature is below 40^{o} F in the shade.

The foundation shall be explored below the bottom of the excavation to determine the type and condition of the foundation. Foundation exploration shall extend to a depth equal to 1/2 inch per foot of fill height of 8 inches, whichever is greater. The Contractor shall report the findings of the foundation exploration to the Engineer for approval prior to placing structure.

Where unsuitable foundation is encountered at the established grade, as determined by the Engineer, such material shall be removed and replaced.

Backfill for areas where unsuitable material has been removed shall be placed and compacted in accordance with the requirements of Section 303.04(g).

Bedding material shall be placed in accordance with the Standard Drawings and shall be aggregate No. 25 or 26 conforming to the requirements of Section 205 except where standing or running water is present in the foundation excavation; then, bedding material shall be aggregate No. 57 for the depth specified on the plans or as directed by the Engineer capped with 4 inches of aggregate No. 25 or 26. Where such conditions are discovered in the field and the Contractor is directed by the Engineer to use No. 57 stone, No. 57 stone will be paid for at the existing contract unit price or, if not in the Contract, in accordance with Section 109.05.

Bedding shall be lightly and uniformly compacted. The depth of bedding material shall be as specified on the standard drawings or in the plans.

Brick and concrete block masonry shall be placed so that each unit will be thoroughly bonded with mortar. Joints shall be full-mortar joints not more than ½ inch in width. Where brick masonry is used, headers and stretchers shall be arranged to bond the mass fully. Every seventh course shall be placed entirely with headers. Inside joints shall be neatly pointed, and the outside of such walls shall be plastered with mortar as they are placed.

Iron fittings entering the masonry shall be placed as the work is built up, thoroughly bonded, and accurately spaced and aligned.

Inlet and outlet pipe connections shall conform to the same requirements as the pipe to which they connect and shall be of the same size and kind. Pipe sections shall be flush on the inside of the structure wall and shall project outside sufficiently for proper connection with the next pipe section. Masonry shall fit neatly and tightly around the pipe.

Immediately following finishing operations, hydraulic cement concrete shall be cured and protected in accordance with the requirements of Section 316.04(j).

Backfilling shall be performed in accordance with the requirements of Section 303.04(g). Surplus material shall be removed, and the site shall be left in a neat and orderly condition.

When grade adjustment of existing structures is specified, frames, covers, and gratings shall be removed and the walls shall be reconstructed as required. Cleaned frames shall be reset at the required elevation. Upon completion, each structure shall be cleaned of silt, debris, and foreign matter and shall be kept clear of such accumulation until final acceptance.

302.04--Measurement and Payment.

Pipe culverts will be measured in linear feet. The quantity will be determined by counting the number of sections and multiplying by the length of the section used. When a partial section is required, the actual length of the partial section will be measured in place.

Structural plate pipe and pipe arches will be measured in linear feet along the invert line.

Pipe tees and elbows will be measured in linear feet of pipe.

Pipe reducers will be measured in linear feet of pipe for payment at the larger pipe size.

Pipe shall be paid for at the contract unit price per linear foot. This price shall include excavating, when not paid for as Minor Structure Excavation, sheeting, shoring, dewatering, disposing of surplus and unsuitable material and restoring existing surfaces. The upper 4 inches of bedding material and the Class I backfill material within the neatlines shown for each foundation type on the Standard PB-1 Drawings shall be included in the price for the related pipe. When unit prices for extended pipelines are not specified, the unit price for new pipe of the same size shall apply. When not a pay item, the cost of the temporary relocation of a stream to facilitate the installation of the pipe shall be included in the price for the pipe. The cost of fittings, anti-seepage collar and anchor blocks shall be included in the price for the pipe.

Jacked and bored pipe will be measured in linear feet to the nearest 0.1 foot along the centerline of completed jacked and bored pipe for the size indicated and will be paid for at the contract unit price per linear foot. This price shall include excavating and backfilling jacking and receiving pits, sheeting, shoring, bracing, jacking equipment, casing pipe, casing chocks, furnishing and installing carrier pipe, grout to install carrier pipe, drainage, safety equipment, and all other items necessary for this operation.

Tunneled pipe will be measured in linear feet to the nearest 0.1 foot along the centerline of completed tunnel for the size of lining and will be paid for at the contract until price per linear foot. This item shall include equipment, materials, handling and disposal of all material encountered, drainage, pumping and dewatering, tunnel support, lining, furnishing and installing pipe, grouting, ventilation, lighting and wiring, coordination and planning with the railroad or other specified entity, and all other appurtenances necessary to complete the work.

Reinstalled pipe will be measured in linear feet along a line parallel to the flow line and will be paid for at the contract unit price per linear foot of pipe and per cubic yard of minor structure excavation. This price shall include excavation involved in removing pipe, hauling, cleaning, relaying, backfilling, necessary cutting for joining to other sections of pipe, furnishing new coupling bands, disposing of surplus excavation, and replacing any otherwise usable sections damaged or broken because of the negligence of the Contractor.

End sections and pipe spillouts will be measured in units of each, complete-in-place, and will be paid for at the contract unit price per each.

Endwalls and arch substructures will be measured in cubic yards of concrete and pounds of reinforcing steel, except that EW-12 endwalls will be measured in units of each complete-in- place. Endwalls and arch substructures will be paid for at the contract unit price per cubic yard of miscellaneous concrete and per pound of reinforcing steel, except that crack control bars shall be included in the price bid for miscellaneous concrete and standard EW-12 endwalls will be paid for at the contract unit price per each.

Minor structure excavation will be measured and paid for in accordance with the requirements of Section 303.06.

Cast-in-place box culverts will be measured in cubic yards of concrete and pounds of reinforcing steel and will be paid for at the contract unit price per cubic yard of concrete and per pound of reinforcing steel. These prices shall include excavating, sheeting, shoring, dewatering, waterproofing, disposing of surplus and unsuitable material, restoring existing surfaces, the upper 6 inches of bedding material within the neat lines shown on the Standard PB-1 drawings, and all necessary work to key the bottom slab into an existing rock foundation. When not a pay item, the cost of the temporary relocation of a stream to facilitate the installation of the structure shall be included in the price for the concrete and steel.

If the Contractor elects to furnish and install precast box culverts or precast arches, payment will be made for the original quantities shown on the plans for cast-in-place units. No additional compensation will be made for casting, prestressing, or shipping precast units or performing additional work, such as waterproofing, epoxy coating, or joint sealing, required as a result of the substitution.

Precast box culverts will be measured in linear feet along the centerline of the barrel from face of curtain wall to face of curtain wall and will be paid for at the contract unit price per linear foot. This price shall include designing, casting, reinforcing, excavating, sheeting, shoring, dewatering, installing, waterproofing, sealing joints, anchoring, disposing of surplus and unsuitable material, restoring existing surfaces, the upper 6 inches of bedding material within the neatlines shown on the Standard PB-1 Drawings, fittings and providing buffer zones and porous backfill for multiple lines. When not a pay item, the cost of the temporary relocation of a stream to facilitate the installation of the structure shall be included in the price for box culvert.

If the Contractor elects to furnish and install precast box culverts or precast arches, payment will be made for the original quantities shown on the plans for cast-in-place units. No additional compensation will be made for casting, prestressing, or shipping precast units or performing additional work, such as waterproofing, epoxy coating, or joint sealing, required as a result of the substitution.

Grates and frames will be measured in units of each and will be paid for at the contract unit price per each.

Pipe grate will be measured in linear feet and will be paid for at the contract unit price per linear foot. This price shall include fabricating, furnishing, galvanizing, and installing.

Drop inlets and intake boxes will be measured as complete units, including the frame and grate or cover, and will be paid for at the contract unit price per each. The contract unit price for drop inlets will be adjusted at the rate of 5% per foot for increases or decreases in the depth indicated on the plans except that no adjustment will be made for changes amounting to less than 6 inches in the height of a single drop inlet. Where curb or curb and gutter extend along the drop inlet, the contract unit price for drop inlets shall include that part of the curb or gutter within the limits of the structure. Bedding material, except aggregate No. 57, will be included in the price of the structure.

Base sections of pipe tee units used as drop inlets and manholes will be measured in linear feet horizontally and will be paid for at the contract unit price per linear foot of pipe specified. The riser section and additional costs for the tee shall be included in the price for the drop inlet or manhole.

Manholes will be measured in linear feet, vertical measure, from top of foundation slab to top of masonry on which the casting frame is placed. However, when manholes are constructed as tee sections, measurement will be made to the pay limits shown on the plans. Manholes will be paid for at the contract unit price per vertical linear foot exclusive of frame and cover. Bedding material, except aggregate No. 57, will be included in the unit price per foot for the manhole.

Concrete spring boxes will be measured in cubic yards of concrete, pounds of reinforcing steel, and linear feet of pipe and will be paid for at the contract unit price per cubic yard of concrete, per pound of reinforcing steel, and per linear foot of pipe.

Junction boxes will be measured in cubic yards of concrete, pounds of reinforcing steel, pounds of structural steel, and each complete frame and cover assembly and will be paid for at the contract unit price per cubic yard of concrete, per pound of reinforcing steel, per pound of structural steel, and per each frame and cover assembly. Bedding material, except aggregate No. 57, will be included in the price of the structure.

Casting frames and covers will be measured in units of one complete frame and cover and will be paid for at the contract unit price per unit.

Reconstructed manholes will be measured as a complete unit and will be paid for at the contract unit price per each.

Precast arches will be measured in meters along the centerline of the invert from face of headwall to face of headwall. When a pay item, precast arches will be paid for at the contract unit price per linear foot. This price shall include designing, forming, casting, reinforcing, excavating, wingwalls, installing, waterproofing, sealing joints, anchoring and bedding, and providing buffer zones for multiple lines. The cost for cast-in-place work other than that specified on the plans shall be included in the price for precast arches.

Temporary diversion channel lining will be measured in square yards for the class specified and will be paid for at the contract unit price per square yard. This price shall include installing the channel lining and removal when no longer required.

Temporary diversion channel excavation will be measured in cubic yards and will be paid for at the contract unit price per cubic yard. This price shall include excavation, temporary pipe culverts and removal of pipe culverts when no longer required, backfilling, site restoration including regrading and seeding.

Excavation, backfill, and disposal of unsuitable or surplus material for drop inlets, intake boxes, manholes both new and reconstructed, spring boxes, junction boxes, and base sections of pipe tee units used as drop inlets and manholes will not be measured for separate payment, and the cost thereof shall be included in the bid price for such items. In the event steps or invert shaping are required, the cost thereof shall also be included in the price for such items.

Storm water management drainage structure will be measured in feet, vertical measure, from top of concrete foundation to the top of the concrete cover. The price bid shall include Class A3 concrete, reinforcing steel, concrete cover, debris rack, orifice, steps when required, and class A1 riprap.

Temporary sediment riser pipe will be measured in feet for the size specified and will paid for at the contract unit price per foot. The price shall include the riser pipe, steel plate, perforated pipe, debris rack, orifice and class A1 riprap, and anti-vortex device when required.

Storm water management dam will be measured and paid for at the contract unit price per cubic yard of concrete and pounds of reinforcing steel.

Payment will be made under:

Pay Item	Pay Unit
Pipe (Size and Type)	Linear foot
Structural plate arch (Size)	Linear foot
Jacked and bored pipe (Size)	Linear foot
Tunneled pipe (Size)	Linear foot
Reinstalled pipe	Linear foot
End section (Standard and size)	Each
Pipe spillout (Standard)	Each
Concrete (Class)	Cubic yard
Reinforcing steel	Pound
End wall grate and frame (Standard)	Each
Precast box culvert (Size)	Linear foot
End wall pipe grate (Type)	Linear foot
Drop inlet (Standard and length)	Each
Intake box (Standard)	Each
Structural steel (Type)	Pound
Manhole (Standard)	Linear foot
Frame and cover (Standard)	Each
Reconstructed manhole Each	Each
Precast arch (Size)	Linear foot
Temporary diversion channel lining (class)	Square yard
Temporary diversion channel excavation	Cubic yard
Endwall, Standard EW-12	Each
Storm water management drainage structure (type)	Linear foot
Temporary sediment rise pipe (Size)	Linear foot

SECTION 303--EARTHWORK

303.01--Description.

This work shall consist of constructing roadway earthwork in accordance with these specifications and in conformity with the specified tolerances for the lines, grades, typical sections, and cross sections shown on the plans or as established by the Engineer. Earthwork shall include regular, borrow, undercut, and minor structure excavation; constructing embankments; disposing of surplus and unsuitable material; shaping; compaction; sloping; dressing; and temporary erosion and siltation control work.

303.02--Materials.

(a) **Borrow excavation** shall consist of approved material required for the construction of the roadway and shall be obtained from approved sources outside the project limits. Borrow excavation shall conform to AASHTO M57 and the requirements herein.

(b) **Materials for temporary silt fences, geotextile fabric silt barriers, and filter barriers** shall conform to the requirements of Sections 242.02(c) and 245.03(a).

(c) **Geotextile materials used for embankment stabilization** shall conform to the requirements of Section 245.003(e).

303.03--Erosion and Siltation Control.

Erosion and siltation shall be controlled through the use of the devices and methods specified herein or as is otherwise necessary. The Department reserves the right to require other temporary measures not specifically described herein to correct an erosion or siltation condition.

Erosion and siltation control devices and measures shall be maintained in a functional condition at all times. Temporary and permanent erosion and siltation control measures shall be inspected after each rainfall and at least daily during periods of prolonged rainfall. Deficiencies shall be immediately corrected. The Contractor shall make a daily review of the location of silt fences and filter barriers to ensure that they are properly located for effectiveness. Where deficiencies exist, corrections shall be made immediately as approved or directed by the Engineer.

When erosion and siltation control devices function by using wet storage, sediments shall be removed when the wet storage volume has been reduced by 50 percent. Sediments shall be removed from dewatering basins when the excavated volume has been reduced by 50 percent. Sediments shall be removed from all other erosion and siltation control devices when capacity, height, or depth has been reduced by 50 percent. Removed sediment shall be disposed of in accordance with the requirements of Section 106.04. Sediment deposits remaining in place after the device is no longer required shall be dressed to conform with the existing grade, prepared, and seeded in accordance with the requirements of Section 603.

Geotextile fabric that has decomposed or becomes ineffective and is still needed shall be replaced. In addition, temporary erosion and sediment control devices except brush silt barriers shall be removed within 30 days after final site stabilization or after the temporary devices are no longer needed as determined by the Engineer.

(a) **Earth Berms and Slope Drains:** The top of earthwork shall be shaped to permit runoff of rainwater. Temporary earth berms shall be constructed and compacted along the top edges of embankments to intercept runoff water. Temporary berms and temporary dikes are to be stabilized immediately following installation. Temporary slope drains shall be provided to intercept runoff and adequately secured to prevent movement. Slope drains may be flexible or rigid but shall be capable of being readily shortened or extended. A portable flume shall be provided at the entrance to temporary slope drains.

(b) **Soil stabilization:** Soil stabilization shall be applied within 7 days after attaining the appropriate grading increment for that stage of the construction operations, or upon suspension of grading operations for an anticipated duration of greater than 15 days, or upon completion of grading operation for a specific areal Areas excluded from this requirement include areas within 100 feet of the limits or ordinary high water or a delineated wetland which shall be continuously prosecuted until completed and stabilized immediately upon completion of the work in each impacted area. Soil stabilization includes: temporary and permanent seeding, riprap, aggregate, sod, mulching, and soil stabilization blankets and matting in conjunction with seeding. The applicable type of soil stabilization shall depend upon the location of areas requiring stabilization, time of year (season), weather conditions and stage of construction operations.

Cut and fill slopes shall be shaped and topsoiled where specified. Seed and mulch shall be applied in accordance with the requirements of Section 603 as the work progresses in the following sequence:

1. Slopes whose vertical height is 20 feet or greater shall be seeded in three equal increments of height. Slopes whose vertical height is more than 75 feet shall be seeded in 25-foot increments.

2. Slopes whose vertical height is less than 20 but more than 5 feet shall be seeded in two equal increments.

3. Slopes whose vertical height is 5 feet or less may be seeded in one operation.

Areas that cannot be seeded because of seasonal or adverse weather conditions should be mulched to provide some protection against erosion to the soil surface. Organic mulch shall be used, and the area then seeded as soon as weather or seasonal conditions permit in accordance with the requirements of Section 303.03(e). Mulch shall be applied in accordance with the requirements of Section 603.04. Organic mulch includes: straw or hay, fiber mulch, wood cellulose, or wood chips conforming to the requirements of Section 244.02(g).

(c) **Check Dams:** As an initial item of work, required check dams shall be constructed at 25-foot intervals, unless otherwise shown on the plans, below the outfall end of drainage structures.

Synthetic check dams recorded in the Department’s Approved List may be substituted for Standard CD-4, Rock Check Dams, Type II, with the approval of the Engineer at no additional cost to the Department. Synthetic check dams shall be installed in accordance with the manufacturer’s recommendation.

(d) **Baled Straw Silt Barriers:** Baled straw silt barriers may be substituted for temporary filter barriers with the approval of the Engineer in noncritical areas, such as pavement areas and rock locations where filter barriers cannot be installed in accordance with the plans and specifications and locations where the Engineer determines that streams and water beds will not be affected.

(e) **Temporary Silt Fences, Geotextile Fabric Silt Barriers, and Filter Barriers:**

1. **Temporary silt fences:** Fences shall be erected at locations shown on the plans or determined by the Engineer. Geotextile fabric used for silt fences shall be provided, and posts shall not be spaced more than 6 feet apart. Posts shall be uniformly installed with an inclination toward the potential silt load area of at least 2 degrees but not more than 20 degrees. Attaching fabric to existing trees will not be permitted.

   Fabric shall be firmly secured to the post or wire fence. The bottom of the fabric shall be entrenched in the ground in a minimum 6-inch by 6-inch trench. Temporary silt fence may also be entrenched using a slicing method with a minimum of 8 inches sliced into the ground. Fabric may be spliced only at support posts and with an overlap of at least 6 inches. The top shall be installed with a 1-inch truck or reinforced top end section. The height of the finished fence shall be a nominal 29 inches.

2. **Geotextile fabric silt barriers:** Existing fences or brush barriers used along the downhill side of the toe of fills shall have geotextile fabric attached at specified locations as shown on the plans. The bottom of the fabric shall be entrenched in the ground in a minimum 6-inch by 6-inch trench and the top shall be installed with a 1-inch tuck or reinforced top end section. Temporary fabric silt barriers may also be entrenched using a slicing method with a minimum 8 inches sliced into the ground.

   Brush barriers shall be installed prior to any major earth-disturbing activity and trimmed sufficiently to prevent tearing or puncturing fabric. Fabric shall be fastened securely to the brush barrier or existing fence. A 6-inch overlap of fabric for vertical and horizontal splicing shall be maintained and tightly sealed.

3. **Temporary filter barriers:** Barriers shall consist of geotextile fabric and shall be securely fastened to wood or metal supports that are spaced at not more than 3- foot intervals and driven at least 12 inches into the ground. At least three supports shall be used. The bottom of the fabric shall be entrenched in the existing ground in a minimum 4-inch by 4-inch trench.

   Temporary filter barriers may also be entrenched using a slicing method with a minimum of 6 inches sliced into the ground. The top of the fabric shall be installed with a 1-inch tuck or reinforced top end section. The height of the finished temporary filter barrier shall be a nominal 15 inches.

   Temporary filter barriers shall be installed at temporary locations where construction changes the earth contour and drainage runoff as directed by the Engineer.

   After removal and disposal of the temporary silt fence, geotextile fabric silt barrier, and temporary filter barrier, the area shall be dressed and stabilized with a permanent vegetative cover or other approved permanent stabilization practice approved by the Engineer.

4. **Sediment Traps and Sediment Basins:** Sediment traps are required if stormwater runoff from less than 3 acres flows across a disturbed area of 10,000 square feet or more. Sediment basins are required if stormwater runoff from three or more acres flows across a disturbed area of

10,000 square feet or more. Once a sediment trap or basin is constructed the dam and all outfall areas shall be stabilized immediately.

5. **Erosion Control Mulch:** This work shall consist of furnishing and applying mulch as a temporary erosion control treatment on slopes exposed to the elements but not at final grade during the period from December 1 to March 1 for periods of up to 30 days prior to final grading or to areas to receive stabilization or paved surfaces within 6 months in accordance with this provision and as directed by the Engineer.

   Mulch shall be applied to exposed slopes requiring mulch or to areas to be stabilized or paved, within 48 hours after performance of grading operations. Straw or hay mulch shall be applied on bare slope areas at the rate of approximately 3 tons per acre (1.24 pounds per square yard). Straw or hay mulch shall be applied at a uniform thickness in such a manner that not more than 10 percent of the soil surface will be exposed. Straw or hay mulch shall be anchored to the slope surface by one of the following methods: spraying with cellulose fiber mulch at the rate of 750 pounds per acre (0.15 pound per square yard); disking or punching the mulch partially into the soil; using approved netting; or using other material or methods approved by the Engineer. The Contractor may use more than one method on the same project.

303.04--Procedures.

Loose rock 3 inches or larger shall be removed from the surface of cut slopes.

When slides occur, the Contractor shall remove and dispose of material as directed by the Engineer.

Where required, surface ditches shall be placed at the top of cut slopes or at the foot of fill slopes and at such other points not necessarily confined to the right of way or shown on the plans and shall be of such dimensions and grades as directed by the Engineer.

Allaying dust, when specified, shall be performed in accordance with the requirements of Section 511.

Prior to the beginning of grading operations in the area, necessary clearing and grubbing shall be performed in accordance with the requirements of Section 301.02.

(a) **Regular Excavation:** Existing foundations and slabs located within the construction limits shall be removed and disposed of in a location approved by the Engineer. In lieu of removal, foundations and slabs located 5 feet or more below the proposed subgrade may be broken into particles not more than 18 inches in any dimension and reoriented to break the shear plane and allow for drainage.

Cisterns, septic tanks, wells and other such structures shall be cleared in accordance with the requirements of Section 516.

Balance points shown on the plans are theoretical and may vary because of actual field conditions.

When the material to be excavated necessitates the use of explosives, the requirements of Section 107.11 relating to the use of explosives shall apply. To prevent damage to newly constructed concrete, the Contractor shall schedule blasting operations in the proximity of proposed concrete structures so that work will be completed prior to placement of concrete.

Regular excavation shall consist of removing and disposing of material located within the project limits, including widening cuts and shaping slopes necessary for preparing the roadbed; removing root mat; stripping topsoil; cutting ditches, channels, waterways and entrances; and performing other work incidental thereto. The Engineer may require materials in existing pavement structures to be salvaged for use in traffic maintenance.

Undrained areas shall not be left in the surface of the roadway. Grading operations shall be conducted so that material outside construction limits will not be disturbed.

Where rock or boulders are encountered, the Contractor shall excavate and backfill in accordance with the plans and contract documents.

When the presplitting method of excavation is specified for rock cuts, work shall be performed in a manner to produce a uniform plane of rupture in the rock and so that the resulting backslope face will be unaffected by subsequent blasting and excavation operations within the section. Rock shall be presplit along rock slopes at locations, lines, and inclinations shown on the plans or as determined by field conditions. A test section shall be provided to establish the spacing of drill holes and the proper blasting charge to be used in the presplitting operation. Drill holes shall be spaced not more than 3 feet apart and shall extend to the plan grade or in lifts of not more than 25 feet, whichever is less. If drilled in benches, an offset may accommodate the head of the drill, but no offset shall be more than 12 inches. Presplitting shall extend at least 20 feet ahead of the limits of fragmentation blasting within the section.

Where the project has been designed and slopes have been staked on the assumption that solid rock will be encountered and the Contractor fails to encounter solid rock atthe depth indicated, he shall cease excavation in the area and immediately notify the Engineer. If it is necessary to redesign and restake slopes, any additional excavation necessary will be paid for at the contract unit price per cubic yard.

Topsoil stockpiled for later use in the work shall be stored within the right of way unless the working area is such that the presence of the material would interfere with orderly prosecution of the work. Stockpile areas outside the right of way shall be located by the Contractor at his expense. Topsoil used in the work shall be removed first from stockpiles located on private property. Surplus topsoil remaining on private property after completion of topsoiling operations shall be moved onto the right of way and stockpiled, shaped, and seeded as directed by the Engineer.

Stripping topsoil shall be confined to the area over which grading is to be actively prosecuted within 15 calendar days following the stripping operation. Grading operations shall be confined to the minimum area necessary to accommodate the Contractor’s equipment and work force engaged in the earth moving work.

(b) **Borrow Excavation:** The Contractor shall make his own arrangements for obtaining borrow and pay all costs involved in accordance with the provisions of Section 106.03.

If the Contractor places an excess of borrow and thereby causes a waste of regular excavation, the amount of such waste, unless authorized, will be deducted from the volume of borrow as measured at the source or computed by vehicle count as specified in Section 109.01.

When borrow is obtained from sources within the right-of-way and the excavation is performed simultaneously with regular excavation, borrow excavation will be designated as regular excavation. Material secured by widening cuts beyond slope stakes, when taken from previously excavated slopes, will be designated as borrow excavation. When such a procedure is approved, slopes shall be uniform and no steeper than shown on the plans.

Borrow excavation areas shall be bladed and left in a shape to permit accurate measurements after excavation has been completed.

CBR values, stipulated for borrow excavation, shall apply to the uppermost three feet of fill below the top of earthwork, as defined in Section 101 of the Specifications. Borrow excavation, installed below the top three feet shall consist of fill material, available from regular excavation or borrow excavation, as defined and of a quality consistent with project requirements.

(c) **Undercut Excavation:** Undercut excavation shall consist of removing and disposing of unsuitable material located within the construction limits in accordance with Section 303.06(a)3.

Undercut excavation shall be disposed of in accordance with Section 106.04.

(d) **Minor Structure Excavation:** Minor structure excavation shall consist of removing material necessary to accommodate the structure, such as box or arch culverts, including pipe arches, structural plate arches, structural plate pipe, pipe culverts, and storm drains with span(s) or opening(s) 48 inches or greater. Minor structure excavation shall also include dewatering, sheeting, bracing, removing existing structures, and backfilling. Removing existing structures shall also include foundations that might be necessary to clear the site.

(e) **Removing Unsuitable Material:** Where excavation to the finished graded section results in a subgrade or slopes of unsuitable material, such material shall be excavated below the grade shown on the plans or as directed by the Engineer. Areas so excavated shall be backfilled with approved material in accordance with (f) herein.

Excavation for structures shall be carried to foundation materials satisfactory to the Engineer regardless of the elevation shown on the plans. If foundation material is rock, the Contractor shall expose solid rock and prepare it in horizontal beds for receiving the structure. Loose or disintegrated rock and thin strata shall be removed. Excavated material, if suitable, shall be used for backfilling around the structure or constructing embankments.

Material shown on the plans as unsuitable and during construction found to be suitable for use shall first be used in embankments where needed in lieu of borrow. However, the use of this material in lieu of borrow shall not alter the provisions of Section 104.02 regarding underruns.

Material shown on the plans as suitable material but found at time of construction to be unsuitable shall be disposed of as unsuitable material.

Unsuitable material shall be disposed of in accordance with Section 106.04.

(f) **Backfill for Replacing Undercut Excavation:** Backfill shall be comprised of regular excavation, borrow, select material, subbase material, or other material as directed by the Engineer. Backfilling operations shall be performed in accordance with (g) herein.

(g) **Backfilling Openings Made for Structures:** Backfill shall be suitable material removed for the structure, although the Engineer may require that backfill material be obtained from a source within the construction limits entirely apart from the structure or other approved material. The opening to be backfilled shall be dewatered prior to backfilling. Backfill shall not be placed against or over cast-in-place box culverts or other structures until the top concrete slab section(s) has been in place 14 days, exclusive of days on which the average high-low ambient temperature is below 40 oF in the shade or until the concrete control cylinder(s) has attained a compressive strength equal to 93 percent of the 28-day design compressive strength.

Backfill shall be compacted in horizontal layers not more than 6 inches in thickness, loose measurement, and as specified in (h) herein. Backfill shall be placed in horizontal layers such that there will be a horizontal berm of compacted undisturbed material behind the structure for a distance at least equal to the remaining height of the structure or wall to be backfilled. Backfill shall be placed in a manner to deter impoundment of water and facilitate existing drainage. Backfill around piers in areas not included in the roadway prism shall be constructed in uniformly compacted layers. However, density requirements will be waived.

Box culverts shall not be opened to construction equipment traffic until concrete has attained 100 percent of the 28-day design compressive strength and has a backfill cover of at least 4 feet. The minimum height of backfill cover required to protect pipe culverts from construction equipment shall be in accordance with standard drawing PC-1 for the type and size specified.

Where only one side of abutments, wingwalls, piers, or culvert headwalls can be backfilled, care shall be taken that the area immediately adjacent to the structure is not compacted to the extent that it will cause overturning or excessive pressure against the structure. When both sides of a concrete wall or box structure is to be backfilled, operations shall be conducted so that the backfill is always at approximately the same elevation on both sides of the structure.

Openings subject to flooding shall be backfilled as soon as practicable or as directed by the Engineer.

(h) **Embankments:** Work shall consist of constructing roadway embankments, placing and compacting approved material within roadway areas where unsuitable material has been removed; and placing and compacting approved material in holes, pits, utility trenches, basements, and other depressions within the roadway area.

Embankment shall be constructed with approved material and placed so as to be uniformly compacted throughout. Embankment shall be placed adjacent to structures in the same manner as for backfill, as described in (g) herein. Embankment shall not contain muck, frozen material, roots, sod, or other deleterious material. Embankment shall not be placed on frozen ground or areas covered with ice or snow.

Unsuitable material used in widening embankments and flattening embankment slopes shall be placed in uniform layers not more than 18 inches in thickness before compaction. Each layer of material placed shall be compacted to the extent necessary to produce stable and reasonably even slopes.

Wherever rock excavation is available on the project, an 8 to 15 inch layer of such materials shall be dump spread over the lower region of embankments in the immediate vicinity of stream crossings and used to cover ditches, channels, and other drainage ways leading away from cuts and fills. However, drainage ways shall be prepared to receive the rock excavation to the extent necessary to avoid reducing their cross section. If rock excavation is not available on the project, rip-rap, jute mesh or soil retention mats shall be used as the covering material and shall be installed in accordance with the requirements of Section 606.03(c). Limits of the area to be covered will be as noted on the plans or as directed by the Engineer.

Wherever sufficient right of way exists, surplus materials shall be used to widen embankments and flatten slopes as directed by the Engineer.

Rock excavation may be placed on slopes by uniform end dumping of the material from along the top of the embankment or as directed by the Engineer. Slopes that are covered with rock excavation shall not receive topsoil or seed.

When geotextile drainage fabric is required under rock fills, preparation shall be as specified in Section 245.

The Contractor shall schedule excavation and embankment work in a manner that will minimize the quantity of unsuitable material for which more than one handling is required prior to final placement. Therefore, the provisions for additional payment for each rehandling of material specified in Section 303.06(a) will not apply to placing unsuitable material for widening embankments and flattening embankment slopes.

The surface area directly beneath the pavement and shoulders on which embankments of less than 5 feet in depth are to be constructed shall be denuded of vegetation. These areas shall be scarified and compacted to a depth of 6 inches to the same degree as the material to be placed thereon.

Areas that contain material unsuitable as foundations for embankments shall be undercut and backfilled in accordance with (e) and (f) herein.

Embankments to be placed over saturated areas that will not support the mass of hauling equipment may be constructed by end dumping successive loads in a uniformly distributed layer of a thickness capable of supporting the hauling equipment while subsequent layers are placed. The nose, or leading edge, of the embankment shall be maintained in a wedge shape to facilitate mud displacement in a manner that will prevent its entrapment in the embankment. The front slope of the embankment shall be maintained steeper than 2:1. The use of compacting equipment will not be required on the original course. However, the remainder of the embankment shall be constructed in layers and compacted in accordance with these specifications.

When geotextile for embankment stabilization is required it shall be placed as shown on the plans. Geotextile shall be spliced by sewing double stitched seams with stitching spaced ¼ inch to ½ inch apart or as shown on the plans.

Once geotextile for embankment stabilization is placed, the initial lift of material to be placed atop shall be end dumped onto the geotextile and spread to thickness as shown on the plans. Free draining material shall be any material having 15 percent or less of which will pass the No. 200 sieve. If the geotextile becomes punctured or torn, the Contractor shall repair the area with geotextile lapped at least 3 feet all around the damaged area.

When embankment is to be placed and compacted on an existing road, the surface shall be scarified to such degree as will permit an ample bond between old and new material. Hydraulic cement concrete and asphalt concrete pavement structures within the proposed roadway prism shall be demolished in accordance with Section 508.02(a).

Existing slopes shall be continuously benched where embankments are constructed 1/2 width at a time, against slopes of existing embankments or hillsides, or across existing embankments, hillsides, and depressions at a skew angle of 30 degrees or more, or the existing slopes are steeper than 4:1. For slopes steeper than 4:1 but not steeper than 1 1/2:1, the bench shall be at least 6 feet in width. For slopes steeper than 1 1/2:1 but less than 1/2:1, the bench shall be at least 4 feet in width. Benching shall consist of a series of horizontal cuts beginning at the intersection with the original ground and continuing at each vertical intersection of the previous cut. Material removed during benching operations shall be placed and compacted as embankment material.

When excavated material consists predominantly of soil, embankment shall be placed in successive uniform layers not more than 8 inches in thickness before compaction over the entire roadbed area. Each layer shall be compacted within a tolerance of ±20 percent of optimum moisture content, to a density of at least 95 percent of the theoretical maximum density as defined in Section 101.02.

Material having a moisture content above optimum by more than 30 percent shall not be placed on a previously placed layer for drying unless it is shown that the layer will not become saturated by downward migration of moisture in the material.

Field density determinations will be performed in accordance with the requirements of AASHTO T191, modified to include material sizes used in the laboratory determination of density, with a portable nuclear field density testing device or by other approved methods. When a nuclear divided is used, density determinations for embankment material will be related to the density of the same material tested in accordance with VTM-1 or VTM-12 and a control strip will not be required.

As the compaction of each layer progresses, continuous leveling and manipulating will be required to ensure uniform density. Prior to placement of subsequent layers, construction equipment shall be routed uniformly over the entire surface of each layer or the layer shall be scarified to its full depth in the area where the equipment is routed.

When the excavated material consists predominantly of rock fragments of such size that the material cannot be placed in layers of the thickness prescribed without crushing, pulverizing, or further breaking down the pieces resulting from excavation methods, such material may be placed in the embankment in layers that are not thicker than the approximate average size of the larger rocks. Rock not more than 4 feet in its greatest dimension may be placed in an embankment to within 10 feet of the subgrade. The remainder of the embankment to within 2 feet of the subgrade shall not contain rock more than 2 feet in its greatest dimension. Each layer shall be constructed so that rock voids are filled with rock spalls, rock fines, and earth. Rock shall be placed, manipulated, and compacted in uniform layers. However, density requirements may be waived. Rock, rock spalls, rock fines, and earth shall be distributed throughout each embankment layer and manipulated as specified herein so that the voids are filled. Rock shall not be end dumped over the edges of the layer being constructed but shall be deposited on the layer and moved ahead so as to advance the layer with a mixture of rock, rock spalls, rock fines, and earth. The 2 feet of the embankment immediately below the subgrade shall be composed of material that can be placed in layers of not more than 8 inches before compaction and compacted as specified herein for embankments. Rock more than 3 inches in its greatest dimension shall not be placed within 12 inches of the subgrade in any embankment.

Rock, broken concrete, or other solid materials shall not be placed in embankment areas where piling is to be placed or driven.

The best material shall be reserved for finishing and dressing the surface of embankments. Work necessary to ensure the reservation of such material shall be the responsibility of the Contractor. The provisions in Section 303.06(a) will not apply to subsequent handling of capping material.

CBR values, stipulated for embankment, shall apply to the uppermost three feet of fill below the top of earthwork, as defined in Section 101 of the Specifications. Embankment installed below the top three feet shall consist of suitable fill material, available from regular excavation, borrow excavation or embankment, as defined and of a quality consistent with project requirements.

Crushed glass shall be limited within the boundaries of the embankment as follows. Crushed glass shall be a minimum of two feet inside the side slope and contain a minimum of two feet of soil embankment cap. For those areas where crushed glass is to be incorporated into the embankment, glass may constitute up to approximately ninety percent (90%) by weight of that portion of the embankment, except where 100% crushed glass is used for drainage purposes (including blankets).

Crushed glass shall be blended with soil and/or soil like materials as follows:

1. The embankment shall be constructed by placing alternate four inch (4”) layers of waste glass and soils and mixing and blending by scarification or other approved methods during compaction. The thickness of uncompacted layers of soil/glass shall be a maximum of 8 inches (loose); or

2. Pugmilled in predetermined ratios to a visually consistent blend and placed in lifts of a maximum of 8 inches (loose); or

3. As directed by the Engineer.

   Compaction of the soil/glass embankment shall be to the satisfaction of the Engineer and shall be accomplished with a vibratory compactor or other approved methods. Moisture and density requirements for the soil/glass embankments shall be the same as other conventional soil embankment in accordance with the requirements of Section 303 of the Specifications.

   Normal compaction procedures and requirements are to be used for compaction of the soil embankment “cap” above the crushed glass/soil blends.

(i) **Settlement Plates and Surcharge:** The Contractor shall expedite construction of embankment to provide the maximum time possible for settlement prior to completing grading operations.

1. **Settlement plates:** The base of settlement plates shall be firmly seated into original ground for the full depth of the steel fins. The base shall be leveled. The Engineer shall be provided time to obtain the elevation of the seated base and the top elevation of the pipe extensions prior to placement of embankment material. Pipe extensions shall not be more than 4 feet in length and shall be vertically installed as the embankment is constructed such that the top of the pipe is not covered. As each extension is added, the Engineer shall be provided time to obtain the top elevation of the existing pipe and the top elevation of the new pipe extension. Pipe extensions shall be properly flagged at all times. Care shall be taken while placing and compacting embankment material around pipe extensions. Settlement plates shall be maintained until no longer required, as determined by the Engineer. Upon completion of the normal embankment plus 2 feet of the specified surcharge, the Contractor shall immediately commence placing the remaining surcharge to the limits shown on the plans or as directed by the Engineer. The remaining surcharge shall be placed in lifts of not more than 1 foot in depth and compacted uniformly with construction hauling and spreading equipment. Each lift shall be completed over the entire surcharge area before the next lift is begun.

   If a settlement plate is damaged, the Contractor shall notify the Engineer immediately and promptly repair it under the observation of the Engineer to the nearest undamaged pipe. Excavation, backfill, compaction, and repair of settlement plates shall be at the Contractor’s expense. The Engineer shall be provided time to obtain the top elevation of the undamaged connection and the top elevation of each subsequent pipe extension.

   Settlement plates shall remain in place until settlement has been completed as indicated by elevation readings taken by the Department at approximately 2-week intervals. Evaluation of the readings by the Engineer will be the final and sole governing factor for releasing embankments for grading operations. Upon written release by the Engineer, extensions of settlement plate pipe shall be removed to at least 2 feet below the subgrade, the pipe capped, and the area backfilled and compacted.

2. **Surcharge:** When authorized by the Engineer, surcharge shall be removed to the subgrade and embankment slopes graded to the typical section. Removed surcharge shall be placed in roadway embankments not previously brought to grade or shall be disposed of in accordance with Section 106.04 or as directed by the Engineer.

(j) **Hydraulic Embankment:** Hydraulic embankment shall consist of dredging and pumping materials approved by the Engineer from designated areas, placing the material in embankments, and dressing and completing the embankment. Material shall be nonplastic and of such grading that not more than 7 percent will pass the No. 200 sieve.

Unless otherwise shown on the plans, material for the embankment shall not be obtained from sources closer than 300 feet from the toe of the slope of the embankment. The Engineer may reject materials considered to be unsatisfactory for use in the embankment, and such materials shall be stripped at the Contractor’s expense before the embankment is built. Muck and unsuitable material shall be removed to the line, grade, and section shown on the plans. Unsatisfactory material brought to the top of the embankment shall be removed by the Contractor at his own expense, and satisfactory material shall be substituted.

In placing material in the embankment, the Contractor shall begin at the center line and deposit material in either or both directions toward the toe of slopes. Discharge shall always be in the direction of and parallel to the center line. The maximum distance from the bottom of the discharge pipe to the surface on which material is being deposited shall be 5 feet unless otherwise directed by the Engineer. Material shall be deposited in a manner that will maintain a higher elevation at the center of the roadway than on either side. The Contractor will not be permitted to construct retaining levees along the roadway of such dimensions as to cause damage to the foundation of the roadway. The Contractor shall conduct operations so as to ensure the completion of an embankment that will conform to the cross section shown on the plans except that he will be permitted to flatten side slopes. However, if material is deposited on private property, the Contractor shall obtain permission in writing from the affected property owner(s). No payment will be made for material beyond the limits of the net pay section.

The embankment shall be placed so as to ensure a minimum relative density of 80 percent of the theoretical maximum density when tested in accordance with (h) herein. If the method of placing the embankment fails to produce the required density, the Contractor shall use approved methods to obtain the specified density.

The Contractor shall take all necessary precautions to prevent placing material in streams. The Contractor shall be responsible for all damage to or caused by the hydraulic embankment. The Contractor shall provide sufficient material to maintain the embankment in accordance with the typical cross section as shown on the plans or as directed by the Engineer until final acceptance.

The Contractor’s plan for support of suction or discharge pipes shall be submitted to and approved by the Engineer. Traffic shall be protected by the display of warning devices both day and night. If dredging operations damage an existing traveled highway, the Contractor shall cease operations and repair damage to the highway.

(k) **Surplus Material:** Surplus material shall not be wasted or sold by the Contractor unless authorized in writing by the Engineer. When authorization has been given for surplus material to be wasted, it shall be disposed of in accordance with Section 106.04.

Material shown on the plans as surplus material will not be considered for overhaul payment.

1. **Disposal of surplus material within the right of way where the haul distance is 2000 feet or less:** Surplus material shall be used or disposed of where directed within a haul distance of 2000 feet of its origin. Usage in this manner will not be considered a change in the character of the work.

2. **Disposal of surplus material within the right of way where the haul distance is more than 2000 feet:** The Department reserves the right to require the Contractor to use surplus material in lieu of furnishing borrow, or as otherwise directed, where the haul distance from the origin of the material is more than 2000 feet. Disposal of surplus material at locations requiring a haul of more than 2000 feet will be considered a change in the character of work unless otherwise noted on the plans.

When material is declared surplus during construction and must be transported more than 2000 feet from its origin, the Department will pay the Contractor $0.03 per station per cubic yard for overhaul. The quantity of surplus excavation will be determined by vehicle measurement in accordance with the provisions of Section 109.01 or from cross-section measurements by the average end area method. The haul distance will be measured along a line parallel to the center line of the roadway from the center of the excavated area to the center of the placement area. Overhaul will be the product of the quantity of surplus material in cubic yards and the haul distance in excess of 2000 feet in 100-foot stations.

303.05--Tolerances.

(a) **Finished grade of subgrade** shall conform to the requirements of Section 305.03(c) of the Specifications.

(b) **Slopes** shall be graded in the following manner:

1. **Earth excavation slopes:**

    a. **Slopes steeper than 2:1** shall be grooved in accordance with the standard drawings and shall not deviate from the theoretical plane surface by more than 0.5 foot.

    b. **Slopes steeper than 3:1** up to and including 2:1 shall be rough graded in a manner to provide horizontal ridges and grooves having no more than 0.5 foot deviation from the theoretical line of the typical cross section as is accomplished by the normal operation of heavy grading equipment.

    c. **Slopes 3:1 or flatter** shall be uniformly finished and shall not deviate from the theoretical plane surface by more than 0.5 foot.

2. **Earth embankment slopes:**

    a. **Slopes steeper than 3:1** shall not deviate from the theoretical plane slope by more than 0.5 foot and shall be rough graded in a manner to provide horizontal ridges and grooves not more than 0.5 foot from the theoretical line of the typical cross section as is accomplished by the normal operation of heavy grading equipment.

    b. **Slopes 3:1 and flatter** shall be uniformly finished and shall not deviate from the theoretical plane surface by more than 0.5 foot.

3. **Rock slopes** shall not deviate from a plane surface by more than 2 feet and shall not deviate from their theoretical location by more than 2 feet measured along any line perpendicular to the theoretical slope line.

    Finished excavation and embankment slopes shall not deviate from their theoretical location by more than 0.5 foot measured along any line perpendicular to the theoretical slope line.

303.06--Measurement and Payment.

(a) **Excavation:** Excavation will be paid for at the contract unit price per cubic yard unless otherwise specified.

Excavation requiring more than one handling prior to final placement will be paid for at the contract unit price for regular excavation for each handling approved by the Engineer unless there is a pay item for the second handling, in which case work will be paid for at the contract price for such handling.

Quantities of regular or borrow excavation used to backfill pipe, pipe culverts and box culverts will not be deducted from quantities due the Contractor for payment.

1. **Regular excavation:** When payment is specified on a cubic yard basis, regular excavation will be measured in its original position by cross sectioning the excavation area. This measurement will include overbreakage or slides not attributable to the carelessness of the Contractor and authorized excavation of rock, muck, root mat, or other unsuitable material except material included in undercut excavation. Volumes will be computed from cross-section measurements by the average end area method.

   When it is impractical to measure material by the cross-section method, other acceptable methods involving three-dimensional measurements may be used.

   Excavation for benching slopes to accommodate roadway embankments as specified in Section 303.04(h) will not be measured for separate payment. The cost thereof shall be included in the price for the related excavation or embankment item.

   Excavation of existing roadways required to incorporate old roadway into new roadway or remove salvageable materials for use in traffic maintenance, other than those covered under Section 508, will be measured as regular excavation.

   When presplitting rock cuts is shown on the plans, the work shall be considered incidental to the cost of excavation and will not be measured for separate payment.

   In cut sections, excavation of topsoil and root mat and material down to a point 1 foot below the elevation of the top of earthwork or to the depth specified on the plans will be measured as regular excavation. When areas of unsuitable material are shown on the plans, excavation down to a point 1 foot below the elevation of such material shown on the plans will be measured as regular excavation.

   In fill sections, excavation of topsoil and root mat and material down to an elevation of 1 foot below the bottom of topsoil and root mat will be measured as regular excavation. When areas of unsuitable material are shown on the plans, excavation down to a point 1 foot below the elevation of such material shown on the plans will be measured as regular excavation.

   If slide material approved for measurement cannot be measured accurately, or if the removal of slide material will require different equipment than that being used in the regular excavation operations, payment therefor may be made on a force account basis when authorized by the Engineer.

Excavation of surface ditches specified on the plans or otherwise required by the Engineer will be paid for as regular excavation except that when required after the slopes have been completed and the work cannot be performed with mechanical equipment, the excavation will be paid for as undercut excavation.

2. **Borrow excavation:** Borrow excavation will be measured in its original position by cross sectioning the area excavated. The number of cubic yards will be computed from cross-section measurements by the average end area method. When it is impractical to measure the borrow excavation, vehicular measurement in accordance with Section 109.01 may be used.

   Borrow excavation with a stipulated CBR value shall be measured and paid for as borrow excavation with the CBR value as specified.

   Borrow excavation without a stipulated CBR value shall be measured and paid for as borrow excavation.

3. **Undercut excavation:** Measurement will be made by cross sectioning the undercut area. The number of cubic yards will be computed by the average end area method. When it is impractical to measure material by the cross-section method because of erratic location of isolated deposits, acceptable methods involving three- dimensional measurements may be used.

   When unsuitable material must be removed from an area of the project where undercut is not shown on the plans, unsuitable material removed after reaching the depth specified in (a) 1 herein, or 1 foot below original ground in fill sections where topsoil and root mat are not required to be removed, will be measured as undercut excavation.

   Excavation of rock or unsuitable material below the elevation of the bottom of the lower theoretical slab or culvert thickness or below the excavation limits shown on the plans or standard drawings for normal earth foundations, whichever is the greater depth, of minor structures having span(s) or opening(s) of less than 48 inches will be measured for payment as undercut excavation. Such excavation for structures having span(s) or opening(s) of 48 inches or greater will be measured as minor structure excavation in accordance with (a)4. herein.

   Undercut excavation will be paid for at the contract unit price per cubic yard. This price shall include removal and disposal. When not a pay item, undercut excavation will be paid for at twice the unit price per cubic yard for regular excavation.

4. **Minor structure excavation:** Excavation of material above the elevation of the bottom of the lower theoretical slab or culvert thickness, or above the excavation limits shown on the plans for earth foundations, whichever is the greater depth, for culverts having a maximum span or opening of less than 48 inches will not be measured for payment.

   Excavation of material for culverts having span(s) or opening(s) of 48 inches or greater and excavation for minor structures not covered elsewhere in these specifications will be measured in cubic yards of minor structure excavation. The quantity allowed for payment will be the actual volume of material removed as bounded by the bottom of the lower theoretical slab or culvert thickness, or lower excavation limits shown on the plans for earth foundations, whichever is the greater depth; the original ground or regular excavation pay line, whichever is the lower elevation; and vertical planes 18 inches outside the neat lines of the structure (excluding wingwalls and other appurtenances) or bound by vertical planes coincident with the applicable bedding excavation limits shown on the plans. Payment for excavation for wingwalls and other appurtenances to structures will be based on the ratio of the plan area of the wingwalls or appurtenances to the plan area of the barrel. Once the ratio has been determined, the pay quantity for minor structure excavation will be increased accordingly.

If embankment is placed prior to installation of a minor structure, excavation of the embankment area will not be measured for payment unless the contract requires placement of the embankment prior to the installation of the minor structure.

The volume of the interiors of culverts, drop inlets, and other existing minor structures that must be removed will not be deducted from the overall quantity of minor structure excavation allowed for payment.

The price of minor structure excavation shall include the cost of backfill above the horizontal planes of the neatlines of the Class I or Class II backfill areas to original ground. Class I and Class II backfill shall be measured and paid for in accordance with Section 302.04.

5. **Earthwork:** When a pay item, earthwork will be paid for at the contract lump sum price, wherein no measurement will be made. This price shall include regular excavation, minor structure excavation, and grading.

(b) **Embankments:**

1. **If embankment is not a pay item**, the cost of embankment construction will be considered incidental to other items of excavation.

2. **If embankment is a pay item and regular excavation is to be paid for on a plan quantity basis**, the quantity of embankment for which payment will be made will not be measured separately but will be computed in accordance with the following:

    a. The regular excavation plan quantity will be adjusted in accordance with (c) herein.

    b. The quantity of unsuitable material will be measured and subtracted from the adjusted regular excavation quantity determined in 2.a. herein. Quantities of unsuitable material removed from fill areas or below the subgrade in cut areas will be determined by using plan dimensions and may be adjusted for deviations based on actual measurement. Actual dimensions will be used to determine the quantity of any other unsuitable material.

    c. The total quantity shown on the plans will be adjusted for quantities not anticipated on the plans, such as changes in grade or undercut determined to be necessary during construction.

    d. The quantity of suitable material determined in 2.b. herein will be subtracted from the adjusted total fill quantity determined in 2.c. herein. The resultant quantity will be the embankment quantity for which payment will be made.

The Contractor shall be responsible for determining the effect of the shrinkage or swell factor of the material, and no adjustment will be made in pay quantities for this factor.

Hydraulic embankment will be paid for as embankment.

3. **If embankment is a pay item and regular excavation is to be paid for on the basis of measured quantities**, the quantity of embankment will be measured in cubic yards computed by the average end area method from the dimensions of the embankment cross section.

   Cross sections of the area to be covered by the embankment will be taken after the denuding or removal of unsuitable material and before any material is placed thereon. These cross sections shall extend laterally from the center line to the toes of slopes as indicated on the typical cross section. The elevations as determined by these sections will be considered the original ground line. The pay quantity to be measured will be the volume of material included in the section above the original ground and below the upper limits of the typical cross section.

   When regular excavation is a pay item, the embankment area to be cross-sectioned will exclude that portion of the fill constructed from regular excavation. Material outside the limits of typical cross sections as shown on the plans will not be measured or paid for.

4. **Extra embankment required for subsurface consolidation** will be determined by the use of settlement plates. The total settlement recorded at each settlement plate will be allowed across 75 percent of the lateral width of each section. Volumes will be computed using the average end area method. Embankment quantities will be adjusted as specified herein to include extra embankment for subsurface consolidation.

   Settlement plates will be measured and paid for in units of each, complete-in- place. This price shall include furnishing, installing, maintaining, and removing when no longer required.

   Surcharge placement and removal will be measured in cubic yards as determined by plan quantity and will be paid for at the contract unit price per cubic yard. This price shall include furnishing, placing, and removing surcharge material and disposing of surplus and unsuitable materials.

5. **If geotextile drainage fabric is a pay item**, measurement and payment will be in accordance with Section 504.

6. **Geotextile for embankment stabilization** will be measured in square yards complete-in-place. Overlaps and seams will not be measured for separate payment. The accepted quantity of geotextile will be paid for at the contract unit price per square yard, which price shall be full compensation for furnishing, placing, lapping or seaming material and for all materials, labor, tools, equipment and incidentals necessary to complete the work.

Embankment with a stipulated CBR value shall be measured and paid for as embankment with the CBR value as specified.

Embankment without a stipulated CBR value shall be measured and paid for as embankment.

(c) **Plan Quantities:** The quantity of regular excavation for which payment will be made when plan quantities are specified will be that specified in the Contract. However, borrow excavation, excavation for entrances, unsuitable material below the top of earthwork, undercut excavation, slide excavation, rock excavation that changes the slopes or causes undercut, and side, inlet, and outlet ditches not covered by plan cross sections will be measured in its original position by cross sections and computed in cubic yards by the average end area method.

Where there are authorized deviations from the lines, grades, or cross sections, measurements will be made and the volume computed in cubic yards by the average end area method for these deviations. The plan quantity will then be adjusted to include these quantities for payment.

When unauthorized deviations occur, allowances will not be made for overruns. However, if the deviation decreases the quantities specified in the Contract, only the actual volume excavated will be allowed.

(d) **Backfill:** Furnishing and placing backfill material, including backfill for undercut, will be included in the price for excavation and will not be measured for separate payment unless specific material is a pay item for backfill or unless suitable material is not available within the construction limits. When a specific material is a pay item, the unit of measure of the material will be in accordance with the unit specified in the Contract. When suitable backfill is not available within the construction limits, the material furnished and placed by the Contractor will be paid for in accordance with Section 109.05.

(e) **Erosion Control Items:**

1. **Limiting the scope of construction operations, shaping the top of earthwork, and constructing temporary earth berms and brush silt barriers for temporary erosion and siltation control** will not be measured for payment but shall be included in the price for other appropriate pay items.

2. **Erosion control riprap** will be measured and paid for in accordance with Section 414.04.

3. **Temporary protective covering** will be measured and paid for in accordance with Section 606.04.

4. **Check dams** will be paid for at the contract unit price per each. This price shall include furnishing, excavating, constructing, maintaining, and removing check dams when no longer required.

   Synthetic checkdams may be substituted for Type II Rock Checkdams (Standard EC-4) at no additional cost to the Department.

5. **Temporary silt fences** will be measured in linear feet, complete-in-place, excluding laps, and will be paid for at the contract unit price per foot. Decomposed or ineffective geotextile fabric replaced after 6 months from the installation date will be measured in linear feet of temporary silt fence and paid for at 1/2 the contract unit price for temporary silt fence. Decomposed geotextile fabric required to be replaced prior to 6 months after installation will not be measured

for payment. This price shall include furnishing, installing, and maintaining the silt fence, including wire reinforcement and posts; removing, and disposing of these materials and dressing and stabilizing the area.

6. **Geotextile fabric** attached to brush barriers or existing fence or used for another function specified on the plans and not included in other pay items will be measured in square yards, complete-in-place, excluding laps, and will be paid for at the contract unit price per square yard. The brush barrier will not be measured for payment. The cost thereof shall be included in the price for clearing and grubbing. This price shall include trimming the brush barrier; furnishing, installing, maintaining, removing the fabric and dressing and stabilizing the area.

7. **Temporary filter barriers** will be measured in linear feet, complete-in-place, excluding laps, and will be paid for at the contract unit price per foot. Decomposed or ineffective geotextile fabric replaced after 6 months from the installation date and decomposed or ineffective burlap fabric replaced after 3 months from the installation date will be measured in feet of temporary filter barrier and paid for at 1/2 the contract unit price for temporary filter barrier. Decomposed geotextile fabric required to be replaced prior to 6 months and decomposed burlap fabric required to be replaced prior to 3 months after installation will not be measured for payment. When permitted, baled straw silt barrier used in lieu of temporary filter barrier will be paid for in linear feet of temporary filter barrier, complete-in-place. This price shall include furnishing, installing, and maintaining the filter barrier, including filter barrier material and posts; removing, disposing of these materials and dressing and stabilizing the area. If the Contractor is permitted to use baled straw silt barrier in lieu of temporary filter barrier, payment will be made at the price for temporary filter barrier.

8. **Silt cleanout**, when approved or directed by the Engineer, will be measured as siltation control excavation in cubic yards of vehicular measurement in accordance with the requirements of Section 109.01 for the full volume of the vehicle.

   Silt removal and sediment cleanout will be paid in cubic yards of siltation control excavation. Payment shall be full compensation for removal of silt and sediment approved or directed by the Engineer and for transportation and disposal of the material.

   If approved or directed by the Engineer, the installation of additional temporary silt fence and temporary filter barrier in lieu of silt cleanout will be measured in feet as specified in (e)5. and (e)7. herein.

9. **Seeding materials** will be measured and paid for in accordance with Section 603.

10. **Temporary erosion and siltation measures required to correct conditions created because of the Contractor's negligence, carelessness, or failure to install permanent controls in accordance with the plans and sequence for performance of such work** will not be measured for payment.

11. **Slope drains** will be measured in units of each, per location regardless of size or length and will be paid for at the contract unit price per each. Raising of the slope drain and addition of pipe lengths will not be measured as a new location. This price shall include furnishing, installing, maintaining, and removing the drain and end section or portable flume.

12. **Sediment traps and basins** will be measured in cubic yards of sediment basin excavation and will be paid for at the contract unit price per cubic yard. This price shall include excavation, maintenance, and backfill or removing to original ground when no longer needed.

13. **Storm Water Management Basin Excavation** will be measured in cubic yards and will be paid for at the contract unit price per cubic yard. The price shall include excavation, maintenance, and shaping of basin.

14. **Temporary Sediment Basin Excavation** will be measured in cubic yards and will be paid for at the contract unit price per cubic yard. The price shall include excavation, maintenance and when no longer required the removal of dam, pipe, riser pipe, trash rack, backfill and site restoration.

15. **Drop Inlet Silt Trap** will be measured in units of each and paid for only one time during the life of the project.

16. **Dewatering basin** will be measured and paid for at the contract unit price per each. This price shall include furnishing, installing, maintaining, and when no longer required, removing the dewatering basin, backfill and site restoration.

17. **Erosion control mulch** shall be paid for per square yard or acre. This includes all materials and equipment necessary for the application.

Payment will be made under:

Pay Item	Pay Unit
Regular excavation	Cubic yard
Borrow excavation	Cubic yard
Borrow excavation (CBR value)	Cubic yard
Sediment basin excavation	Cubic yard
Siltatation control excavation	Cubic yard
Undercut excavation	Cubic yard
Minor structure excavation (Item)	Cubic yard
Earthwork	Lump sum
Embankment	Cubic yard
Embankment (CBR value)	Cubic yard
Settlement plate	Each
Surcharge placement and removal	Cubic yard
Geotextile (Embankment stabilization)	Square yard
Checkdam(Type)(Log, rock, or straw)	Each
Temporary silt fence	Linear foot
Geotextile fabric	Square yard
Temporary filter barrier	Linear foot
Slope drain	Each
Storm water management basin excavation	Cubic yard
Temporary sediment basin excavation	Cubic yard
Drop Inlet Silt Trap (Type)	Each
Dewatering Basin	Each
Erosion control mulch	Square yard or acre

SECTION 304--CONSTRUCTING DENSITY CONTROL STRIPS

304.01--Description.

This work shall consist of constructing control strips in accordance with the requirements of these specifications for the purpose of determining density requirements.

304.02--Materials.

Materials shall conform to the requirements for the material to be used in the course. Material used in each control strip shall be furnished from the same source and shall be of the same type as the material used in the test sections whose density requirements are established by the control strip.

304.03--Equipment.

Equipment shall be approved by the Engineer prior to use. The type and weight of compaction equipment shall be such that a uniform density is obtained throughout the depth of the layer of material being compacted. Control strips shall be compacted using equipment of the same type and weight to be used on the remainder of the course.

304.04--Procedures.

The subgrade or pavement structure course upon which a control strip is constructed shall be approved by the Engineer prior to construction of the control strip.

One control strip shall be constructed at the beginning of work on each roadway and shoulder course and each lift of each course. An additional control strip shall be constructed when a change is made in the type or source of material or whenever a significant change occurs in the composition of the material from the same source.

The project will be divided into “control strips” and “test sections” by the Engineer for the purpose of defining areas represented by each series of tests. The size of each control strip and test section will be in accordance with the requirements of VTM-10.

Control strips shall be constructed using the same procedure to be used in the construction of the remainder of the course. Rolling of the control strip shall be continued until no appreciable increase in density is obtained by additional roller coverages.

Upon completion of rolling, the mean density of the control strip will be based on 10 tests taken at randomly selected sites within the control strip area using a nuclear testing device. Compaction of the remainder of the course shall be governed by the density obtained in the control strip.

Each test section will be tested for required thickness. Areas that are deficient by more than the specified allowable tolerance shall be corrected in accordance with the applicable requirements of these specifications.
The Engineer may require an additional control strip after the completion of each 10 test sections. Each control strip shall remain in place and become a section of the completed roadway.

304.05--Tolerances.

If the mean density of a test section (roadway or shoulder) does not conform to the applicable requirements stated herein, the Contractor shall continue his compactive effort or shall rework the entire test section until the required mean density is obtained. If an individual test value does not conform to the requirements stated herein, the Contractor shall continue his compactive effort or shall rework the entire area represented by that test until the required density is obtained.

(a) **Roadway:** The density of each test section will be evaluated based on the results of five tests performed at randomly selected sites within the test section. The mean density obtained for the five tests in each test section shall be at least 98 percent of the mean density obtained in the approved control strip. In addition, each individual test value obtained within a test section shall be at least 95 percent of the mean density obtained in the approved control strip.

(b) **Shoulders:**

1. **Aggregate shoulders:** The density of each test section of select or aggregate material used in the construction of shoulders will be evaluated based on the results of five tests performed at randomly selected sites within the test section. The mean density obtained for the five tests in each test section shall be within 95 ± 2 percent of the mean density obtained in the approved control strip. In addition, each individual test value obtained in a test section shall be within 95 ± 5 percent of the mean density obtained in the approved control strip.

2. **Asphalt shoulders:** The density of each test section of asphalt concrete used in the construction of shoulders will be evaluated based on the results of five tests performed at randomly selected sites within the test section. The mean density obtained for the five tests in each test section shall be at least 98 percent of the mean density obtained in the approved control strip. In addition, each individual test value obtained within a test section shall be at least 95 percent of the mean density obtained in the approved control strip.

304.06--Measurement and Payment.

This item is considered incidental to the cost of furnishing, placing, and compacting the specified course and will not be measured for payment. The cost of constructing density control strips shall be included in the cost of the material for which the control strip is required.

SECTION 305--SUBGRADE AND SHOULDERS

305.01--Description.

This work shall consist of constructing the subgrade in reasonably close conformity to the cross section shown on the plans and constructing the shoulders in reasonably close conformity with the plans and these specifications.

305.02--Materials.

Materials may consist of material in place, treated material in place, or imported material. Imported material may be borrow material, select material, or other material as shown on the plans or specified in the Contract.

Materials other than regular excavation or borrow material that are shown on the plans or specified in the Contract shall conform to the applicable requirements of these specifications.

Geotextile material used for subgrade stabilization shall conform to the requirements of Section 245.03(d).

305.03--Procedures.

(a) **Shaping and Compacting Subgrade:**

1. **Subgrade consisting of material in place:** The subgrade area shall be scarified to a depth of 6 inches for a distance of 2 feet beyond the proposed edges of the pavement on each side. If sandy or other soil is encountered that will not compact readily, clay or other suitable material shall be added or water applied in such quantity and within the allowable moisture content specified herein as will permit compaction of the subgrade. Subgrade material shall be compacted at optimum moisture, within ±20 percent of optimum. The density of the subgrade when compared to the theoretical maximum density as determined in accordance with the requirements of VTM-1 shall conform to the following:

% Retained on No. 4 Sieve	Min. % Density
0 – 50	100
51 – 60	95
61 – 70	90

Percentages of material will be reported to the nearest whole number.

The subgrade shall then be shaped and checked to ensure a typical cross section and uniform grade prior to placement of any subsequent courses. If the subgrade becomes eroded or distorted prior to placement of material for subsequent courses, it shall be scarified, reshaped, and recompacted in accordance with the original requirements.

At the time of placing material for subsequent courses, the subgrade shall be compacted to the required density, free from mud and frost, and in a condition that will permit compaction of subsequent courses without distortion.

If the approved subgrade becomes unstable after placement of the subbase or base course and becomes mixed with the aggregate therein, material from the unstable area and contaminated aggregate shall be removed. The area shall then be backfilled and compacted, and the subsequent course thereon reconstructed.

2. **Subgrade consisting of treated materials in place:** Subgrade shall be treated in accordance with the requirements of the applicable provisions of Sections 306.03 and 307.05 except that the tolerance for depth will be waived when lime or cement is being used to bridge or correct extremely weak areas.

   If lime can be satisfactorily manipulated during initial mixing, and bridging of the weak area has been performed satisfactorily, additional mixing and compacting will not be required. Additional layers of fill may be placed without delay.

   Field density determinations will be performed in accordance with the requirements of AASHTO T191, modified to include material sizes used in the laboratory determination of density; with a nuclear density testing device; or by other approved methods. When a nuclear device is used, the nuclear density determination for treated in-place subgrade material will be related to the density of the same material tested in accordance with the requirements of VTM-1 or VTM-12 and a control strip will not be required.

3. **Subgrade consisting of imported material:** The area to receive the material shall be graded to a true crown and cross section.

   Material shall be placed and compacted in accordance with the requirements of the applicable specifications governing the type of material. When select material is used, material shall be placed and compacted in accordance with the requirements of Section 308.02 except that the provision for mixing will be waived. The top 6 inches of the finished subgrade shall be compacted in accordance with the requirements of the provisions of 1. herein.

   The provisions of 1. herein that are not specifically amended herein shall apply. Imported material shall be placed in approximately equal layers not more than 8 inches for commercial material and 6 inches for local material, compacted measure. Material will be tested after compaction for thickness and density. If material fails to conform to thickness requirements, it shall be corrected by scarifying, adding material if necessary, mixing, reshaping and recompacting, or removing and replacing. If the material fails to conform to density requirements, additional rolling will be required until the required density is obtained provided the material is compacted at optimum moisture, within ±20 percent of optimum. If the moisture content is outside the allowable tolerance, the layer shall be scarified, brought to optimum moisture within the allowable tolerance, and recompacted to the specified density.

   An aggregate spreader will not be required in the placement of select material and other imported materials used as subgrade and shoulder courses.

(b) **Treatment of Unsuitable Subgrade:** When solid rock occurs in cuts or the material is not suitable for subgrade or finishing purposes, the roadbed shall be excavated below the grade shown on the plans in accordance with the standard drawings.

When solid rock or other unsuitable material has been removed, excavated areas shall be backfilled in accordance with the standard drawings.

(c) **Finishing Subgrade:** The Contractor shall provide effective drainage for the subgrade and maintain it in a satisfactory condition until the next course is placed.

When practicable, the subgrade shall be prepared at least 500 feet ahead of placement of any subbase, base, or surface course. Material for subsequent courses shall not be placed until the subgrade has been checked and approved. The finished subgrade elevation shall be within ±0.04 foot of the plan elevation unless otherwise specified. When imported material is used, acceptance of the course will be based on the requirements of Section 308.04.

(d) **Geotextile (Subgrade Stabilization):** When geotextile for subgrade stabilization is required it shall be placed as shown on the plans. Geotextile shall be spliced by an overlap of at least 2 feet or by sewing double stitched seams with stitching spaced ¼ inch to ½ inch apart or as shown on the plans.

(e) **Shoulders:** Aggregate shoulder material shall be placed in accordance with the requirements of the applicable specifications governing the type of material or construction being used and shall be compacted at optimum moisture, within ±2 percentage points of optimum. Except when aggregate material No. 18 is used, the density of the aggregate shoulder material, when compared to the theoretical maximum density as determined in accordance with the requirements of VTM-1 or VTM-12, shall conform to the following:

% Retained on No. 4 Sieve	**Min. % Density**
0 – 50	95 – 100
51 – 60	90 – 100
61 – 70	85 – 100

Percentages of material will be reported to the nearest whole number.

When aggregate material No. 18 is used, the density, when compared to the theoretical maximum density, shall be not less than 90 or more than 95 percent.

Aggregate in the guardrail section of fills (1 foot from the roadway side of the guardrail face to the outside of the shoulder) shall be compacted until a density of at least 90 percent of the theoretical maximum density has been obtained. The asphalt mixture in this area shall be sealed immediately after the hot mixture is spread. Rolling of the asphalt mixture shall continue until roller marks are eliminated and a density of at least 85 percent of the theoretical maximum density has been obtained.

Stabilized and paved shoulders shall be constructed in accordance with the requirements of the applicable specifications for pavement stabilization. If the aggregate shoulder material becomes over-consolidated prior to final finishing, it shall be scarified for the approximate depth, reshaped, and recompacted to conform to the specified grade and cross section.

Shoulders shall be constructed simultaneously with nonrigid types of base or surface courses other than asphalt concrete or in advance of the base or surface course so as to prevent spreading of base or surface materials. The area of shoulders 12 inches adjacent to the pavement shall be rolled simultaneously with the course being deposited.

Where base or surface courses are being constructed under traffic and are more than 1 inch in depth, shoulder material adjacent thereto shall be placed within 72 hours after placement of the base or surface course.

305.04--Measurement and Payment.

When material in place is used for the subgrade and shoulders, no measurement will be made. Treated material in place will be measured in accordance with the method of measurement for the specified stabilizing material. When imported material is specified, it will be measured as follows:

(a) **Select material, Type I**, will be measured in tons.

(b) **Select material, Types II and III**, will be measured in cubic yards in its original position.

(c) **Borrow** will be computed in its original position by cross sectioning the area excavated. If cross sectioning the area excavated is not practical, the quantity will be determined from compacted measurements in the road and then converted to pit volume.

When cubic yard measurement is specified and the plans do not show the thickness of material required, the material will be measured in the original position by the cross- section method. Where it is impractical to cross section the area, measurement will be made in trucks in accordance with the requirements of Section 109.01.

When the ton unit is specified, the quantity shall be determined in accordance with the requirements of Section 109.01.

Moisture in excess of optimum, +2 percentage points, will be deducted from the net weight of both truck and rail shipments.

Allowance will not be made for unauthorized depths beyond those shown on the plans and the allowable tolerances. When tonnage measurement is used, deduction for material exceeding the allowable tolerance will be based on 110 pounds per square yard per inch of depth.

When material in place is used for subgrade and shoulders, no separate payment will be made. The cost thereof shall be included in the price for other applicable pay items.

When imported materials are used, the subgrade and shoulders will be paid for at the contract unit price per cubic yard or per ton as specified. Treated material in place will be paid for in accordance with the requirements of the applicable specification.

Stabilized or paved shoulders shown as a pay item will be measured and paid for in accordance with the requirements of Section 306.04, Section 307.06, Section 312.05, or Section 315.08, as applicable.

(d) **Geotextile for subgrade stabilization** will be measured in square yards complete-in- place. Overlaps and seams will not be measured for separate payment. The accepted quantity of geotextile will be paid for at the contract unit price per square yard, which price shall be full compensation for furnishing, placing, lapping or seaming material and for all materials, labor, tools, equipment and incidentals necessary to complete the work.

These prices shall include furnishing, hauling, placing, manipulating, and compacting material; clearing and grubbing local pits; material royalties; and access roads.

Payment will be made under:

Pay Item	**Pay Unit**
Borrow excavation	Cubic yard
Select material (Type and min. CBR)	Cubic yard or ton
Aggregate material (No.)	Cubic yard or ton
Aggregate base material (Type and no.)	Cubic yard or ton
Geotextile (Subgrade stabilization)	Square yard

SECTION 306--LIME STABILIZATION

306.01--Description.

This work shall consist of stabilizing roadbed material by constructing one or more courses of the pavement structure using a mixture of soil or approved aggregates, lime or lime and fly ash, and water.

306.02--Materials.

(a) **Lime** shall conform to the requirements of Section 240.

(b) **Fly ash** shall conform to the requirements of Section 241. Bulk fly ash may be transported dry in bulk trucks and stored in tanks or may be transported in the dampened condition (15 percent moisture, maximum) and stockpiled at the job site. Excessively wet or contaminated surface material shall not be used in mixing operations. Stockpiled material shall be covered with a non-absorptive cover material or periodically moistened to prevent moisture loss and becoming airborne.

(c) **Water** shall conform to the requirements of Section 216.

(d) **Aggregate** shall conform to the applicable requirements of Sections 205, 207, and 208 or other requirements described in the Contract.

306.03--Procedures.

Lime stabilization will not be permitted when aggregate or the surface on which the course is to be placed is frozen. Manipulation shall not be started until the surface is free from mud and frost and the ambient air temperature is at least 40^{o}F.

(a) **Preparing the Roadbed:** The surface of the roadbed shall be cut or bladed to the approximate line, grade, and cross section. However, compaction of the roadbed for the depth of the material to be treated will not be required prior to application of lime. When the course placed directly on the roadbed is to be stabilized, the surface of the roadbed shall be prepared in accordance with the requirements of the applicable provisions of Section 305.

Temporary ramps constructed adjacent to existing pavements, bridges, culverts, and similar items shall be removed to the depth necessary to provide the required thickness of pavement structure.

Drains shall be cut through excavated shoulder material on shoulders to drain the roadbed. Drains shall be cut through windrowed base materials at sufficient intervals to prevent ponding of water. Windrowed material shall be moved, when necessary, to permit the subgrade to dry.

(b) **Preparing Materials:** The prepared roadbed shall be scarified to the depth and width required for stabilization. The material thus prepared shall be partially pulverized. The depth of scarification and the blading operation shall be controlled in such a manner that the surface of the roadbed below the scarified material shall remain undisturbed and shall conform to the established cross section. Prior to the beginning of stabilization work, material retained on the 3-inch sieve shall be removed.

(c) **Applying Lime:** The application rate of lime shall be as shown on the plans or as directed by the Engineer. Lime may be applied to the partially pulverized material as a slurry or in a dry form. When quicklime is used in a dry form it shall be applied at the same rate as hydrated lime.

Where quicklime is slaked on the project to produce a slurry, measurement will be calculated as indicated herein for each truckload using the certified lime purity for that load. No measurement will be made of any lime added or replaced for corrective measures during construction or for repairing damaged areas.

A = Certified weight of quicklime delivered x % purity x 1.32

B = Certified weight of quicklime delivered x % inert material

A + B = Total hydrated lime produced (pay quantity)

Lime applied by slurry application shall be mixed with water in approved agitating equipment and applied to the roadbed as a thin water suspension or slurry. The distributing equipment shall provide continuous agitation from the mixing site until applied on the roadbed. The proportion of lime shall be such that the "Dry Solids Content" shall be at least 30 percent by mass. A lower percent solid may be authorized by the Engineer provided a uniform suspension of the slurry can be maintained. A weight and purity certification shall accompany each shipment of quicklime to be used in slurry applications.

Spreading equipment shall uniformly distribute the lime without excessive loss. No equipment, except water trucks and equipment used for mixing and spreading, shall pass over the spread lime until it is mixed. Any procedure which results in excessive loss or displacement of the lime shall be immediately discontinued.

When a stationary mixer is used to mix aggregate material, the lime may be added to the mix by an approved feeder.

When applied in dry form, lime shall be spread uniformly over the top of the scarified material by an approved screw-type spreader box or other approved spreading equipment. The spreading operation shall be shrouded to minimize dust. Dry lime shall not be applied pneumatically, dropped from a dump truck, front end loader or bottom dumped. A motor grader shall not be used to spread the dry lime.

Dry lime shall not be applied when, in the opinion of the Engineer, wind conditions are such that the blowing material would become objectionable to adjacent property owners or create potential hazards to traffic.

(d) **Adding Water:** Sufficient water shall be added by means of pressure water distributors or through the mixing chamber of a rotary mixer to provide a moisture content at the time of compaction of not less than the optimum for the mixture or more than optimum +20 percent of optimum.

(e) **Mixing:** Lime and water shall be mixed throughout the scarified material as thoroughly as practicable using a self-propelled rotary mixer capable of mixing to a compacted depth of at least 12 inches. Disc harrows or motor graders shall not be used for mixing. The mixture shall then be spread over the roadbed. The surface shall be sealed with a steel wheel or pneumatic tire roller to retard the loss of moisture and then allowed to mellow for 4 to 48 hours. After mellowing, the lime- treated material shall be remixed with a rotary mixer until at least 60 percent of the material, exclusive of aggregates, will pass a No. 4 sieve. Additional water may be added, if necessary, during the remixing operations to ensure proper moisture for compaction.

When a stationary mixer is used, the material may be placed, compacted, and finished immediately after mixing.

When traveling plants are used, additional mixing with blades, tillers, discs, harrows, or repeated passes of the plant may be required.

During the interval of time between lime application and initial mixing, lime that has been exposed to the open air for 6 hours or more or lime that has been lost because of washing or blowing will not be measured for payment.

(f) **Compacting and Finishing:** The mixture shall be placed and compacted to a density of at least 95 percent of the maximum density determined in accordance with the requirements of VTM-1 or VTM-12. Light sprinkling may be required during placement operations to maintain the specified moisture content. Compaction shall be accompanied by sufficient blading to eliminate irregularities.

The surface shall be lightly scarified during finishing operations and bladed to eliminate imprints left by the equipment. Final rolling of the completed surface shall be accomplished with a pneumatic tire roller or steel wheel roller. Final compaction and finishing shall be completed within 12 hours after final mixing.

(g) **Tolerances:** The finished stabilized course shall conform to the specified thickness, subject to the following tolerances: Thickness will be determined in accordance with the requirements of VTM-38A. Areas that are deficient in thickness by more than 1 inch shall be removed or reworked with an additional amount of lime equal to 50 percent of the original amount. In the case of stabilized base courses, the Contractor may correct sections deficient in depth by applying asphalt concrete provided such correction is authorized by the Engineer. Areas that are excessive in thickness by more than 2 inches shall be reworked, and an amount of lime equal to 50 percent of the original amount added to the mixture. Any replacement, corrective work and additional lime required to address deficiencies shall be at the Contractor’s expense.

(h) **Protecting and Curing:** After finishing of the subgrade, no vehicles, except sprinkling equipment, shall be permitted on the subgrade for a curing period of 7 days or until the next course is placed, whichever is less. During the curing period, the subgrade shall be lightly sprinkled with water at frequent intervals to prevent the surface from drying and cracking. The Contractor shall plan and prosecute the work in such a manner as to place the next course during the curing period. If the Contractor has not placed the next course by the end of the curing period, he shall apply liquid asphalt and cover material at the rate specified on the plans.

Damage to the stabilized course attributable to other phases of construction by the Contractor shall be repaired at the Contractor’s expense. At least one subsequent course shall be constructed on the stabilized course before hauling operations for the other phases of construction are permitted on the treated course. If the material loses the required stability, density, or finish before the next course is placed or the work accepted, it shall be recompacted and refinished at the Contractor’s expense.

306.04--Measurement and Payment.

Lime stabilization will be measured in tons of lime or fly ash, square yards of manipulation, and cubic yards or tons of aggregate material, complete-in-place, and will be paid for at the contract unit price per ton of lime or ton of fly ash, per square yard of manipulation, and per cubic yard or ton of aggregate material. Weighing shall be performed in accordance with the requirements of Section except that transporting vehicles shall be tared prior to each load.

Manipulation shall include preparing the roadbed, scarifying, pulverizing, drying material, mixing, compacting, finishing, protecting, curing, and maintaining the completed course.

Payment will be made under:

Pay Item	Pay Unit
Lime	Ton
Fly Ash	Ton
Manipulation	Square yard
Aggregate material (Type)	Cubic yard or ton

SECTION 307--HYDRAULIC CEMENT STABILIZATION

307.01--Description.

This work shall consist of stabilizing roadbed material as specified or as directed by the Engineer and constructing one or more courses of the pavement structure using a mixture of soil, or approved aggregates and hydraulic cement, on a prepared surface in accordance with the requirements of these specifications and in reasonably close conformity with the lines, grades, typical sections, and cross sections shown on the plans or as established by the Engineer.

307.02--Materials.

(a) **Cement** shall conform to the requirements of Section 214, Type I, IP, or II. Cement shall be transported, stored, and otherwise protected in accordance with the requirements of Section 217.03.

(b) **Water** shall conform to the requirements of Section 216.

(c) **Asphalt** used for curing or priming shall conform to the applicable requirements of Section 210.

(d) **Aggregate** shall conform to the applicable requirements of Sections 205, 207, or 208 or other contract requirements.

(e) **Select borrow** shall consist of approved material having the specified CBR.

307.03--Field Laboratory.

When a field laboratory is furnished by the Department, the Contractor shall move the laboratory to various points along the project as necessary.

307.04--Weather Limitations.

Cement stabilization will not be permitted when aggregate or the surface on which the course is to be placed is frozen. Manipulation operations shall not be started until the air temperature is at least 40 oF in the shade and rising. When material may be exposed to freezing temperatures during the first 24 hours of curing, the Contractor shall protect the stabilized material from freezing for 7 days or shall cover the stabilized surface with the next pavement course within 4 hours after the cement stabilization has been finished as specified.

307.05--Procedures.

If full-width paving equipment is to be used in the subsequent placement of asphalt concrete base, the width of the stabilized course upon which the base will be placed may be extended 1 foot beyond the designed typical section on each side.

(a) **Preparing Existing Surface:** When the roadbed is to be stabilized, its surface shall be cut or bladed to the approximate line, grade, and cross section. However, compaction of the roadbed for the depth of the material to be treated will not be required prior to application of cement. When the course placed directly on the roadbed is to be stabilized, the surface of the roadbed shall be prepared in accordance with the requirements of the applicable provisions of Section 305.03.

Additional material needed to bring the roadway surface into compliance with the required specifications shall be obtained from within the limits of the right of way, if available. When authorized, the Contractor shall obtain such material from borrow pits as provided for in Section 303.

The surface shall be sufficiently firm to support, without displacement, the construction equipment and shall be in such condition that the compaction can be obtained as specified herein. Soft, yielding, or wet areas shall be corrected and made stable before construction proceeds.

(b) **Preparing Materials:** When the roadbed is to be stabilized, material to be treated shall be scarified and pulverized prior to application of cement. Pulverizing shall continue during mixing operations until at least 80 percent of the material, exclusive of coarse aggregate, will pass the No. 4 sieve. Any material retained on the 3-inch sieve and other objectionable objects shall be removed.

Applying and mixing cement with material in place or aggregate material shall be performed in accordance with the following methods except that aggregate subbase, aggregate base course, select material, and select borrow specified on the plans shall be mixed in accordance with the requirements of 2. herein. If the closest central mixing plant is located more than 30 road miles from the project, the Contractor may elect to mix cement with aggregate subbase, aggregate base, select material, and select borrow in accordance with the requirements of 1. herein provided an additional 1 percent cement by weight is added to the in-place mixing operation and the cement is mixed to a depth of approximately 1 inch less than the depth of the course being stabilized. No additional compensation will be allowed for the changes described herein.

1. **Mixed-in-place method:** Any additional material required shall be blended with the existing material prior to application of cement.

   Cement shall be applied uniformly on the material to be processed. When bulk cement is used, the equipment shall be capable of handling and spreading the cement in the required amount. The moisture content of the material to be processed shall be sufficiently low to permit a uniform mixture of the aggregate material and cement. Spread cement that has been lost shall be replaced without additional compensation before mixing is started.

   Mixing shall be accomplished by means of a self-propelled or self-powered machine equipped with a mechanical rotor or other approved type of mixer that will thoroughly blend the aggregate with the cement. Mixing equipment shall be constructed to ensure positive depth control. Care shall be taken to prevent cement from being mixed below the depth specified. Water shall be uniformly incorporated into the mixture. The water supply and distributing equipment shall be capable of supplying the amount of water necessary to obtain optimum moisture in the material within 1 hour. If more than one pass of the mixer is required, at least one pass shall be made before water is added. Mixing shall continue after all water has been applied until a uniform mixture has been obtained for the full depth of the course.

   Any mixture that has not been compacted and remains undisturbed for more than 30 minutes shall be remixed. If rain adds excessive moisture to the uncompacted material, the entire section shall be reworked. If the Contractor is unable to finish the section within the same day, the section shall be reconstructed and an amount equal to 50 percent of the original amount of cement shall be added to the mixture at the Contractor's expense.

2. **Central plant method:** Material shall be proportioned and mixed with cement and water in an approved central mixing plant. The plant shall be equipped with feeding and metering devices that will introduce materials into the mixer in the specified quantities. Mixing shall continue until a uniform mixture has been obtained.

   Mixed material shall be transported to the roadway in suitable vehicles and spread on a moistened surface in a uniform layer by a self-propelled or other approved spreader. Not more than 60 minutes shall elapse between the start of mixing and the start of compacting the cement-treated mixture on the prepared subgrade.

   a. **Mixing aggregate subbase and base material:** The cement content will be determined by the titration method as described in VTM-40. Sampling and testing for determining cement content will be performed at the plant. However, nothing herein shall be construed as waiving the requirements of Sections 106.06 and 200.02.

      Acceptance for cement content will be based on the mean of the results of tests performed on samples taken in a stratified random manner from each lot. The rate of sampling will be four samples per lot. A lot of material is defined as 2,000 tons, or 4,000 tons for contract items in excess of 50,000 tons, of material unless the project requires less than 2,000 tons, or 4,000 tons when the contract item is in excess of 50,000 tons; a portion of the lot is rejected for deficient cement content, the job-mix formula for the aggregates is modified within a lot, or a portion of the lot is rejected for an excessive liquid limit or plasticity index.

      A lot will be considered acceptable for cement content if the mean result of the test(s) is within the following process tolerance(s) of the plan design for the number of tests taken: mean of two tests, -1.1 percent; mean of three tests, -0.9 percent; mean of four tests, -0.8 percent. However, no one sample shall have a cement content more than 1.6 percent below the design cement content.

      If an individual test result indicates that the cement content of the material represented by the test is deficient by more than 1.6 percent from the design cement content, the portion of the material represented by the sample will be considered a separate part of the lot and shall be removed from the road.

      If the value of the test results falls below the allowable process tolerance, a payment adjustment will be applied to the contract unit price at the rate of 1.0 percent for each 0.1 percent the material is outside the process tolerance. If the total adjustment is 8.0 percent or less and the Contractor does not elect to remove and replace the material, the contract unit price paid for the material will be reduced at the rate specified herein. The adjustment will be applied to the metric tonnage represented by the samples.

   b. **Mixing select borrow:** Cement in the mixture shall not vary more than ±7.0 percent by mass from that specified. Feeders and meters for introducing cement into the mixer shall be of such design that the amount of cement can be accurately determined before cement is introduced into the mixer.

(c) **Compacting and Finishing:** Prior to the beginning of compaction, the mixture shall be brought to a uniformly loose condition for its full depth and shall have a moisture content of not less than optimum or more than optimum +20 percent of optimum. For subgrade stabilization, the mixture shall be compacted to a density of at least 100 percent of the maximum density as determined in accordance with the requirements of VTM-1 or VTM-12. For subbase and base stabilization, the mixture shall be compacted to conform to the density requirements of Section 309.05.

Compaction equipment shall be subject to the approval of the Engineer, and the number of such units shall be sufficient to ensure the specified density and completion of the processed section within 4 hours from the time the water is added to the mixture. Initial compaction of soil mixtures shall be accomplished with a tamping roller.

After the mixture has been compacted, the surface shall be shaped to the required lines, grades, and cross sections.

If the material to be shaped is a type in which surface compaction planes will form, the Contractor shall lightly scarify the surface continuously with a drag harrow or similar equipment during the shaping operation. The surface shall then be rolled with steel wheels or pneumatic tire rollers, or both. The moisture content of the surface material shall be maintained at not less than the specified optimum during finishing operations. Compacting and finishing operations shall be completed within the specified time and carried out in a manner that will produce a smooth, dense surface, free from surface compaction planes, cracks, ridges, or loose material.

(d) **Construction Joints:** Each day's operation shall tie into the completed work of the previous day by the remixing of approximately 2 feet of the completed course prior to the processing of additional sections. An amount equal to 50 percent of the original amount of cement shall be added to such sections. When the completed section remains undisturbed for more than 24 hours, a transverse construction joint shall be made by cutting back into the completed work to form an approximate vertical face.

(e) **Tolerances:** The finished stabilized course shall conform to the specified thickness and density, subject to the following tolerances:

1. **Density:** The density of the completed work for each day's operations will be determined at representative locations. Any portion on which the density is more than 5 pounds per cubic foot less than that specified shall be removed and replaced.

2. **Thickness:** Thickness will be determined in accordance with the requirements of VTM-38A. The Contractor shall remove and replace areas that are deficient in thickness by more than 1 inch; or, with the approval of the Engineer, the Contractor shall correct sections on stabilized base courses that are deficient in depth by applying asphalt concrete at his own expense. Mixed-in-place areas that are excessive in thickness by more than 1 inch shall be removed and replaced.

   When the central plant method of mixing is used, acceptance of the course will be based on the requirements of Section 308.04 except when the depth is deficient by more than 1 inch. In such event, correction shall be as specified herein.

(f) **Protecting and Curing:** The next course may be placed after the cement stabilization has been approved. In the event the next pavement course is not placed immediately, then the cement-treated aggregate course shall be moist cured continually or covered by the application of liquid asphalt to prevent surface drying until the next pavement course is placed. The Contractor shall endeavor to place the next pavement course within 7 days after cement stabilization is finished. In the event this is not possible and a liquid asphalt cover has not been applied then the Contractor shall either seal the cement stabilized layer with approved cover material or continually maintain the surface of the cement stabilized course with moisture until the next pavement course can be successfully applied. The surface of the cement-treated aggregate course shall be maintain in such a manner that the entire surface of the course remains in a moistened condition. If asphalt cover material is used, it shall be applied at the rate of approximately 0.25 gallon per square yard or as shown on the plans. The Engineer shall direct the exact rate of application necessary to produce full coverage without excessive runoff. If asphalt is used, it shall be applied with an approved pressure distributor as specified in Section 314.04 and the asphalt material shall be immediately covered with the specified cover material.

Prior to placing the next course or the application of asphalt cover material the surface of the cement stabilized layer shall be lightly moistened. In no case shall the cement-treated aggregate course be allowed to dry out completely or go uncovered through the winter. The stabilized course shall be tightly knit and free from loose and extraneous material.

The Contractor shall maintain the cement-stabilized course, including shoulders and ditches, within the limits of the Contract in a condition satisfactory to the Engineer from the time work first starts until the work has been officially accepted. Maintenance shall include immediate repairs of defects that may occur either before or after cement is applied, which work shall be performed by the Contractor and repeated as often as is necessary to keep the course continuously intact. Repairs to the course shall be performed in a manner that will ensure the restoration of a uniform surface and stability of the area repaired.

307.06--Measurement and Payment.

Hydraulic cement stabilization will be measured in tons of hydraulic cement, cubic yards or tons of aggregate, and square yards of manipulation in accordance with the requirements of Section 109.01 and will be paid for at the contract unit price per ton of hydraulic cement, per ton or cubic yard of aggregate, and per square yard of manipulation for the depth specified. This price shall include furnishing and applying water for moisture curing and, when grading is not a pay item, restoring shoulders and ditches.

Hydraulic cement-stabilized aggregate material or aggregate base material will be measured in cubic yards or tons and will be paid for at the contract unit price per ton or cubic yard. This price shall include furnishing and installing cement, aggregate, moisture for curing and, when grading is not a pay item, restoring shoulders and ditches.

Cement-stabilized select borrow will be measured in cubic yards, pit measure, in accordance with the requirements of Section 109.01 and will be paid for at the contract unit price per cubic yard. This price shall include furnishing component and curing materials and hauling, placing, and curing the cement stabilized material.

When bulk cement is used, scales capable of determining the mass of loaded cement transports or lesser loads shall be provided at locations approved by the Engineer. Weighing shall be performed in accordance with the requirements of Section 109.01 except that transporting vehicles shall be tared prior to each load.

When **manipulation** is a pay item and the Contractor elects to centrally mix the materials, the quantity of manipulation shown on the plans will be paid for. Manipulation shall include only the mixing operation.

Asphalt and cover material for curing will not be measured for separate payment.

Payment will be made under:

Pay Item	Pay Unit
Hydraulic cement	Ton
Aggregate material (No.)	Cubic yard or ton
Aggregate base material (Type and no.)	Cubic yard or ton
Cement-stabilized borrow (Min. CBR)	Cubic yard
Manipulation (Depth)	Square yard
Cement-stabilized aggregate material (Type and No.)	Cubic yard or ton

SECTION 308--SUBBASE COURSE

308.01--Description.

This work shall consist of furnishing and placing one or more courses of mineral aggregate on a prepared subgrade in accordance with the required tolerances within these specifications and in conformity with the lines, grades, typical sections, and cross sections shown on the plans or as established by the Engineer.

308.02--Materials.

Material shall conform to the requirements of Section 208 except where other types of aggregate material are specified in the Contract, in which case the applicable specifications governing the material shall apply. When material is obtained from local sources, the sources shall conform to the requirements of Section 106.03.

308.03--Procedures.

Prior to placement of the subbase course, the subgrade shall be constructed in accordance with the requirements of the applicable provisions of Sections 304 and 305.

Subbase material shall be mixed in an approved central mixing plant of the pugmill or other mechanical type in accordance with the requirements of Section 208.05. The mixed material shall be placed on the subgrade by means of an approved aggregate spreader, except that the use of such spreader will not be required where the material is being applied solely for the temporary maintenance of traffic or where the width of the course shown on the plans is transitional and impracticable to place with a spreader box.

Where the required thickness is more than 6 inches, the material shall be spread and compacted in two or more layers of approximately equal thickness. The compacted thickness of any one layer shall be not more than 6 inches. When vibrating or other approved types of special compacting equipment are used, the compacted depth of a single layer of subbase course may be increased to 10 inches upon the approval of the Engineer.

Each layer of subbase course shall be compacted at optimum moisture, within ±2 percentage points of optimum. The density of each layer of subbase aggregate material, when compared to the theoretical maximum density as determined in accordance with the requirements of VTM-1, shall conform to the following:

% Retained on No. 4 Sieve	Min. % Density
0 – 50	100
51 – 60	95
61 – 70	90

Percentages will be reported to the nearest whole number.

Not more than one sample in every five shall have a density less than that specified, and the density of such sample shall be not more than 2 percent below that specified.

If the surface of the subbase becomes uneven or distorted and sets up in that condition, it shall be scarified, reshaped, and recompacted. If the subbase when compacted and shaped shows a deficiency in thickness or if depressions occur in the surface, the Contractor shall scarify such sections at his own expense before additional material is added.

Field density determinations will be performed with the nuclear field density device using the density control strip as specified in Section 304 and VTM-10 or in accordance with the requirements of AASHTO T191. The method of density determination will be as directed by the Engineer.

308.04--Tolerances.

The thickness of the subbase course will be determined by the depth measurement of holes dug in the subbase in accordance with the requirements of VTM-38B.

Acceptance of the subbase course for the physical property of depth will be based on the mean result of tests performed on samples taken from each lot of material placed. A lot of material is defined as the quantity being tested for acceptance except that the maximum lot size will be 2 miles of paver application width.

A lot will be considered acceptable for depth if the mean result of the tests is within the following tolerance of the plan depth for the number of tests taken except that each individual test shall be within ±1 inch of the plan depth: mean of two tests, ±0.75 inch; mean of three tests, ±0.60 inch; and mean of four tests, ±0.50 inch.

If an individual depth test exceeds the ±1 inch tolerance, that portion of the lot represented by the test will be excluded from the lot. If the individual test result indicates that the depth of material represented by the test exceeds 1 inch, the Contractor will not be paid for that material in excess of the tolerance throughout the length and width represented by the test. If the individual test result indicates that the depth of the material represented by the test is deficient by more than 1 inch, correction of the subbase course represented by the test shall be made as specified herein.

If the mean depth of a lot of material is in excess of the allowable tolerance, the Contractor will not be paid for that material in excess of the tolerance throughout the length and width represented by the test.

If the mean depth of a lot of material is deficient by more than the allowable tolerance, correction will not normally be required and the Contractor will be paid for the quantity of material that has been placed in the lot.

For excessive depth subbase courses, when tonnage measurement is used, the rate of deduction from the tonnage allowed for payment as subbase material will be calculated at a weight of 110 pounds per square yard per 1 inch of depth in excess of the tolerance. Areas that are deficient in depth by more than 1 inch and areas that do not provide a smooth uniform surface shall be scarified, material added or removed, reshaped, and recompacted to the specified density so as to conform with the depth tolerance and provide a smooth, uniform surface.

308.05--Measurement and Payment.

Subbase course will be measured in cubic yards or tons as specified and will be paid for at the contract unit price per cubic yard or ton. When the cubic yard unit is specified, the quantity will be determined by compacted measurements on the road unless otherwise specified. When the ton unit is specified, the quantity shall be determined in accordance with the requirements of Section 109.01.

This price shall include furnishing, hauling, placing, manipulating, and compacting subbase course; clearing and grubbing local pits; material royalties; and access roads.

Moisture, in excess of optimum +2 percentage points, will be deducted from the net mass of both truck and rail shipments.

Payment will be made under:

Pay Item	**Pay Unit**
Aggregate material (No.)	Cubic yard or ton
Aggregate base material (Type and No.)	Cubic yard or ton

SECTION 309--AGGREGATE BASE COURSE

309.01--Description.

This work shall consist of furnishing and placing one or more courses of aggregates and additives, if required, on a prepared surface in accordance with the requirements of these specifications and in conformity with the lines, grades, and typical sections and cross sections shown on the plans or as established by the Engineer.

309.02--Materials.

(a) **Aggregate material** shall conform to the requirements of Section 208 except where other types of aggregate material are specified, in which case the applicable specifications governing the material shall apply.

(b) **Calcium chloride and sodium chloride** shall conform to the requirements of Section 239.

309.03--Equipment.

Equipment used for the construction of aggregate base course shall be approved prior to performance of such work. Any machine, combination of machines, or equipment that will handle the material without undue segregation and produce the completed base in accordance with the requirements of these specifications for spreading, moistening, mixing, and compacting will be acceptable.

309.04--Procedures.

The surface or course upon which the base course is to be placed shall be prepared in accordance with the requirements of the applicable provisions of Sections 304 and 305.

Base course material shall be mixed in an approved central mixing plant of the pugmill type. The mixed material shall be placed by means of an approved aggregate spreader.

309.05--Density Requirements.

Where the required thickness is more than 6 inches, the material shall be spread and compacted in two or more layers of approximately equal thickness. The compacted thickness of any one layer shall not exceed 6 inches except when vibrating or other approved types of special compacting equipment are used. In such event, the compacted depth of a single layer of the base course may be increased to 10 inches upon the approval of the Engineer.

After mixing and shaping, each layer shall be compacted at optimum moisture within ±2 percentage points of optimum. The density of each layer of base aggregate material, when compared to the theoretical maximum density as determined in accordance with the requirements of VTM-1, shall conform to the following:

% Retained on No. 4 Sieve	Min. % Density
0 – 50	100
51 – 60	95
61 – 70	90

Percentages will be reported to the nearest whole number.

Not more than one sample in every five shall have a density less than that specified, and the density of such sample shall be not more than 2 percent below that specified. The surface of each layer shall be maintained during the compaction operations in a manner such that a uniform texture is produced and the aggregates are firmly keyed. Water shall be uniformly applied over the base materials during compaction in the amount necessary to obtain proper density.

Irregularities in the surface shall be corrected by scarifying, remixing, reshaping, and recompacting until a smooth surface is secured. The surface shall therefore be protected against the loss of fine materials by the addition of moisture, when necessary, and shall be maintained in a satisfactory and smooth condition until accepted by the Engineer.

The base course will be tested in place for depth and density. Field density determinations will be performed with a nuclear field density device, using a density control strip as specified in Section 304 and VTM-10, or in accordance with the requirements of AASHTO T191. The method of density determination will be as directed by the Engineer.

Acceptance of the aggregate base course for depth will be based on the requirements of Section 308.

309.06--Measurement and Payment.

Aggregate base course will be measured in cubic yards or tons, as specified, and will be paid for at the contract unit price per cubic yard or ton. When the cubic yard unit is specified, the quantity will be determined by compacted measurements on the road unless otherwise specified. When the ton unit is specified, the quantity shall be determined in accordance with the requirements of Section 109.01 and moisture, in excess of optimum +2 percentage points, will be deducted from the net mass of both truck and rail shipments.

Calcium chloride and sodium chloride will be measured in tons and will be paid for at the contract unit price per ton.

These prices shall include preparing and shaping the subgrade or subbase and shoulders, adding moisture, removing and replacing unstable subgrade or subbase and constructing the base course thereon, and filling test holes.

Payment will be made under:

Pay Item	Pay Unit
Aggregate material (No.)	Cubic yard or ton
Aggregate base material (Type and No.)	Cubic yard or ton
Calcium chloride	Ton
Sodium chloride	Ton

SECTION 501--UNDERDRAINS

Section 501.01--Description.

This work shall consist of constructing underdrains, using pipe, aggregate, and geosynthetics, in accordance with these specifications and in reasonably close conformity to the lines and grades shown on the plans or as designated by the Engineer.

501.02--Materials.

(a) **Pipe** shall conform to the requirements of Section 232.

(b) **Aggregate** shall conform to the requirements of Section 202 or 203.

(c) **Geosynthetics, to include geotextile fabric and prefabricated geocomposite pavement edgedrains**, shall conform to the requirements of Section 245.

501.03--Procedures.

(a) **Excavation:** The trench shall be excavated so that the walls and bottom are free of loose and jagged material. Large depressions shall be filled with sandy material, and sharp contours and rises shall be leveled. Excavated material shall be handled in a way that prevents contamination with the aggregate used to backfill the trench for the underdrain.

(b) **Placing Geosynthetics:** When geotextile fabric or prefabricated geocomposite pavement edgedrain, PGPE, is required, it shall be placed as shown on the plans. Torn or punctured fabric shall be replaced at the Contractor’s expense. Splices, when required for PGPE shall be made using splice kits furnished by the manufacturer and in accordance with the manufacturer’s written instructions. Spliced joints shall not damage the panel, shall not impede the open flow area of the panel, and shall maintain the vertical and horizontal alignment of the drain within 5 percent. Splices shall be made in such a manner as to prevent infiltration of the backfill or any fine material into the water flow channel.

(c) **Installing Pipe:** Perforated pipe shall be placed with the perforations facing downward on a bed of aggregate material. Pipe sections shall be joined with appropriate couplings. Semi-round underdrain pipe shall be placed with the rounded section down.

Wherever the depth of the trench is modified to a lesser depth than shown on the standard drawings, concrete or corrugated pipe shall be used.

Pipe shall be placed with the bell end upgrade. Open joints shall be wrapped with the same geotextile used for lining the excavation.

Upgrade ends of pipe, except for combination underdrains, shall be closed with suitable plugs. Where an underdrain connects with a manhole or catch basin, a suitable connection shall be made through the wall of the manhole or catch basin.

After the Engineer has approved the pipe installation, aggregate backfill material shall be placed and compacted. Pipe and covering at open joints shall not be displaced during subsequent operations.

Outlet pipes shall be installed at the low points of sag.

End walls for outlet pipes shall be placed on a prepared surface that has been compacted to meet the requirements of Section 303.04. If settlement of the end wall occurs, the Contractor shall make necessary repairs at his expense.

Prior to final acceptance of the underdrain system, the Contractor shall conduct a video inspection of the installed system in accordance with the requirements of VTM-108.

(d) **Combination Underdrian Outlets:** Pipe shall be placed in the trench with sections securely joined. After the Engineer has approved pipe installation, the trench shall be backfilled with aggregate material in layers not more than 6 inches in depth and thoroughly compacted.

(e) **Inspection Ports:** Inspection ports shall be installed on the PGPE at a rate of 2 per mile of installed PGPE or a minimum of 4 per project. Inspection ports shall meet and be installed in accordance with the manufacturer's specification. The Department will use these ports in conjunction with a borscope camera as part of the basis for acceptance of the PGPE. The Department will perform inspection after PGPE installation, but prior to paving the shoulder. Bends, water flow restrictions, J-shaped panels, tears in the geotextile, debris in pipes and sags are unacceptable and shall be removed and replaced at no cost to the Department.

501.04--Measurement and Payment.

Underdrains and combination underdrains will be measured in linear feet, complete-in-place, and will be paid for at the contract unit price per linear foot. The contract unit price for underdrains installed at depths greater than that shown in the standard drawings will be increased 20 percent for each 1-foot increment of increased depth. No adjustment in the contract unit price will be made for an increment of depth of less than 6 inches. When drains are to be placed under pavement that is not constructed under the Contract, the contract unit price shall include removing and replacing pavement.

Geotextile drainage fabric, when a pay item, will be measured and paid for in accordance with the requirements of Section 504.04.

Outlet pipe for underdrains will be measured in linear feet, complete-in-place, and will be paid for at the contract unit price per linear foot.

These prices shall include geotextile drainage fabric when not a pay item, excavating, aggregate, backfilling, compaction, splicing, inspection ports, if any, disposing of surplus and unsuitable materials, and installing outlet markers.

Payment will be made under:

Pay Item	Pay Unit
Underdrain (Standard)	Linear foot
Combination underdrain (Standard)	Linear foot
Outlet pipe	Linear foot

SECTION 508--DEMOLITION OF PAVEMENT AND OBSCURING ROADWAY

508.01--Description.

This work shall consist of demolition of pavement and obscuring roadway to restore areas that are no longer needed for highway use in accordance with these specifications and in reasonably close conformity to the lines and contours shown on the plans or as established by the Engineer.

508.02--Procedures.

(a) **Demolition of Pavement Structures:**

1. **Hydraulic cement concrete pavement shall be demolished as follows:**

    a. Pavement shall be broken into pieces and either used in fill areas as rock embankment in accordance with the requirements of Section 303 or disposed of at locations selected by the Contractor and approved by the Engineer; or

    b. Material within the proposed roadway prism and more than 3 feet below the subgrade may be broken into pieces not more than 18 inches in any dimension, sufficiently displaced to allow for adequate drainage, and left in the roadway prism.

2. **Asphalt concrete pavement** that does not overlay or underlie hydraulic cement concrete pavement shall be removed as follows:

    a. Pavement shall be removed and used in the work as designated on the plans or as directed by the Engineer; or

    b. When approved by the Engineer, pavement shall be removed and disposed of at locations selected by the Contractor.

3. **Cement stabilized courses** underlying pavement designated for demolition shall be disposed of in accordance with (a)1.a. or (a)1.b. herein.

4. **Aggregate underlying pavement designated for demolition**, except hydraulic cement concrete pavement disposed of in accordance with (a)1.b. herein, shall be salvaged and used for maintenance of traffic or, when approved by the Engineer, disposed of in accordance with (a)2.a. herein.

(b) **Obscuring Roadway:**

1. **Areas outside construction limits consisting of asphalt concrete or hydraulic cement concrete pavement demolished in accordance with (a) herein** shall be conditioned in accordance with the following:

    1. Tops of slopes that do not contain rock shall be rounded for a distance of not more than 10 feet but not less than 5 feet (where sufficient right of way exists) beyond the point of

intersection of the existing slope and the natural ground surface. The depth of the rounding shall be not more than 2 feet below the original surface of slopes.

2. Disturbed areas that are to receive vegetation shall be scarified or plowed, harrowed, and shaped.
3. Clearing and grubbing shall be performed in accordance with the requirements of Section 301.

2. **Areas outside construction limits consisting of pavement structures, other than asphalt concrete or hydraulic cement concrete, that are designated for obscuring roadway** shall be conditioned in accordance with (b)1. herein. Prior to the obscuring, pavement structures shall be removed in accordance with the applicable requirements of (a) herein.

508.03-Measurement and Payment.

Demolition of hydraulic cement concrete pavement and shoulder structure courses or a combination thereof will be measured as demolition of pavement (rigid) and will be paid for in square yards based on the width of the widest course. Such price shall include all demolition, removal and disposal costs of pavement, base, subbase and stabilized subgrade materials.

Demolition of asphalt concrete pavement and shoulder structure courses or a combination thereof will be measured as demolition of pavement (flexible) and paid for in square yards based on the width of the widest course. Such price shall include all demolition, removal and disposal costs of pavement, base, subbase and stabilized subgrade materials.

Demolition of a combination of hydraulic cement concrete pavement and asphalt concrete pavement and shoulder structure courses or a combination thereof will be measured as demolition of pavement (combination) and paid for in square yards based on the width of the widest course. Such price shall include all demolition, removal and disposal costs of pavement, base, subbase and stabilized subgrade materials.

Obscuring roadway will be measured in units of 1,000 square feet computed to the nearest 1/10 unit and will be paid for at the contract unit price per unit. The area measured will be entirely outside the construction limits of the new roadway, as evidenced by slope stakes. Areas disturbed by the operations, including tops of slopes to be rounded, will be included in the measurement. Removing pavement structures other than hydraulic cement-stabilized, hydraulic cement concrete, and asphalt concrete pavement structures in accordance with (b) 2. herein will be measured as regular excavation in accordance with the requirements of Section 303 or as lump sum grading on minimum plan and no plan projects. Clearing and grubbing will be paid for in accordance with the requirements of Section 301.

Payment will be made under:

Pay Item	Pay Unit
Demolition of pavement	Square yard
Demolition of pavement (Type)	Square yard
Obscuring roadway	Unit

APPENDIX D

VIRGINIA TEST METHODS

Virginia Test Method – 1

Laboratory Determination of Theoretical Maximum Density Optimum Moisture Content of Soils, Granular Subbase, and Base Materials (Soils Lab)

June 13, 2013

AASHTO T 99 Method A shall be followed, except as modified below:

12. Moisture Density Relationship

Note 12a: If there is 10% or greater material retained on the No. 4 (4.75 mm) sieve, use the following corrective procedure for determining the theoretical maximum dry density and optimum moisture content.

<u>Material Containing Plus No. 4 (4.75 mm) Sieve Particles</u>

AASHTO T 99 Method A procedure is applicable to soil that contains little or no material retained on the No. 4 (4.75 mm) sieve. Since the maximum density curve determined in the laboratory is obtained by utilizing only that material passing the No. 4 (4.75 mm) sieve, any appreciable amount of larger material contained in the embankment, which is being checked for compaction, will increase the apparent density, due to the higher specific gravity of the stone as compared to the bulk gravity of the compacted dry soil. At the same time, the optimum moisture content will be less, because some of the material passing the No. 4 (4.75 mm) sieve is replaced with coarser material (the void space is reduced and the total surface area is decreased).

(1) The theoretical maximum density, "D" of mixtures containing coarse aggregate larger than a No. 4 (4.75 mm) sieve will be determined by the formula:

$$D = \frac{D_f \times D_c}{(P_c \times D_f) + (P_f \times D_c)}$$

Where:

D_f = Maximum dry laboratory density of minus No. 4 material (by AASHTO Designation: T 99), in lb/ft^3

D_c = Maximum density of Plus No. 4 material (62.4 lb/ft^3 x bulk specific gravity by AASHTO Designation: T85 or as estimated by the Engineer), in lb/ft^3

P_c = Percent plus No. 4 material, expressed as a decimal, and

P_f = Percent minus No. 4 material, expressed as a decimal or by nomograph (see Figure 1).

(2) The optimum moisture for the total soil will be determined by the formula:

$$W_t = (P_c W_c + P_f W_f)100$$

Where:

W_t = Optimum moisture content for total soil,

W_c = Optimum moisture content (absorption), expressed as a decimal, for material retained on No. 4 sieve (estimated between 1% and 3%),

W_f = Optimum moisture content, expressed as a decimal, for material passing No. 4 sieve,

P_c = Percent, expressed as a decimal, of material retained on a No. 4 sieve, and

P_f = Percent, expressed as a decimal, of material passing a No. 4 sieve.

General Notes:

1. The density required in the work will be a variable percentage of the theoretical maximum density, "D", depending upon variations in the percentage of plus No. 4 material in the mixture and upon the position of the material in the work, and will be specified in the applicable section of the specifications.

2. The District Materials Engineer will inform the Inspector of the results of the compaction tests on the minus 4 material and the specific gravity of the +4 material. With this information, the Inspector can then prepare a chart showing the density of the total sample for varying percentages of the +4 material.

3. When performing this test on #10 tertiary screenings (stone dust), be guided by the unique recommendations for field compaction as stated in the Materials Division Manual of Instructions, Section 309.06."

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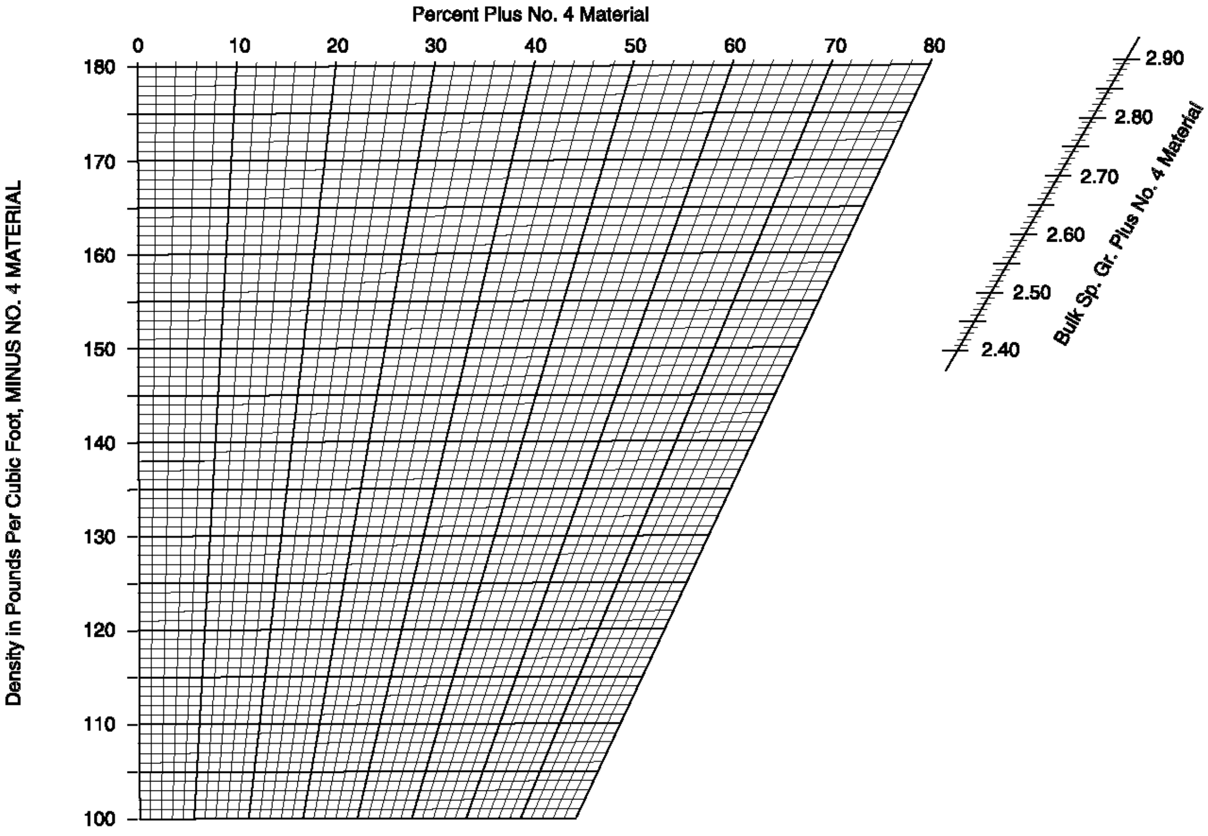
NOMOGRAPH FOR DETERMINING TOTAL DENSITIES OF SOILS



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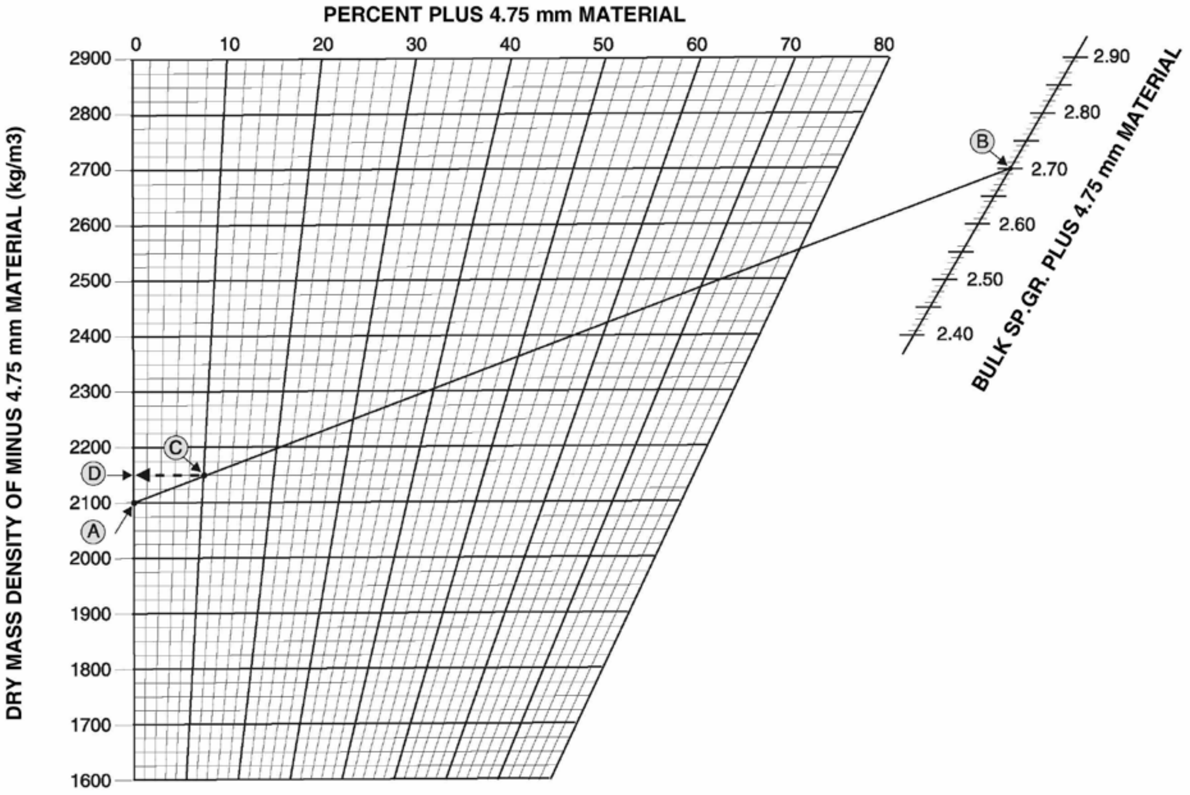
NOMOGRAPH FOR DETERMINING TOTAL DENSITIES OF SOILS



Virginia Test Method – 10

Determining Percent of Moisture and Density of Soils, Aggregate, and Full-Depth Reclamation Courses, and Density of Cold In-Place Recycling and Cold Plant Recycling
(Nuclear Method – Soils Lab)

June 25, 2013

AASHTO T 310 shall be followed, except as modified below:

3. Scope

This test method covers the procedure to be used in determining the percent of moisture and density of embankment, base, subbase, subgrade, backfill, and Full-Depth Reclamation (FDR) courses, and the percent density of Cold In-Place Recycling (CIR) and Cold Plant Recycling (CPR).

4. Apparatus

The apparatus required shall consist of the following:

A. Portable Nuclear Moisture-Density Gauge (nuclear gauge or gauge)
B. Transport case (blue)
C. Charger
D. Reference Standard Block
E. Transport Documents (Bill of Lading)
F. Leveling Plate / Drive Pin Guide
G. Drive Pin w/ extraction tool
H. 4 lb Hammer used for Driving the Pin
I. Safety Glasses
J. Square-Point Shovel
K. No. 4 (4.75 mm) sieve
L. Set Balance Scales
M. Drying Apparatus
N. Miscellaneous Tools such as Mixing Pans and Spoons

5. Direct Transmission and Backscatter Procedures

There are two (2) different methods to determine percent density and percent moisture using the nuclear gauge. The methods are the direct transmission and backscatter.

The direct transmission method requires punching a hole into the surface of the material being tested and lowering the source rod to the desired depth of test. This method is used to test natural soil materials, aggregate backfill, FDR, CIR, and CPR courses, and as verification testing for aggregate base and subbase as it is more representative over the compacted layer than the backscatter method. It is also used as acceptance testing for those projects not having a sufficient quantity of aggregate base and/or subbase to run a roller pattern and control strip.

In the backscatter method the source rod is lowered to the first notch below the safe position placing the source and detectors in the same horizontal plane. No hole is required for the probe since it is flush with the bottom of the gauge. This method is used to test aggregate (subbase and base course) and asphalt materials. When testing soils, the backscatter position **shall not** be used as a means of acceptance for density.

6. Moisture-Density Determination for Embankment, Subgrade, and Backfill (Direct Transmission Method)

All nuclear gauge density tests on embankment, subgrade, backfill, FDR, CIR, and CPR courses using the nuclear gauge shall be tested using the Direct Transmission Method. This is because embankment, subgrade, and structure backfill (except aggregate pipe backfill) are typically comprised of natural soils that can be readily tested by Direct Transmission, and Full-Depth Reclamation courses are treated similarly. The method is as follows:

1. Establish an area at least ten feet from any structure and 33 ft. from other radioactive sources (another gauge) to take standard counts. This area can be concrete, asphalt, or a well compacted soil with a minimum dry density of 100 lb/ft^3. Do not use truck beds, tailgates, tabletops, etc. When using the nuclear gauge, turn it on and wait for it to perform its self-test. When it is completed the gauge will enter the “Ready” mode. At this time, standard counts can be taken and recorded.

   Note: A standard count will be taken each day of use. If counts fail, refer to the gauge’s Manual of Operations and Instructions for further instructions or call your VDOT District Materials Section for assistance.

2. Level off an area of the embankment or subgrade on which to place the gauge using the leveling plate furnished with the gauge. The surface of this area should be as smooth as possible to obtain an accurate test. Care should be taken not to additionally compact the surface during its preparation.

3. Place the guide plate on the surface. Make a hole in the material with the driving pin provided, using the guide plate to be sure the hole is straight and vertical. The hole should extend approximately two (2) inches deeper than the desired test depth.

4. Extend the source rod just enough to place it in the hole in order to avoid soil disturbance around the hole. Then, after the minimal initial insertion, extend the rod to the desired depth of test making sure the device is sitting flush on the surface and the rod is pulled back tight against the backside of the hole. Take a one-minute count in this position.

5. The test is complete and the results are recorded on Form TL-124A.

If the material tested is represented by a predetermined Proctor Test (VTM-1 or VTM-12, which give the theoretical maximum density), the dry density (corrected for +4 oversize material when necessary) should be entered into the gauge prior to testing. This allows the gauge to calculate the percent of compaction.

When it is apparent that the material being placed is different from the material that is specified, due to noticeable changes in color, texture, rock size, etc., another Proctor Test may need to be made on the new material.

In the event the material contains appreciable amounts retained on the No. 4 sieve (greater than 10%, per VTM-1), the Proctor Test Density used shall be the corrected density. This corrected density is typically already furnished by the testing laboratory, but the gauge operator must ensure the corrected density is being used. (Not doing so is one of the most common errors made when testing field density.)

If the material being placed is determined to be “rock fill” an entry must be recorded on the TL-124A form, showing location and elevation of rock.

Direct Transmission testing of aggregate will be required in rare instances when the embankment, subgrade, or backfill material (except pipe backfill which is always aggregate to the springline and in some cases above that) is comprised not of natural soil but of a dense-graded aggregate, such as 21A or B or a dense-graded aggregate select material. Dry density of aggregate material shall always be compared to the theoretical maximum dry density as determined by VTM-1 or VTM-12. When Direct Transmission testing is performed on these occasions, because of the difficulty of driving the pin through dense-graded aggregate and the disturbance of the hole it causes, the density shall conform to the following requirements in Table I, which are reduced by 5% from the requirements for aggregate that may be tested by other means of less disturbance. These reduced densities in Table I also apply to natural soil embankment, subgrade, and backfill with greater than 50% retained on the No. 4 sieve.

Table I
Reduced Density Requirements for Direct Transmission Testing of Aggregate

% Retained on No. 4 (4.75 mm) Sieve*	Minimum % Dry Density
0 – 50	95
51 – 60	90
61 – 70	85

* Percentages of material shall be reported to the nearest whole number.

5. Moisture-Density Determination for Aggregate Base and Subbase (Backscatter Method)

Aggregate base and subbase are tested by means of a roller pattern, control strip, and test sections. The backscatter method is used with the nuclear gauge when testing aggregate base and subbase courses and asphalt, because of the difficulty of driving a pin through these materials. (However, a direct transmission test on aggregate base and subbase courses is made to verify densities as described in Note 1 in Paragraph B below.)

The Roller Pattern is performed first. The purpose is to determine the number of passes to be made by the roller in various combinations of static and/or vibratory rolls to achieve the maximum density for that depth of material using that roller. The data collected from the gauge is entered on the TL-53A form. Properly plotted, this will provide a graphical comparison of the number of roller passes necessary to produce a properly compacted product. Once completed this information is used to establish a Control Strip(s).

The Control Strip determines the target values for density that will define the acceptance criteria for the material placed and compacted using the previously determined roller pattern. The values determined by the control strip will not change until a new roller pattern is required. The data collected is to be entered on the TL-54A form. The Control Strip provides an accurate method of evaluating materials, which are relatively uniform and exhibit smooth surfaces.

A. Roller Pattern

The Roller Pattern is constructed on the same material being placed and once established, will be used for the remainder of the project. The Roller Pattern is 75 ft in length plus some additional area to accommodate the lateral positioning of the roller. The width and depth of the material depends on the project design.

Listed below are the steps used to construct a Roller Pattern:

1. Establish an area at least ten feet from any structure and 33 ft. from other radioactive sources (another gauge) to take standard counts. This area can be concrete, asphalt, or a well compacted soil with a minimum dry density of 100 lb/ft^3. Do not use truck beds, tailgates, tabletops, etc. When using the nuclear gauge, turn it on and wait for it to perform its self-test. When it is completed the gauge will enter the "Ready" mode. At this time, standard counts can be taken and recorded.

   Note: A standard count will be taken each day of use. If counts fail, refer to the gauge's Manual of Operations and Instructions for further instructions or call your VDOT district materials section for assistance.

2. To prepare a Roller Pattern, place the material on a section of roadway approximately 75 ft. in length for the typical application width (an area of at least 100 yd^2), and at the proper loose depth before any rolling is started. (The Contractor should be allowed to place 100 ft. of material prior to the 75 ft. section for plant mix stabilization, adjustment, and compaction purposes, with testing to be conducted at the completion of the roller pattern.) The compaction is to be completed uniformly and in the same manner for the remainder of the job. (It is also recommended that a 50 ft. section be placed before and after the roller pattern section for positioning of the roller.)

   The moisture content of aggregates should be kept as near optimum as possible throughout the rolling operation. Water must be added when needed to maintain optimum moisture in accordance with Section 308 and 309 of the Road and Bridge Specifications during the compaction process.

   To speed up operations, select 15-second mode on the read-out panel and record the density and moisture readings. When testing the control strip and test section, select the 60-second mode for acceptance.

3. Make two (2) passes (one (1) pass is counted each time the roller crosses the test site) with the roller over the entire surface of the Roller Pattern. Make sure the previous passes have been completed over the entire surface before the next pass is started. The above test on aggregates shall be made at three randomly selected points within the area to be tested.

Choose points with good surface conditions and try to spread the three tests over most of the 75 ft. section, making sure not to place the gauge closer than 18 in. to an unsupported edge. Be sure to mark the exact location where the gauge is placed. (If using spray paint to mark the locations, do not spray the gauge with paint.) The gauge, when in use, shall always be positioned parallel with the roadway, with the source end toward the direction of the paver. Record these results on the Roller Pattern Form TL-53A and obtain the total and average for both moisture and density.

All further tests for the Roller Pattern must be made in the same three locations, with the gauge source rod pointing in the same direction as the first test. Plot the average dry density versus the number of roller passes on the graph.

4. Make additional passes with the roller over the entire surface of the Roller Pattern, and again obtain and record the three readings for density and moisture in the same location as the previous set of readings. Calculate the average from the readings and record them on the Form TL-53A. Continue the rolling and testing of the section until the Roller Pattern reaches its maximum density before decreasing or the curve levels off. To be certain this is a sufficient degree of compaction, make one additional roll over the entire surface and test again.

Note 1: The number of passes that are indicated do not necessarily have to be set at two (2) each time. It may be found that in some instances one (1) pass would be sufficient between readings, and, in other instances, three (3) or four (4) passes would be required. An accurate count of the required passes should be maintained and may vary, depending on subgrade conditions, roller efficiency, type of materials and moisture content.

Note 2: Regarding determination of Maximum Attainable Density with Roller Pattern/Control Strip Technique:

The Control Strip shall be rolled until maximum dry density for granular materials is obtained. Materials compacted to maximum density provide a solid platform on which to construct pavement. Materials at maximum density increase pavement load carrying capacity and pavement life; opportunities for future pavement distress will be greatly decreased if maximum density is achieved. These guidelines should be considered good construction practice, not as an addition to the VDOT Road and Bridge Specifications.

In brief, the change in density in a typical Roller Pattern, for example, on Aggregate Base Material, Type I, Size 21B, may look as shown below in Table II below:

Table II
Example Roller Pattern Density Readings

Number of Passes	Change in Density, lb/ft^3
4	+3.1
6	+2.1
8	+2.3
10	+0.9
11	+0.4

It can be seen from the above that continued rolling after ten (10) passes resulted in diminishing returns. This is typical for many Roller Patterns. Based on an analysis of this type, the following is recommended as a guideline for granular materials: In the event that the increase in dry density for a Roller Pattern on granular material is less than 1 lb/ft^3, one (1) additional pass shall be required.

Occasionally, there will be instances where a decrease in density rather than a small increase will occur. This usually occurs for two (2) reasons: a false break, where the density levels off well before maximum density is achieved, and over rolling. In this case, consideration should be given to the number of passes already made and the materials involved, making certain that the break occurring in the Roller Pattern curve is not greater than 1.5 lb/ft^3. When the break is greater than the above value, re-compact the material to the maximum dry density based on the peak of the roller pattern.

A new roller pattern should be established whenever there are multiple lifts of material or there is a change in the following:

Source of material

Compaction equipment

Visual change in subsurface conditions

Gradation or type of material

Portable Nuclear Density Gauge: When this occurs, only another Control Strip is to be performed.

Test section readings are significantly above the target values by more than 8 lb/ft^3. When this occurs review the items in this list. Ask the roller operator if they are doing anything other than the number of passes that was established in the roller pattern. If these things do not produce the reason, then perform another Control Strip.

B. Control Strip

1. To prepare a Control Strip, an additional 300 ft. of roadway is required extending from Roller Pattern area (same spreader box width at the same design depth). This area is to be rolled the same number of passes from the Roller Pattern.

2. In order to determine the maximum dry density of the Control Strip, ten (10) readings for density and moisture should be performed and recorded over the entire 300 ft. section. Calculate and enter the data on the TL-54A Form. The Target Values of 98% and 95% of the average dry density can now be determined. The dry density determined from the average of the Control Strip densities should compare within 3 lb/ft^3 of the roller pattern's maximum dry density.

Note 1: Upon completion of the control strip, perform a direct transmission test to verify that compaction has been obtained comparing the result to the theoretical maximum dry density

obtained by VTM-1 or VTM-12. Refer to Table I above for the minimum percent dry density required.

C. Test Sections

1. To complete a test section, five (5) readings are required. Each test section for aggregate base, subbase, and select materials will be one-half (1/2) mile in length per application width. The length of test sections for shoulders will be the same as the mainline. If possible, test alternating sides. Five (5) readings will be made on each test section for dry density and moisture for aggregate courses using the same method of test used on the Roller Pattern and Control Strip. Rolling is continued until none of the five (5) readings is less than 95% of the Control Strip density, and the average of the five (5) readings is equal to or greater than 98% of the Control Strip density. This does not apply to aggregate shoulder material, which requires an average density of 95 ± 2 percentage points of the control density, with individual densities within 95 ± 5 percentage points of the control density. No other test will be required, unless specified by the Engineer. When test section readings are significantly above or below the target values by more than 8 lb/ft^3, another Control Strip will be established.

2. When testing turn lanes, acceleration lanes, deceleration lanes, and crossovers, take two (2) or three (3) readings on each, whichever is needed, to complete the full test section.

   Note: For sections of roadway less than 900 ft., the direct transmission method or other approved testing methods for density determinations may be used.

   If obvious signs of distress are observed while rolling, cease rolling and evaluate the area of distress. Such signs include cracking, shoving, etc. Structural failures of the aggregate will cause the gauge to give an erroneous reading indicating more compaction is needed, when actually over-compaction is causing the failure. If this situation occurs, it should be brought to the attention of the VDOT district materials section for an evaluation.

6. Moisture-Density Determination for FDR, CIR, and CPR Courses (Direct Transmission Method)

FDR, CIR, and CPR courses require roller pattern and control strip determinations in the same manner as for aggregate base and subbase courses (Section 5 above), except that:

Density test locations shall be marked and labeled by the Contractor in accordance with the requirements of VTM-76.

The roller pattern and control strip shall not be used for density acceptance. These courses require density acceptance based on the maximum density from the approved mix design. Hence Part “C. Test Sections” of Section 5 above does not apply.

Where Section 5 requires backscatter method, direct transmission method shall be used for FDR, CIR, and CPR courses.

Where Section 5 refers to dry density, these courses require the recording of wet density. (Moisture content is determined from laboratory moisture tests, and the dry density obtained. However, in order to facilitate quicker dry density determinations, at the discretion of the District Materials Engineer on a project basis, a water content correction factor based on previous gauge readings or laboratory tests may be used.)

Where Section 5 refers to Standard Proctor tests (VTM-1 or VTM-12 or AASHTO T 99), these courses require use of the Modified Proctor test (AASHTO T 180).

For FDR, CIR, and CPR courses, the same guidelines as for granular materials should be used in Section 5 above, with the exception that after the increase becomes less than 0.5 lb/ft3 per pass, one (1) additional pass shall be required. If the density does not increase by 1.0 lb/ft3 with the additional pass, rolling should be discontinued.

7. Moisture and Trench Wall Offsets

Moisture Offsets

Moisture in certain soil properties containing high amounts of hydrogen rich compounds, such as ash, mica, organics, cement, boron and cadmium, will give inaccurate readings and as a result a moisture offset should be performed. The moisture offset should be a minus for ash, mica, organics and cement and a plus for boron and cadmium. See Page 5-4 in Troxler's Manual of Operation and Instruction for the 3440 Series gauge.

Other methods of determining moisture are the use of the Speedy Moisture Tester or the hotplate method.

Trench Wall Offsets

When a 3440 Nuclear Moisture-Density Gauge is operated within 24 in. of a vertical structure, the density and moisture counts will be influenced by the structure.

Due to the moisture present in trench walls on occasion, a higher moisture reading will be observed when testing backfill materials around pipe, culverts, abutments, etc. It is necessary, therefore, to determine the "background" effect and apply this correction to the observed moisture count readings. The background correction count should be determined each day of testing and when trench wall conditions (distance from wall, moisture content, material composition, etc.) vary. See Page 5.8 in Troxler's Manual of Operation and Instruction for the 3440 Series gauge.

The procedure to determine the background effect and apply the necessary correction is as follows:

1. Take a standard count with the gauge on the standard block outside the trench and record these values.

2. Place the gauge on the standard block inside the trench in the testing area and select trench offset. The density and moisture trench offset constants will be calculated and stored. When the gauge is not being used for trench measurements, disable the offset.

Virginia Test Method – 12

Use of One-Point Proctor Density (Soils Lab)

February 24, 2012

AASHTO T 272 (Method A) shall be followed, except as modified below:

4. Apparatus

Add the following to Section 4.1:

a. Drying apparatus (MARTCP SA 1.3) or "Speedy" moisture tester (AASHTO T217).

6. Procedure

6.3 Take a sample for moisture content determination by field stove method in accordance with MARTCP method SA 1.3. Use "Speedy" moisture tester, if available, except for heavy clays, in which case the field stove should be used. "Speedy" Tester shall be performed in accordance with AASHTO T 217, or the manufacturer's directions labeled on the instrument. Record the moisture content.

14. Maximum Density and Optimum Moisture Content Determination

14.1 Results for wet density of the soil in pounds per cubic foot and moisture content shall be plotted on Typical Moisture Density Curves Set "C" (Figure 1).

A. Correction for +No. 4 (4.75 mm) in the sample, if there is 10% or greater material retained on the No. 4 (4.75 mm) sieve.

The correction to be used for the +No. 4 (4.75 mm) material is determined by the following procedures:

(1) Record the percent of +No. 4 (4.75 mm) material from density hole.

(2) The theoretical maximum density, "D" of mixtures containing coarse aggregate larger than a No. 4 (4.75 mm) sieve will be determined by the formula:

$$D = \frac{D_f \times D_c}{(P_c \times D_f) + (P_f \times D_c)}$$

Where:

D_f = Maximum dry laboratory density of minus No. 4 material (by AASHTO Designation: T 99), in lb/ft^3

D_c = Maximum density of Plus No. 4 material (62.4 lb/ft^3 x bulk specific gravity by AASHTO Designation: T85 or as estimated by the Engineer), in lb/ft^3

P_c = Percent plus No. 4 material, expressed as a decimal, and

P_f = Percent minus No. 4 material, expressed as a decimal or by nomograph (see Figure 1).

(3) The optimum moisture for the total soil will be determined by the formula:

$$W_t = (P_c W_c + P_f W_f)100$$

Where:

W_t = Optimum moisture content for total soil,

W_c = Optimum moisture content (absorption), expressed as a decimal, for material retained on No. 4 sieve (estimated between 1% and 3%),

W_f = Optimum moisture content, expressed as a decimal, for material passing No. 4 sieve,

P_c = Percent, expressed as a decimal, of material retained on a No. 4 sieve, and

P_f = Percent, expressed as a decimal, of material passing a No. 4 sieve.

Alternatively, the corrected maximum dry density can be determined herein with the aid of Figure 2.

B. Percent Compaction

$$\text{Percent Compaction} = \frac{\text{Field Dry Density}}{\text{Maximum Dry Density}} \text{x } 100$$

General Notes:

1 The density required in the work will be a variable percentage of the theoretical maximum density, "D", depending upon variations in the percentage of plus No. 4 (4.75 mm) material in the mixture and upon the position of the material in the work, and will be specified in the applicable section of the specifications.

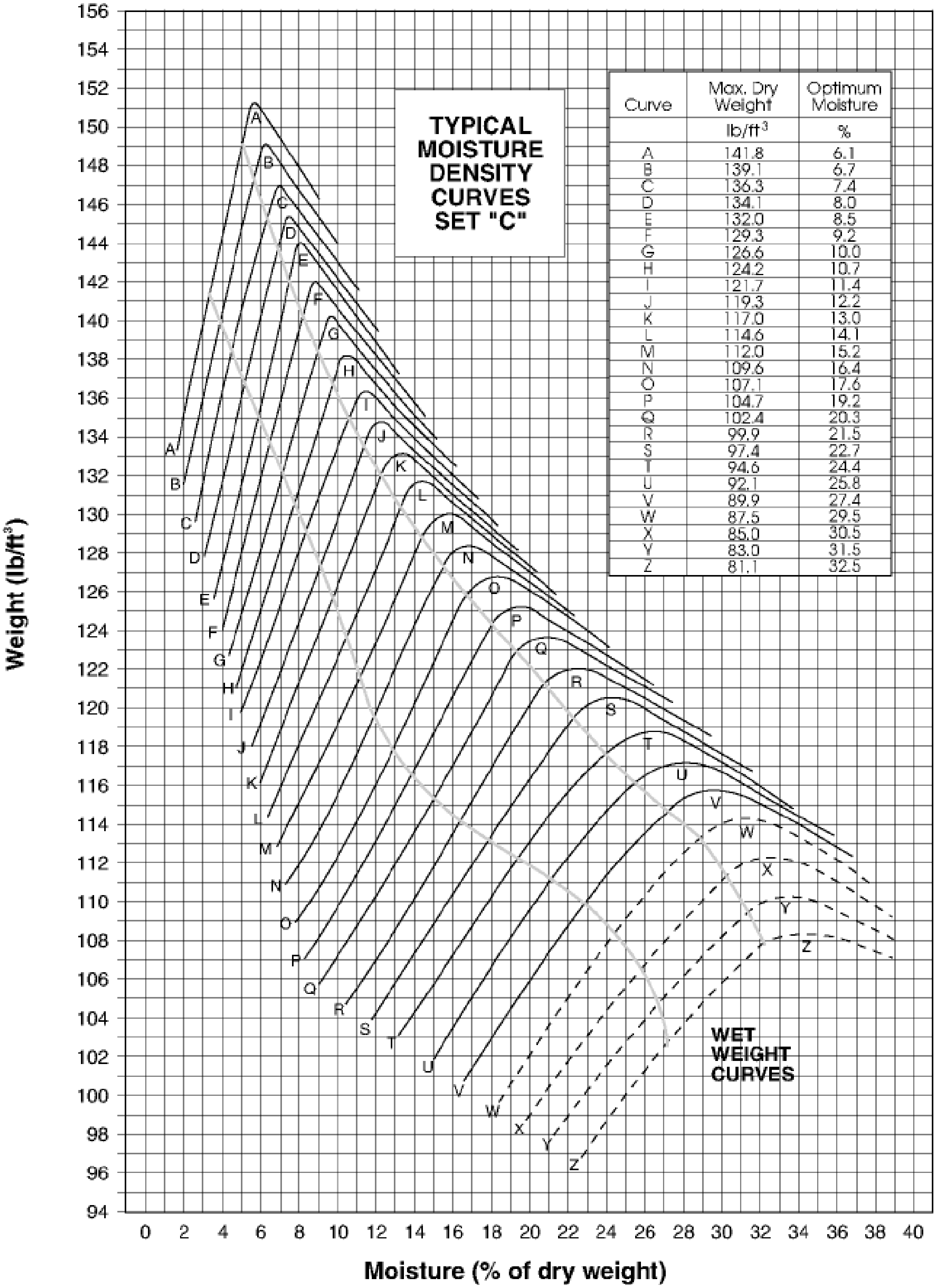
2 The specific gravity of +4 material can be found in soil survey reports and contractor borrow material submittals for soils and Approved List No. 5 for aggregates. (http://www.virginiadot.org/business/resources/Materials/Approved_Lists.pdf)

If this information is not available, the specific gravity can be assumed as directed by the District Material Engineer.

14.3 Replace Note 4 with the following:

Note 4 - If the one point plotted within or on the family of curves (Figure 1) does not fall within the minimum and maximum curve range, compact another specimen, using the same material, at an adjusted moisture content that will place the one-point within this range.

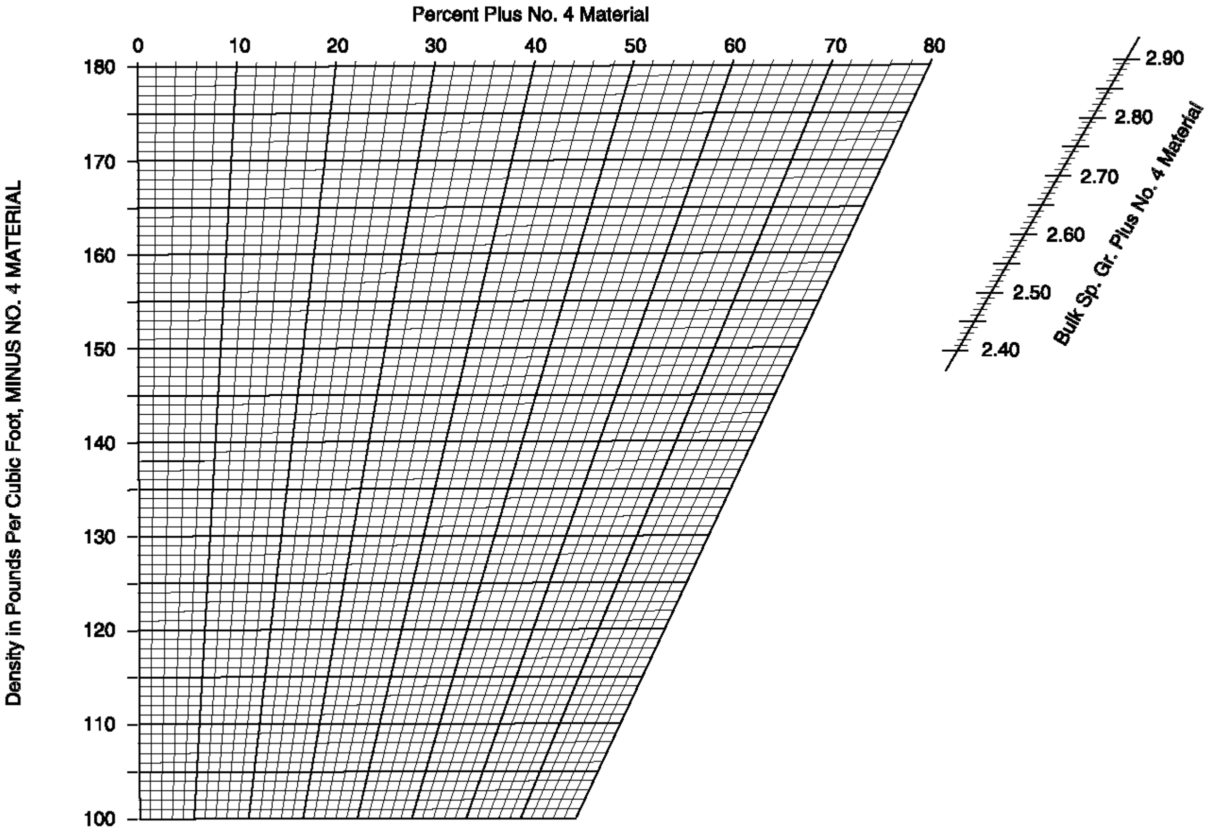
ONE POINT PROCTOR



Curve	Max. Dry Weight lb/ft³	Optimum Moisture %
A	141.8	6.1
B	139.1	6.7
C	136.3	7.4
D	134.1	8.0
E	132.0	8.5
F	129.3	9.2
G	126.6	10.0
H	124.2	10.7
I	121.7	11.4
J	119.3	12.2
K	117.0	13.0
L	114.6	14.1
M	112.0	15.2
N	109.6	16.4
O	107.1	17.6
P	104.7	19.2
Q	102.4	20.3
R	99.9	21.5
S	97.4	22.7
T	94.6	24.4
U	92.1	25.8
V	89.9	27.4
W	87.5	29.5
X	85.0	30.5
Y	83.0	31.5
Z	81.1	32.5

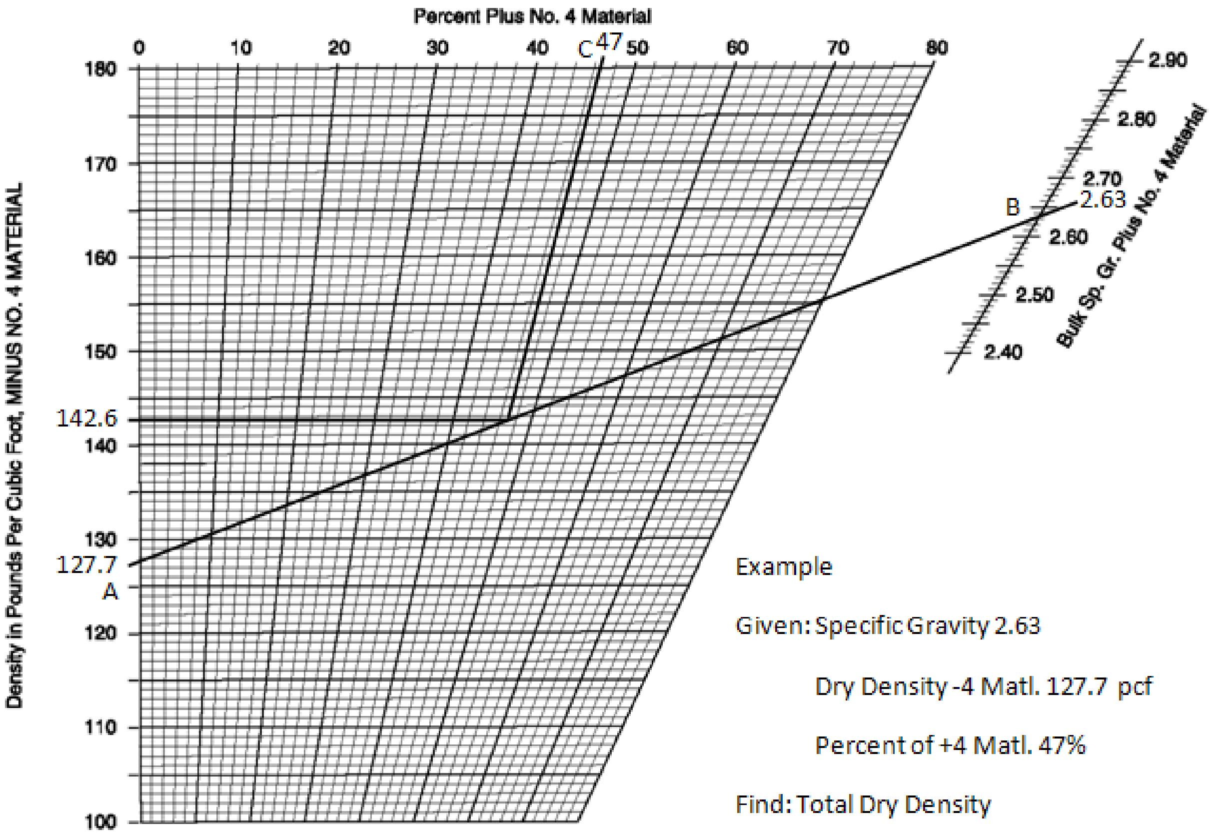
V · I · R · G · I · N · I · A
TRANSPORTATION RESEARCH COUNCIL

NOMOGRAPH FOR DETERMINING TOTAL DENSITIES OF SOILS



V·I·R·G·I·N·I·A
VTRC
TRANSPORTATION RESEARCH COUNCIL

NOMOGRAPH FOR DETERMINING TOTAL DENSITIES OF SOILS



Example

Given: Specific Gravity 2.63

Dry Density -4 Matl. 127.7 pcf

Percent of +4 Matl. 47%

Find: Total Dry Density

1. Plot A, B and C
2. Using a straight edge draw a line from A to B
3. From C draw a line at the same slant as the nomograph lines to intersect line AB
4. Draw a straight line from the point of intersection to the left edge of the nomograph
5. Total Dry Density =142.6 pcf

VIRGINIA TEST METHOD – 123

Post Installation Inspection of Buried Storm Drain Pipe and Pipe Culverts

June 25, 2010

SCOPE

For all roadway projects that are constructed by private contractors for VDOT and for all roadway projects constructed by others that are or will be proposed to be accepted into the VDOT highway system, a visual/video camera post installation inspection is required on all storm sewer pipes and for a selected number of pipe culverts in accordance with the instructions contained in this VTM and Section 302.03 of the VDOT Road and Bridge Specifications. The video camera inspection is to be conducted with a VDOT representative present.

The inspection can be conducted manually if adequate crawl/walking space and ventilation is available to safely conduct the inspection and the individual(s) conducting the inspection have undergone training on working in confined spaces in accordance with VDOT's current Safety Policy and Procedure #8 Confined Space Entry Policy and Procedure - General*,* or the inspection can be conducted with a video camera. If the inspection is to be conducted with a video camera, the video camera shall have fully articulating lenses that will provide a 360 degree inspection of the pipe/culvert, including each joint and any deficient areas of the pipe/culvert, as well as a means to measure deformations/deflections of the pipe (items such as a laser range finder or other appropriate device for taking such measurements as specified herein and approved by the Engineer).

If the inspection is conducted manually, the person performing the inspection may use a standard video camera or a digital camera to document any observed deficiencies. If the mandrel test is to be performed to mechanically measure deformations/deflections of the pipe/culvert, the mandrel used shall be a nine (or greater odd number) arm mandrel, and shall be sized and inspected by the Engineer prior to testing. The diameter of the mandrel at any point shall not be less than the allowable percent deflection of the certified actual mean diameter of the pipe or culvert being tested. The mandrel shall be fabricated of metal, fitted with pulling rings at each end, stamped or engraved on some segment other than a runner with the nominal pipe/culvert size and mandrel outside diameter. The mandrel shall be pulled through the pipe or culvert by hand with a rope or cable. Where applicable, pulleys may be incorporated into the system to change the direction of pull so that inspection personnel need not physically enter the pipe*,* culvert or manhole.

A copy of the Storm Sewer/Culvert Inspection Report (inspection report)including any video tape/Digital Video Recording (DVD)/digital photographs shall be provided to the VDOT Inspector within two business days of the completion of the inspection and made part of the project records. Additionally, a copy shall be furnished to local VDOT Asset Management personnel to document the pipe/culvert condition at that point in time. The video tape/DVD/digital photographs should be of such clarity, detail and resolution as to clearly show the conditions of the interior of the pipe/culvert and detect any defects within the pipe or culvert as specified herein. Post installation inspections shall be conducted no sooner than 30 days after completion of installation and placement of final cover (except for pavement structure).

PROCEDURES

The post installation inspection shall be conducted in accordance with the requirements of Section 302.03(d) of the Road and Bridge Specification*s* and the instructions included herein. The inspection report shall identify the location of the pipe/culvert being inspected with respect to the project site. The inspection report shall identify the location of the inspection access point of the pipe/culvert being inspected with respect to the plans (e.g., north/south/east/west end of the pipe/culvert, manhole/drop inlet/junction box structure number, etc.). The location of any deficiencies within the pipe/culvert shall be noted in the inspection report by identifying the distance from the inspection access point. If no deficiencies are noted, an "OK" entry shall be made in the report under the remarks column for each section of pipe/culvert inspected.

Where deficiencies are found, a video recording is to be used to identify the deficiency in addition to it being noted on the report form. The video camera system shall be capable of capturing clear images. The camera system shall have a titler/keyboard for data entry and an audio microphone for verbal descriptions; both a textual note on the video/images and a verbal description shall be used to note deficiencies. The camera system shall have a locator system for locating the position of the camera, and a footage counter on the cable reel. The location and description of the deficiency should be added to the recording by the use of an audio microphone. When deficiencies are noted that require remedial actions, the contractor's proposed remediation measures shall be noted in the report form.

The Department shall review the post construction inspection report including any proposed remediation measures and communicate its findings to the Contractor within 10 days of receiving the report. Where the Department agrees with the proposed remediation measures, the contractor shall be notified of such approval and authorized to begin such work. Where the Department disagrees with the proposed remediation measures or where the Department identifies additional deficiencies that require remedial action, the contractor shall be notified of such findings and requested to submit a supplemental remediation plan. Pipes or culverts that require~~d~~ coating should have the coating inspected. Cracks (longitudinal and circumferential) shall be noted in the inspection report and photographed (if not videoed) and digitally scanned to allow for accurate measurement. Spalls and slabbing locations shall be photographed (or videoed) and noted in the report.

Upon completion of the corrective measures, the remedial locations are to be re-inspected prior to final acceptance of the project by the same test methods noted herein. Re-inspection shall be made within 10 days of correction except where sections of pipe/culvert have been replaced re-inspection shall not occur sooner than 30 days after replacement of pipe/culvert and final cover (except for pavement structure).

DEFICIENCIES

Deficiencies may include, but are not limited to, the following:

1. Crushed, collapsed or deformed pipe/culvert or joints.
2. Alignment defects would include sags in the longitudinal profile and invert heaving.
3. Improper joints that can allow leaking of water or infiltration of backfill or surrounding soils.
4. Misaligned joints that can cause debris accumulation.
5. Pipe/culvert that has been penetrated by guardrail or other posts or improper backfill materials or methods.
6. Debris, construction or other materials in the pipe/culvert or structures.
7. Coating material shall be free of cracks, scratches and peeling.

8. Cracks (longitudinal and circumferential).
9. Spalls and slabbing.
10. For metallic and plastic pipes/culverts, localized buckling, bulging, cracking at bolt holes (metallic only), flattening, or racking, as well as the applicable points noted above.

REPORTS

The attached example form below is to be used to report the inspection findings. Proposed remedial actions, if required, can be attached on separate pages.

Storm Sewer/Culvert Inspection Report
Video Camera/Visual Inspection

Project Description ____________________ Date of Inspection ____________________
Camera Owner ____________________ VDOT Inspector ____________________
Camera Operator ____________________ Weather Conditions ____________________

Test Section Number	Storm Sewer	Culvert	Pipe Material	Size	Description/Location Test Section (e.g. from Structure ID to Structure ID	Description of Access	Total Length Tested	Any Flow in Pipe	Any Deficiency (Y/N)	Comments

APPENDIX E

PROFICIENCY CHECKLISTS

SPEEDY MOISTURE TEST

Equipment Needed: Complete speedy kit, No. 4 sieve, speedy chart, and sample of soil.

- Make sure moisture tester is clean and in good working order. Place three measures of calcium carbide and two steel balls in the large part of the moisture tester. Do not let the steel balls fall against the dial.
- Sieve sample of soil through the No. 4 sieve.
- Weigh soil sample on tared balance in kit and place in the cap. Holding tester horizontally, insert cap and tighten clamps.
- Holding tester vertically, tap top to allow soil to fall into large chamber.
- Holding tester horizontally, rotate it so that the steel balls are put into orbit around the inside.
- Rotate for 10 seconds, rest for 20 seconds. Repeat for a total of three (3) minutes.
- Holding tester horizontally, read the pressure dial. Determine the moisture content of the soil from the speedy moisture chart by finding the dial reading and next to it reading the moisture content.
- Carefully remove the cap making sure to point the instrument away from the operator to avoid breathing the fumes, and away from any potential source of ignition of acetylene gas. Empty the contents and examine the material for lumps. If sample is not completely pulverized repeat the test with a new sample.

Half sample procedure:

- If the moisture content exceeds the limit of the pressure gauge (more than 20 on the dial) a half sample must be used.
- Hang weight off balance.
- Weigh out sample of soil.
- All other steps are the same; except, double the dial reading before going to speedy chart.

ONE POINT PROCTOR

Equipment Needed: No. 4 sieve, proctor mold, 5.5 lb. drop hammer, beveled straightedge, knife, scales, scoop, TL-125A, and set of "Ohio Curves".

- Information obtained from this test: Maximum Dry Density and Optimum Moisture.
- Weigh the mold (without collar) and base plate and record. Attach collar.
- Sieve a sample of soil through a No. 4 sieve.
- Place mold on a stable surface (concrete block weighing at least 200 lbs., concrete floor, concrete box culvert, bridge abutment).
- Compact the soil into the Proctor mold in three approximately equal layers, compacting each layer 25 blows with the hand held 5.5 lb. drop hammer dropped 12 inches. Distribute the blows evenly around the surface of each layer.
- Soil should be at least ¼ inch inside the collar when compaction is finished. If sample is shy in the mold or you have too much start over.
- Cut around edge of mold before collar is removed to prevent shearing. If sample shears below top of mold start over.
- Remove the collar, and using a beveled straightedge strike off the surface evenly.
- If surface voids are present, use soil trimmings to fill in and apply finger pressure.
- Trim the sample again.
- Clean off the mold and base plate and weigh mold and base plate and wet sample.
- Subtract empty weight from full weight and multiply by 30 (molds per ft3) to determine the Wet Density.
- Use a field hot plate or "Speedy" Moisture Test to determine Moisture Content.
- Plot the wet density and moisture content on the "Ohio Curves" chart to determine the optimum moisture and maximum dry density. The point should fall within "Moisture Limit Lines" on graph. If the point falls to the right, let the soil dry out or start over and use less water. If the point falls to the left of moisture limit lines add more water.

FIELD MOISTURE CONTENT

Equipment Needed: Electric hot plate or gas burner, scale, metal container, large spoon, and 1.1 lbs. (500 grams) of soil.

- 500 grams is the minimum sample required for soils and for aggregate the sample size depends on the Nominal Maximum Size Aggregate.
- Weigh clean dry container and record weight.
- Place sample in container and weigh.
- Place container on stove or hot plate. Mix sample continuously to expedite drying. Use low flame or heat.
- When sample looks dry, remove from stove, cool and weigh.
- Place sample back on stove or hot plate. Continue to dry for 2 to 3 minutes. Cool and reweigh.
- When constant weight is achieved, sample is dry. Record the weight.
- To determine the moisture content, use the following formula:

$$W_{\%} = \frac{(W_{wet} - W_{dry})}{(W_{dry} - W_{con})} \times 100$$

Where:

W% = Percent Moisture
Wwet = Weight of Wet Aggregate and Container (g or lb)
Wdry = Weight of Dry Aggregate and Container (g or lb)
Wcon = Weight of the Container (g or lb)

NUCLEAR DENSITY TESTING

Equipment Needed: Nuclear gauge, reference block, drill rod guide, extraction tool, drill rod, hammer and safety glasses.

Gauge Warm Up and Standard County Procedure

- Wear TLD. Warm gauge up.
- Place reference block on flat surface with a minimum density of 100 lb/ft3 and a minimum distance of 10 feet from any structure and 33 feet from any other radioactive source.
- Place gauge on reference block (seated flat, within raised edges, proper side of gauge against metal butt plate).
- Take Standard Counts.

Direct Transmission Procedure

- Prepare a smooth flat test area free of surface voids.
- Place drill rod guide on test site. Insert drill rod into guide sleeve. Place foot on drill rod guide. Drive rod 2” deeper than depth of test. Carefully remove drill rod and drill rod guide.
- Select one minute count and soils mode on gauge.
- Place gauge over hole. Extend source rod into hole the required test depth.
- Source rod should not disturb hole.
- Gently pull on gauge housing so source rod is tight against hole. (Make sure the gauge is flush on the surface, with the source rod locked in correct depth position.)
- Retract handle to safe position and record gauge readings.

ROLLER PATTERN

Equipment Needed: Nuclear gauge, reference block, drill rod guide/ leveling plate, extraction tool, drill rod, hammer and compaction equipment that is typical for the rest of the project.

- Gauge has been warmed up and standard counts have been taken.
- 75 feet plus additional space to accommodate roller positioning (50 feet on each end).
- Roller will make 2 passes (this varies) over the entire 75’ section.
- Position gauge parallel with the roadway, with the source end toward the direction of the paver. Backscatter position in 15-second (fast) mode
- Take 3 readings for density and moisture spread out over most of the 75’ section and record on TL-53. Mark locations. Do not test any closer than 18 inches to an unsupported edge or in areas that have been overlapped (such as the center).
- Add and average readings.
- Make 2 more passes over the entire 75’ section.
- Take 3 readings for density and moisture in the same locations as before. Add and average them.
- Continue until increase in dry density is less than 1 lb/ft^3 or until mat shows distress (cracking of aggregate).
- When the dry density is less than 1 lb/ft^3, cut vibrator off and make 1 additional pass to be certain there is a sufficient degree of compaction. If the dry density increases by more than 1 lb/ft^3, make one more pass with the roller.
- Graph the results on the roller pattern curve. To be acceptable, each moisture reading must fall within the Optimum Moisture Range and the break should not be over 1.5 lb/ft^3.
- A new roller pattern should be established when there is a change in: source of material, compaction equipment, gradation or type of material, or a visual change in subsurface or subgrade.

CONTROL STRIP

Equipment Needed: Nuclear gauge, reference block, drill rod guide/ leveling plate, extraction tool, drill rod, hammer and compaction equipment that is typical for the rest of the project.

- Gauge has been warmed up and standard counts have been taken.
- 300 feet plus additional space to accommodate roller positioning (50 feet on each end).
- Backscatter position in 1-minute mode.
- Roller will make number of passes established by the Roller Pattern over entire 300’ section.
- Take 10 readings for density and moisture spread out over most of the 300’ section and record on TL-54. Do not test any closer than 18 inches to an unsupported edge.
- Add and average density readings.
- To be an acceptable Control Strip - all moisture readings must fall within optimum moisture range and the average dry density must be within 3 lb/ft3 of the roller pattern’s peak density. If moisture is below optimum moisture range, add water. If moisture is above optimum moisture range, wait for it to dry out and retest that area.
- Calculate individual dry density and average dry density requirements to be used for the test section.
- At the completion of the Control Strip, run a Direct Transmission test on aggregate and compare density results to theoretical maximum density (VTM- 1).

TEST SECTION

Equipment Needed: Nuclear gauge, reference block, drill rod guide/leveling plate, extraction tool, drill rod, hammer and compaction equipment that is typical for the rest of the project.

- Gauge has been warmed up and standard counts have been taken.
- Half-mile (2640 feet) per application width.
- Backscatter position in 1-minute mode.
- Roller will make number of passes established by the Roller Pattern and Control Strip over entire half-mile section.
- Take 5 readings for density and moisture spread out over most of the half-mile section and record on TL-55. Do not test any closer than 18 inches to an unsupported edge.
- Add and average density readings.
- To be an acceptable Test Section, all moisture readings must fall within optimum moisture range, each individual dry density must be at least 95% of the Control Strip Average Dry Density, and the average of the 5 dry density readings must be at least 98% of the Control Strip Average Dry Density.
- If one test fails, roll that area again. If the test section readings are above or below the target values by more than 8 lb/ft^3, establish a new control strip.

APPENDIX F

NUCLEAR GAUGE DOCUMENTS

NUCLEAR GAUGE DOCUMENTS

VDH SECURITY GUIDANCE

VDH regulations require a portable gauge licensee to use a minimum of two independent physical controls that form tangible barriers to secure portable gauges from unauthorized removal whenever the portable gauge is not under the control and constant surveillance by the licensee. “Control and maintain constant surveillance” of portable gauges means being immediately present or remaining in close proximity to the portable gauge to prevent unauthorized removal of the portable gauge. The objective of the security guidance is to reduce the opportunity for unauthorized removal and/or theft by providing a delay and deterrent mechanism.

The following security requirements apply to portable gauge licensees regardless of the location, situation, and activities involving the portable gauge. Licensees are required to either maintain control and constant surveillance of the portable gauge when in use or use two independent physical controls to secure the portable gauge from unauthorized removal while in storage. The physical controls used must be designed and constructed of materials suitable for securing the portable gauge from unauthorized removal, and both physical controls must be defeated in order for the portable gauge to be removed. Using two chains is not the preferred method; licensees are encouraged to use other combinations.

As long as the licensee maintains constant control and surveillance while transporting the portable gauges, the licensees need only to comply with the DOT requirements for transportation (e.g., placarding, labeling, shipping papers, blocking and bracing). However, if the licensee leaves the vehicle and portable gauge unattended (e.g., while visiting a gas station, restaurant, store), the licensee needs to ensure that the portable gauge is secured by two independent controls in order to comply with the requirements of 12VAC5-481-840 D.

While transporting a portable gauge, a licensee should not modify the transportation case if it is being used as the Type A container for transporting the device. This includes, but is not limited to, drilling holes to mount the case to the vehicle or to mount brackets or other devices used for securing the case to the vehicle. In order to maintain its approval as a Type A shipping container, the modified package must be re-evaluated by any of the methods described in 49 CFR Part 178.350 or 173.461(a). The re-evaluation must be documented and maintained on file in accordance with DOT regulations.

Physical controls used may include, but are not limited to, a metal chain with a lock, a steel cable with a lock, a secured enclosure, a locked tool box, a locked camper, a locked trailer, a locked trunk of a car, inside a locked vehicle, a locked shelter, a secured fenced-in area, a locked garage, a locked non-portable cabinet, a locked room, or a secured building. To assist licensees, examples of two independent physical controls are provided below.

Securing a Portable Gauge at a Licensed Facility

When a portable gauge is stored at a licensed facility, the licensee is required to use two independent physical controls to secure the gauge. Examples of two independent physical controls used to secure a portable gauge when stored at a licensed facility are:

1) The portable gauge or transportation case containing the portable gauge is stored inside a locked storage shed within a secured outdoor area, such as a fenced parking area with a locked gate;

2) The portable gauge or transportation case containing the portable gauge is stored in a room with a locked door within a secured building for which the licensee controls access by lock and key or by a security guard;

3) The portable gauge or transportation case containing the portable gauge is stored inside a locked, non-portable cabinet inside a room with a locked door, if the building is not secured;

4) The portable gauge or transportation case containing the portable gauge is stored in a separate secured area inside a secured mini-warehouse or storage facility; or

5) The portable gauge or transportation case containing the portable gauge is physically secured to the inside structure of a secured mini-warehouse or storage facility.

Securing a Portable Gauge in a Vehicle

12VAC5-481 ‘Virginia Radiation Protection Regulations’, Part XIII ‘Transportation of Radioactive Material’ requires that licensees who transport licensed material, or who may offer such material to a carrier for transport, must comply with the applicable requirements of the DOT that are found in 49 CFR Parts 170 through 189.

Licensees commonly use a chain and a padlock to secure a portable gauge in its transportation case to the open bed of a pickup truck, while using the vehicle for storage. Because the transportation case is portable, a theft could occur if the chain is cut and the transportation case with the portable gauge is taken. If a licensee simply loops the chain through the handles of the transportation case, a thief could open the transportation case and take the portable gauge without removing the chain or the case. Similarly, because the transportation case is also portable, it must be protected by two independent physical controls if the portable gauge is inside. A lock on the transportation case, or a lock on the portable gauge source rod handle, is not sufficient because both the case and the gauge are portable.

A vehicle may be used for storage, however, it is recommended by the agency and DOT that this practice only be used for short periods of time or when a portable gauge is in transit. Storage in a hotel room is not authorized. When a portable gauge is being stored in a vehicle, the licensee is specifically required to use a minimum of two independent physical controls to secure the portable gauge.

Examples of two such independent physical controls approved by VDH to secure portable gauges in this situation are:

1) The locked transportation case containing the portable gauge is physically secured to a vehicle with brackets, and a chain or steel cable (attached to the vehicle) is wrapped around the transportation case such that the case cannot be opened unless the chain or cable is removed;

2) The portable gauge or transportation case containing the portable gauge is stored in a box physically attached to a vehicle, and the box is secured with (1) two independent locks; (2) two separate chains or steel cables attached independently to the vehicle in such a manner that the box cannot be opened without the removal of the chains or cables; or (3) one lock and one chain or steel cable is attached to the vehicle in such a manner that the box cannot be opened without the removal of the chain or cable; or

3) The portable gauge or transportation case containing the portable gauge is stored in a locked trunk, camper shell, van, or other similar enclosure and is physically secured to the vehicle by a chain or steel cable in such a manner that one would not be able to open the case or remove the portable gauge without removal of the chain or cable.

Securing a Portable Gauge at a Temporary Jobsite or at Locations Other Than a Licensed Facility

When a job requires storage of a portable gauge at a temporary jobsite or at a location other than a licensed facility, the licensee should use a permanent structure for storage, if practicable. When storing a portable gauge at a temporary jobsite, the licensee should limit access by storing the gauge as far away from members of the public as possible. The licensee must also meet the radiation exposure limits specified in 12VAC5-481-720. When a portable gauge is stored at a temporary jobsite or at a location other than an authorized facility, the licensee is required to use two independent physical controls to secure the portable gauge. Examples of two independent physical controls to secure portable gauges at these locations are:

1) At a temporary job site, the portable gauge or transportation case containing the portable gauge is stored inside a locked building or in a locked non-portable structure (e.g., construction trailer, sea container, etc.), and is physically secured by a chain or steel cable to a non-portable structure in such a manner that an individual would not be able to open the transportation case or remove the portable gauge without removing the chain or cable. A lock on the transportation case or a lock on the portable gauge source rod handle would not be sufficient because the case and the portable gauge are portable;

2) The portable gauge or transportation case containing the portable gauge is stored in a locked garage, and is within a locked vehicle or is physically secured by a chain or steel cable to the vehicle in such a manner that an individual would not be able to open the transportation case or remove the portable gauge without removing the chain or cable; or

3) The portable gauge or transportation case containing the portable gauge is stored in a locked garage, and is within a locked enclosure or is physically secured by a chain or steel cable to a permanent or non-portable structure in such a manner that an individual would not be able to open the transportation case or remove the portable gauge without removing the chain or cable.

NOTICE TO EMPLOYEES

The Virginia Department of Health (VDH) has established standards to protect you from hazards associated with radioactive materials and radiation emitting machines and has established certain provisions for the options of workers engaged in work under a VDH license or registration. In particular, the following information is available for your review:

Virginia Radiation Protection Regulations 12VAC5-481; Part IV - Standards for Protection Against Radiation;
Virginia Radiation Protection Regulations 12VAC5-481; Part X - Notices, Instructions and Reports to Workers; Inspections; and
Any other documents your employer must provide, as listed in "Your Employer's Responsibility" below.

A copy of the regulations specified above and the documents listed in Item 2 of "Your Employer's Responsibility" may be found at the following locations:

Virginia Department of Transportation; License No.: 760-437-1, 1401 East Broad Street, Richmond, VA 23219

Radiation Safety Officer for this License is: Paul M. Baldwin, Jr. (804) 328.3142

YOUR EMPLOYER'S RESPONSIBILITY

1. Apply the provisions of Virginia Radiation Protection Regulations to work involving radiation sources.
2. Post or otherwise make available to you a copy of the license, certificate of registration, conditions or documents incorporated into the license by reference and amendments thereto, and the operating procedures applicable to activities under the license or registration.
3. Post any notice of violation involving radiological working conditions, proposed imposition of civil penalty, or order issued pursuant to the Virginia Radiation Protection Regulations, and any response from the licensee or registrant.

YOUR RESPONSIBILITY AS A WORKER

1. Know the provisions of the Virginia Radiation Protection Regulations and the precautions, operating procedures, and emergency procedures applicable to the work in which you are engaged.
2. Observe the provisions for your own protection and protection of your co-workers.
3. Report unsafe working conditions or violations of the license or registration conditions or regulations to your employer or VDH.

WHAT IS COVERED BY THESE REGULATIONS

1. Limits on exposure to radiation and radioactive material in restricted and unrestricted areas;
2. Measures to be taken after accidental exposure;
3. Personnel monitoring, surveys, and equipment;
4. Caution signs, labels, and safety interlock equipment;
5. Exposure records and reports;
6. Options for workers regarding VDH inspections; and
7. Related matters.

REPORTS ON YOUR OCCUPATIONAL RADIATION DOSE HISTORY

1. 12VAC5-481 Sections 640, 700, and 710 establish limits for occupational dose resulting from exposure to radiation and concentrations of radioactive material in air and water. 12VAC5-481-2280 requires your employer to provide you a written report if you receive a dose in excess of those limits. While these are your maximum allowable limits, your employer is required to take steps to keep your radiation dose as far below limits as is reasonably achievable.
2. If the monitoring of your radiation dose is required by 12VAC5-481-760, your employer must provide a written report of your radiation dose:
    a. Annually.
    b. At your request, for the current year upon your termination of employment in work involving radiation or radioactive material.

INSPECTIONS

All licensed or registered activities are subject to inspection by VDH. Any worker or representative of workers who believes that a violation of Virginia Radiation Protection Regulations or license conditions has occurred in work under a license or registration with regard to radiological working conditions may request an inspection. The request must be in writing and sent to the address listed below. The request must describe the alleged violation in detail and must be signed by the worker or representative of workers. During inspections, VDH inspectors may confer privately with workers, and any worker may bring to the attention of the inspectors any past or present condition believed to have contributed to or to have caused a violation. Refer to 12VAC5-481-2310.

Direct all inquiries on matters outlined above to:

Virginia Department of Health, Radioactive Materials Program, 109 Governor Street, Room 730, Richmond, VA 23219. Phone: (804) 864-8150

POSTING REQUIREMENTS

Copies of this notice must be posted in a sufficient number of places to permit individuals engaged in work under the license or registration to observe them on the way to or from the work location. Each posted copy must be conspicuous and replaced if defaced or altered. Refer to 12VAC5-481-2260.

EMERGENCY NOTIFICATION CONTACT LIST

Rev. Date: 03/10/2015

Follow these steps in case of Emergency:

- From list below Notify Personnel in your respective District (if can't be reached, go to next step).
- Central Office Materials Division (if can't be reached, go to next step).
- The VDH Radiological Health & Safety unless none of the other contacts listed below cannot be reached.

District	District Nuclear Technician	Business Phone No.	Cell Phone No.
Bristol	Mike Austin	276-645-1607	423-502-4606
	P. A. (Trish) Miller	276-645-1693	423-571-4382
	Brian Truelove	276-645-1647	423-360-5426
Salem	Jeff Padgett		540-312-3451
Lynchburg	Bill Wise	434-856-8105	434-841-7079
	Roger Falls	434-856-8358	434-907-1030
Richmond	Danny Morris	804-524-6200	804-720-6428
	Anthony Sanchez	804-524-6187	
Hampton Roads	T. E. Bazemore	757-925-2687	757-334-1562
	W. B. Jenkins	757-925-2277	757-334-2812
Fredericksburg	Michael Whanger	540-899-4243	540-207-6855
	Brian Buckle	540-899-4243	540-907-6047
Culpeper	John (Dicky) Finks	540-829-7580	540-718-7412
Staunton	Darren Galford		540-280-3591
Northern Virginia	John Russell	703-259-1955	703-975-0185
	Ronnie Seale	703-259-1987	703-409-0030

Richmond Central Office
Paul M. Baldwin, Jr. (VDOT Radiation Safety Officer)
Office No: 804-328-3142
Home No: 804-677-0293
Fax: 804-328-3136
paul.baldwin@vdot.virginia.gov

VDH Radiological Health & Safety
During normal business hours: 804-864-8150
www.vdh.virginia.gov

VA Department of Emergency Management
After normal business hours
24-Hour Emergency No: 800-468-8892

VA Department of Radiological Health
Mike Welling, Program Manager
Phone number: (804) 864-8168
Fax number: (804)-864-8155
Mike.Welling@vdh.virginia.gov

PORTABLE NUCLEAR GAUGE EMERGENCY PROCEDURES

These emergency instructions apply whenever a nuclear gauge is involved in an event that might cause damage to the source or its shielding or prevent the return of the source to the shielded position (e.g. when the gauge is struck by a piece of equipment, is contained in a vehicle involved in an accident or involved in a fire).

Gauge User/Operator

- Immediately cordon off the area around the gauge (approximately 15 foot radius) and prevent unauthorized personnel from entering the area to minimize personnel exposure. The gauge operator should stand by outside the cordoned area and maintain constant surveillance of the gauge until emergency response personnel arrive.

- Detain any equipment or vehicle involved in the accident and the operator until it is determined that no contamination is present. Gauge users and other potentially contaminated personnel should not leave the scene until they have been checked for contamination by emergency response personnel.

- Notify appropriate emergency response personnel (See Emergency Phone List) as soon as possible.

RSO and Licensee Management

- Evaluate the condition of the gauge. Determine if the source(s) are present and if they are in the shielded position (if applicable). If the source(s) are out of the gauge they must be located immediately.

- Arrange for a radiation survey to be conducted if necessary (ASAP) by a knowledgeable person using appropriate radiation detection instrumentation. This person could be a VDOT, emergency personnel or a consultant competent in the use of radiation survey meters. The Troxler gauge operation manual contains a radiation profile chart which gives the normal radiation levels near the gauge. The radiation survey readings can be compared to the radiation profile for the gauge contained in the gauge operation manual to determine if the readings are normal.

- The radioactive materials in the Troxler gauge do not pose any immediate health hazard. However, prolonged direct contact with the sources should be kept to a minimal for potential radiation exposure.

COMMONWEALTH OF VIRGINIA

DEPARTMENT OF TRANSPORTATION

1401 East Broad Street
Richmond, Virginia23219-2000

BILL OF LADING

Shipper: Virginia Department of Transportation
Materials Division, Elko
1401 East Broad Street
Richmond, Virginia 23219

Attn: Radiation Safety Officer

UN3332, RADIOACTIVE MATERIAL, TYPE A PACKAGE,
SPECIAL FORM 7, RQ

CONTAINING: Cesium-137 8.0 mCi, (.30 GBq)
Americium-241 Be, 40 mCi, (1.48 GBq)

RADIOACTIVE YELLOW II LABEL, TI = 0.5

Gauge Model 3440 Gauge Serial No. xxxxx

EMERGENCY CONTACT: (804) 328-3142

THIS IS TO CERTIFY THAT THE ABOVE NAMED MATERIALS ARE PROPERLY CLASSIFIED, DESCRIBED, PACKAGED, MARKED AND LABELED, AND ARE IN PROPER CONDITION FOR TRANSPORTATION ACCORDING TO THE APPLICABLE REGULATIONS OF THE COMMONWEALTH OF VIRGINIA.

Paul M Ballman Jr.

Radiation Safety Officer

NUCLEAR GAUGE TRANSFERAL AND TRANSPORTER'S LOG

I (the undersigned) have assumed responsibility for the care and safekeeping of the following equipment for the recorded time.

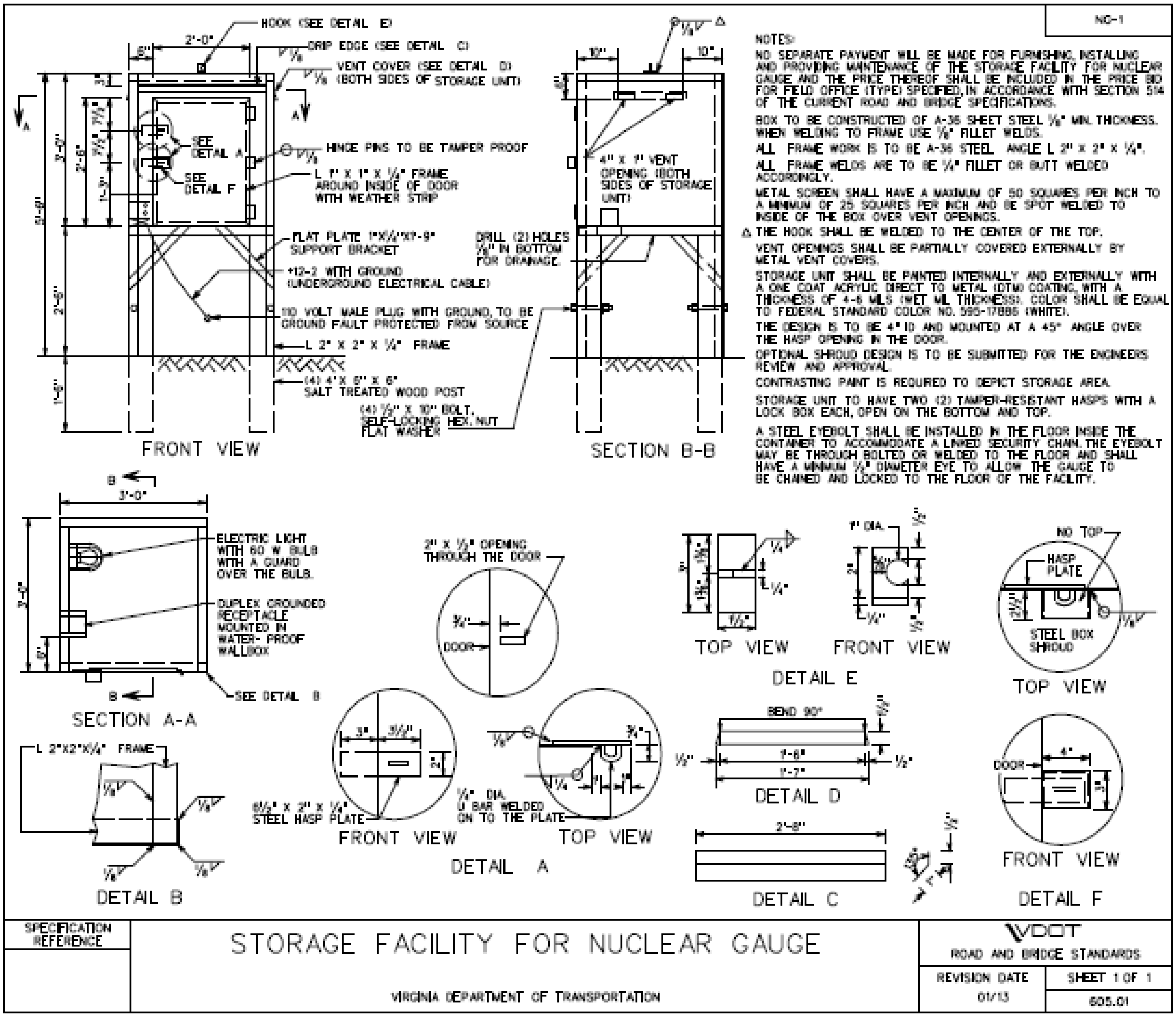
Gauge Model Number: ____________________ **Gauge Serial Number:** ____________________

Date	VDH License No.	Gauge User	Vehicle License No.	Time In	Time Out

Location of Storage Area: ____

** VDH License Number for VDOT Inspectors – 760-437-1 **

STORAGE FACILITY FOR NUCLEAR GAUGE



NOTES:

NO SEPARATE PAYMENT WILL BE MADE FOR FURNISHING, INSTALLING AND PROVIDING MAINTENANCE OF THE STORAGE FACILITY FOR NUCLEAR GAUGE AND THE PRICE THEREOF SHALL BE INCLUDED IN THE PRICE BID FOR FIELD OFFICE (TYPE) SPECIFIED, IN ACCORDANCE WITH SECTION 514 OF THE CURRENT ROAD AND BRIDGE SPECIFICATIONS.

BOX TO BE CONSTRUCTED OF A-36 SHEET STEEL ⅛" MIN. THICKNESS. WHEN WELDING TO FRAME USE ⅛" FILLET WELDS.

ALL FRAME WORK IS TO BE A-36 STEEL ANGLE L 2" X 2" X ¼".

ALL FRAME WELDS ARE TO BE ¼" FILLET OR BUTT WELDED ACCORDINGLY.

METAL SCREEN SHALL HAVE A MAXIMUM OF 50 SQUARES PER INCH TO A MINIMUM OF 25 SQUARES PER INCH AND BE SPOT WELDED TO INSIDE OF THE BOX OVER VENT OPENINGS.

△ THE HOOK SHALL BE WELDED TO THE CENTER OF THE TOP.

VENT OPENINGS SHALL BE PARTIALLY COVERED EXTERNALLY BY METAL VENT COVERS.

STORAGE UNIT SHALL BE PAINTED INTERNALLY AND EXTERNALLY WITH A ONE COAT ACRYLIC DIRECT TO METAL (DTM) COATING, WITH A THICKNESS OF 4-6 MILS (WET MIL THICKNESS). COLOR SHALL BE EQUAL TO FEDERAL STANDARD COLOR NO. 595-17886 (WHITE).

THE DESIGN IS TO BE 4" ID AND MOUNTED AT A 45° ANGLE OVER THE HASP OPENING IN THE DOOR.

OPTIONAL SHROUD DESIGN IS TO BE SUBMITTED FOR THE ENGINEERS REVIEW AND APPROVAL.

CONTRASTING PAINT IS REQUIRED TO DEPICT STORAGE AREA.

STORAGE UNIT TO HAVE TWO (2) TAMPER-RESISTANT HASPS WITH A LOCK BOX EACH, OPEN ON THE BOTTOM AND TOP.

A STEEL EYEBOLT SHALL BE INSTALLED IN THE FLOOR INSIDE THE CONTAINER TO ACCOMMODATE A LINKED SECURITY CHAIN. THE EYEBOLT MAY BE THROUGH BOLTED OR WELDED TO THE FLOOR AND SHALL HAVE A MINIMUM ½" DIAMETER EYE TO ALLOW THE GAUGE TO BE CHAINED AND LOCKED TO THE FLOOR OF THE FACILITY.

APPENDIX G

ANSWERS TO STUDY QUESTIONS

CHAPTER 1 – ANSWERS TO STUDY QUESTIONS

1) True or False. The voids in a saturated soil are partly filled with water and partly filled with air.
False – They are completely filled with water.

2) VDOT uses AASHTO and Unified Soil Classification Systems to classify soils.

3) Consistency refers to the texture and firmness of a soil.

4) Silt and clay are made up of particles that are smaller than the No. 200 (75 µm) sieve.

5) The gradation is the distribution of various particle sizes within the material.

6) Dense graded means that the particles in a mixture are sized so that they fill most of the voids; there is very little space in between soil or stone particles.

7) The moisture content at which a soil begins to behave like a liquid is called the liquid limit.

8) The behavior of a material where the material deforms under load and does not go back to its original shape is called plasticity.

9) The moisture content at which a soil can be compacted to its maximum dry density with the least amount of compactive effort is called the optimum moisture content.

10) True or False. A soil that contains a high percentage of fines is more affected by water than one with a low percentage of fines. True

11) True of False. Open graded aggregates are used in a pavement to give the structure more strength. False – Dense graded aggregates are used in a pavement to give the structure more strength.

CHAPTER 2 – ANSWERS TO STUDY QUESTIONS

1) True or False. Clearing and Grubbing is required in fill sections less than 5 feet in depth, in borrow areas before excavation can begin, and in all cut sections. True.

2) In fill sections where stumps may be left in place, they must be no more than 6 inches high.

3) Grading to drain means to crown surface of embankment, roll surface of embankment smooth, direct water to appropriate erosion and siltation controls.

4) The first lift of embankment material placed in swampy areas is called a work platform.

5) How should layers of embankment material be placed? Layers of embankment material should be placed with uniform thickness and parallel to finished grade.

6) Please answer the following questions:

   a. For a fill with a height of 8 feet, a length of 1500 feet, and a volume of 61,200 cubic yards what is the minimum number of density tests required? 45 tests – 1 per 2,500 cubic yard increment = 25; 2 per 6 inch layer within the top 5 feet of fill = 20.

   b. For a fill with a height of 8 feet, a length of 400 feet, and a volume of 61,200 cubic yards what is the minimum number of density tests required? 33 tests – 1 per 2,500 cubic yard increment = 25; plus 1 for every other layer from bottom of fill to top of fill, starting with the second lift = 8.

   c. For a fill with a height of 10 feet, a length of 2200 feet, and a volume of 80,000 cubic yards what is the minimum number of density tests required? Volumetric requirement is 80,000 cubic feet ÷ 2500 = 32 tests. Greater than 2,000 feet split into two equal parts. For first 1100 feet, 2 tests per 6 inch layer within the top 5 feet of fill = 20 tests; and for last 1100 feet, 2 tests per 6 inch layer within the top 5 feet of fill = 20 tests. Total number of tests = 32 + 20 + 20 = 72 tests.

7) Material is being placed 15 feet below the proposed subgrade in a rock fill. The maximum nominal size of the rocks is 3 feet. The maximum lift thickness in this case is 3 feet.

8) True or False. In building an embankment on a hillside, benching provides a place to test. False – In building an embankment on a hillside, benching provides a foundation for the new embankment and a bond to the existing slope.

9) Is frozen embankment material acceptable to use in embankments? No.

10) Is 108 % compaction acceptable for embankment? No.

11) True or False. For subgrade and embankment, the specifications require that each lift be compacted at optimum moisture content with a tolerance of ±40%. False - ± 20%.

12) True or False. Embankment is a structure of soil, soil aggregate, soil-like materials, or broken rock between the existing ground and the subgrade. True.

13) Six (6) feet is the minimum bench width for a slope steeper than 4:1 and less steep than 1½:1?

14) What is the density testing rate for fill areas less than 500 feet long? One test per 2,500 cubic yards, plus one test for every other 6 inch layer in the embankment from the bottom of the fill to the top of the fill, starting with the second lift.

15) What is the density testing rate for fill areas between 500 feet and 2000 feet? One test per 2,500 cubic yards, plus two tests for every 6 inch layer within the top 5 feet of fill.

16) What is the maximum distance from the heel of an abutment/gravity or cantilever retaining wall that is to be tested by the specified rates for walls if the structure is 12 feet high? The height of the structure plus 10 feet (12 + 10 = 22).

17) Material having a moisture content of more than 30% above optimum cannot be placed on a previously placed layer for drying, unless it is shown that it will not detrimentally affect the previously placed layer due to downward migration of water.

18) The typical lift thickness for soil is 8 inches loose, 6 inches compacted.

19) The maximum diameter of the material placed in the top 12 inches of an embankment is 3 inches.

20) The maximum diameter of material that can be placed 9 feet under the embankment surface is 2 feet.

CHAPTER 3 – ANSWERS TO STUDY QUESTIONS

1) Subgrade is the top surface of the embankment and the foundation for the pavement structure.

2) Subgrade must be scarified for a distance of 2 feet beyond the proposed edges of pavement to a depth of 6 inches and recompacted to the original requirements.

3) Seven (7) days after placement of the Cement Stabilized Subgrade the next course of pavement or approved cover material must be applied.

4) True or False. Cement is used with soil or aggregate to make the soil or aggregate more workable. False – Cement is used to add strength the mixture.

5) Why is lime used with soil? Lime is used with soil to add strength to the mixture, to raise the pH of the mixture, to assist in drying out soils, and to reduce soil plasticity.

6) The tolerance on the optimum moisture content at which aggregate must be compacted is ± 2 percentage points.

7) The tolerance on the optimum moisture content for cement treated subgrade is optimum moisture to 20% above optimum moisture.

8) The most common type of geosynthetic used is a geotextile.

9) True or False. Sewing of embankment stabilization fabric seams is not required. False – Sewing of the seams is required in all cases.

10) What is the minimum number of tests required for finished subgrade from Station 453+60 to Station 553+60? 5 tests are required; one test for each 2000 feet of subgrade full width. Calculation: 553+60 – 453+60 = 100+00 or 10,000 feet.

11) Cement Stabilized Subgrade has been placed 48 feet in width from Station 392+20 to Station 550+60, with a paver application width of 12 feet. Determine the number of tests required and the density and moisture requirements. Minimum number of tests required is 24, density must be 100%, and optimum moisture must be between optimum moisture to 20% above optimum moisture.

    Calculation:
    1) 550+60 – 392+20 = 158+40 or 15,840 feet
    2) 15,840 ÷ 5280 (feet in a mile) = 3 miles
    3) 48 feet ÷ 12 feet paver width = 4 pulls
    4) One test per ½ mile per paver width = 3 miles x 4 pulls = 12 x 2 = 24 tests

CHAPTER 3 – ANSWERS TO STUDY QUESTIONS (CONT.)

Chapter 3 - Practice Problem Number 1
Cement Application Rate (Volume Method)

The plans call for 12% cement <u>by volume</u>, 6" depth. Width of treatment is 26 feet. The net weight of the cement in the tanker is 23.09 tons. How many feet of roadway should this load of cement treat?

1) Application Rate = $[(W_t \text{ x } D_t)] \text{ x } [(D_c \text{ x } 94)]$

$= [(26 \text{ x } 0.5) \text{ x } [(0.12 \text{ x } 94)]$

$= 13 \text{ x } 11.28$

Application Rate = 146.64 lb/ft^3

2) Application Length = $\frac{\text{(Cement Weight x 2000)}}{\text{Application Rate}}$

$= \frac{(23.09 \text{ x } 2000)}{146.64}$

$= \frac{(46180)}{146.64}$

Application Length = 315 Feet

Chapter 3 - Practice Problem Number 2
Cement Application Rate (Volume Method)

The plans call for 6.5% cement <u>by volume</u>, 6" depth. Width of treatment is 24 feet. The net weight of the cement in the tanker is 22 tons. How many feet of roadway should this load of cement treat?

1) Application Rate = $[(W_t \text{ x } D_t)] \text{ x } [(D_c \text{ x } 94)]$

$= [(24 \text{ x } 0.5) \text{ x } [(0.065 \text{ x } 94)]$

$= 12 \text{ x } 6.11$

Application Rate = 73.32 lb/ft^3

2) Application Length = $\frac{\text{(Cement Weight x 2000)}}{\text{Application Rate}}$

$= \frac{(22 \text{ x } 2000)}{73.32}$

$= \frac{(44000)}{73.32}$

Application Length = 600 Feet

CHAPTER 4 – ANSWERS TO STUDY QUESTIONS

1) What should be located before starting to dig? Utilities.

2) True or False. When moving concrete pipe you should pick it up by one end. False – You should use leather or nylon slings or a pipe fork.

3) What are the testing requirements for backfilling around pipe? When backfilling around pipe, you should test every other lift on alternating sides beginning after the first 4 inch compacted layer above the structure's bedding and continue until backfill is 1 foot above the pipe for a maximum of 300 feet of pipe length.

4) What is the maximum size a rock to be placed within 12 inches of a pipe? 2 inches.

5) True or False. You do not have to place pipe bedding material down first when installing a UD-4. True.

6) Where can the typical underdrain drawings be found? VDOT Road and Bridge Standards.

7) What is the maximum height of cover for a 48 inch pipe diameter Class IV concrete pipe culvert? 21 feet.

8) A 36 inch diameter pipe, 290 feet long, is placed on a project as a drainage culvert. What is the minimum number of density tests that should be run on the backfill material? 11 tests; [(36 ÷ 4) + (12 ÷ 4)] – 1 = 11.

9) When can No. 57 stone be used? No. 57 stone can be used with sub-bedding when standing water is encountered.

10) What is the maximum backfill lift thickness? 6 inches loose compacted to 4 inches.

11) Pipe openings in precast drainage structures shall not exceed the outside cross sectional dimensions of the pipe by more than how much? 8 inches.

12) How long after installation is complete can the video inspection can be done? 30 days.

13) What is the maximum allowed crack size of a rigid pipe? 0.1 inches.

14) What is the maximum deflection allowed for flexible pipe? 7.5%.

15) What end of the pipe system do you start installation? Upstream or down- stream? Downstream.

16) What is the level of compaction required for pipe backfill? 95%.

CHAPTER 5 – ANSWERS TO STUDY QUESTIONS

1) What are the three differences between AASHTO T-99 and AASHTO T-180? The three differences between AASHTO-T99 and AASHTO T-180 are 1) the weight of the hammer; 2) height of drop of the hammer; and 3) the number of layers of soil compacted in the mold.

2) Three (3) layers of soil are required to make a standard proctor mold and each layer must be compacted 25 blows with a 5.5 lb. hammer dropped 12 inches.

3) The moisture content corresponding to the peak of the curve will be termed the optimum moisture content and the density corresponding to the peak of the curve will be termed the maximum dry density.

4) Three (3) scoops of reagent are placed in the body of the “speedy” moisture tester.

5) According to AASHTO, the base on which the proctor test molds are made must weigh at least 200 lbs.

6) If the dial on the Speedy exceeds 20, a half-size sample must be used and the dial reading must be multiplied by 2.

7) The proctor is run on soil which passes the No. 4 sieve.

8) Rotate the Speedy for 10 seconds, rest for 20 seconds for a period of 3 minutes.

9) Calculate the moisture content using the following information:

$W_{wet} = 10.85$

$W_{dry} = 10.05$

$W_{con} = 1.69$

$$W\% = \frac{(10.85 - 10.05)}{(10.05 - 1.69)} \times 100$$

$$= \frac{0.80}{8.36} \times 100$$

$W\% = 9.569$ or 9.6%

CHAPTER 5 – ANSWERS TO STUDY QUESTIONS (CONT.)

Chapter 5 – Practice Problem Number 1
Establishing Target Densities (One-Point Proctor)

A. Complete the one-point proctor form (Form TL-125A) on soil using the information provided.

Date: Today's Date
Compacted Depth of Lift: 6"

Weight of Mold + Weight of Soil = 8.45 lbs.
Weight of Mold = 4.41 lbs.
Speedy Dial Reading = 13.2

B. Answer the following questions.

a) What is the maximum dry density? 107.1 lb/ft^3

b) What is the optimum moisture and optimum moisture range? 17.6% (Range = 14.1% to 21.1%)

17.6 x 0.20 = 3.52
17.6 – 3.52 = 14.1
17.6 + 3.52 = 21.1

c) A nuclear density test determines the dry density to be 102 lb/ft^3 with a moisture content of 18.2%. Does this test pass? Yes, it meets density and moisture requirements.

1) (102 ÷ 107.1) x 100 = 95.2% (which is greater than the minimum required density of 95.0%)
2) Moisture content of 18.2% falls within the optimum moisture range of 14.1% to 21.1%

Form TL-125A (Rev. 07/15)

CHAPTER 5 – ANSWERS TO STUDY QUESTIONS (CONT.)
PRACTICE PROBLEM #1

Route No. 635 **County** Amherst

Project No. 0635-005-187, C501 **Inspector**

FHWA No. FH-151(102)

Field Test No.		1	2	3
Date of Test				
Location of Test	Station Number – ft. (m)	77+50		
	Reference to Center Line – ft. (m)	7' Lt. C/L		
Reference Elevation	Original Ground – ft. (m)	+10 ft.		
	Finished Grade – ft. (m)	-23 ft.		
Type of Roller		Sheepsfoot		
A. Weight (mass) of mold and wet soil – lb. (kg)		8.45		
B. Weight (mass) of mold – lb. (kg)		4.41		
C. Weight (mass) of wet soil (A - B) – lb. (kg)		4.04		
D. Wet density of soil (Line C x 30 lb/ft^3) or (Line C x 1060 kg/m^3)		121.2		
E. "Speedy" Dial Reading		13.2		
F. Moisture Content (%) from Speedy Chart		15.3		
G. Maximum Dry Density – lb/ft^3 (kg/m^3)		107.1		
H. Optimum Moisture (%)		17.6		
I. Field Density – lb/ft^3 (kg/m^3) from TL-125				
J. No. 4 (+4.75 mm) material from field density hole				
K. Corrected Maximum Density – lb/ft^3 (kg/m^3)				
L. Compaction (%)				

Comments:

BY:

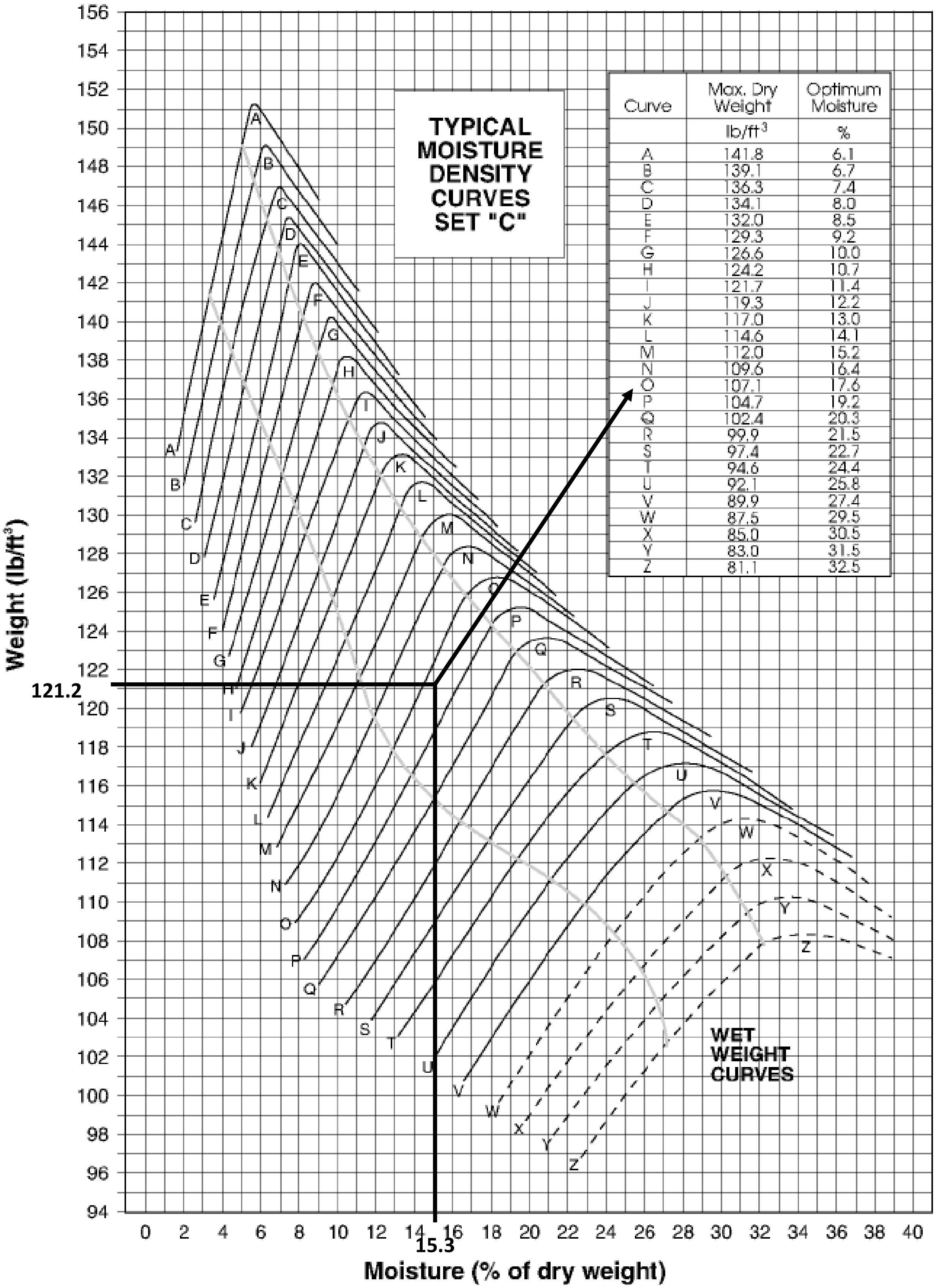
TITLE:

SPEEDY MOISTURE CHART

SPEEDY MOIST.		SPEEDY MOIST.		SPEEDY MOIST.		SPEEDY MOIST.		SPEEDY MOIST.		SPEEDY MOIST.		SPEEDY MOIST.	
READ.	CONT.	READ.	CONT.	READ.	CONT.	READ.	CONT.	READ.	CONT.	READ.	CONT.	READ.	CONT.
1.0	1.0	8.2	9.0	15.4	18.3	22.6	29.2	29.8	42.5	37.0	58.8	44.2	79.2
1.2	1.3	8.4	9.2	15.6	18.5	22.8	29.6	30.0	42.9	37.2	59.3	44.4	79.9
1.4	1.5	8.6	9.5	15.8	18.8	23.0	30.2	30.2	43.3	37.4	59.8	44.6	80.5
1.6	1.8	8.8	9.7	16.0	19.1	23.2	30.6	30.4	43.8	37.6	60.3	44.8	81.2
1.8	2.0	9.0	9.9	16.2	19.4	23.4	30.9	30.6	44.2	37.8	60.8	45.0	81.8
2.0	2.2	9.2	10.1	16.4	19.6	23.6	31.3	30.8	44.6	38.0	61.3	45.2	82.5
2.2	2.4	9.4	10.4	16.6	19.9	23.8	31.6	31.0	45.0	38.2	61.8	45.4	83.2
2.4	2.6	9.6	10.6	16.8	20.2	24.0	31.9	31.2	45.4	38.4	62.4	45.6	83.1
2.6	2.9	9.8	10.8	17.0	20.5	24.2	32.3	31.4	45.8	38.6	62.9	45.8	84.5
2.8	3.1	10.0	11.1	17.2	20.8	24.4	32.7	31.6	46.2	38.8	63.5	46.0	85.2
3.0	3.3	10.2	11.4	17.4	21.1	24.6	33.0	31.8	46.7	39.0	64.0	46.2	85.9
3.2	3.5	10.4	11.6	17.6	21.4	24.8	33.4	32.0	47.1	39.2	64.5	46.4	86.6
3.4	3.7	10.6	11.9	17.8	21.7	25.0	33.7	32.2	47.5	39.4	65.0	46.6	87.3
3.6	4.0	10.8	12.1	18.0	22.0	25.2	34.1	32.4	48.0	39.6	65.6	46.8	88.0
3.8	4.2	11.0	12.4	18.2	22.3	25.4	34.5	32.6	48.4	39.8	66.1	47.0	88.7
4.0	4.4	11.2	12.7	18.4	22.6	25.6	34.9	32.8	48.8	40.0	66.7	47.2	89.4
4.2	4.6	11.4	12.9	18.6	23.0	25.8	35.4	33.0	49.3	40.2	67.2	47.4	90.2
4.4	4.8	11.6	13.2	18.8	23.2	26.0	35.7	33.2	49.7	40.4	67.8	47.6	90.8
4.6	5.1	11.8	13.4	19.0	23.5	26.2	35.9	33.4	50.2	40.6	68.4	47.8	91.6
4.8	5.3	12.0	13.7	19.2	23.8	26.4	36.3	33.6	50.6	40.8	68.9	48.0	92.3
5.0	5.5	12.2	13.9	19.4	24.1	26.6	36.6	33.8	51.1	41.0	69.5	48.2	93.1
5.2	5.7	12.4	14.2	19.6	24.4	26.8	37.0	34.0	51.6	41.2	70.1	48.4	93.8
5.4	5.9	12.6	14.4	19.8	24.8	27.0	37.4	34.2	52.0	41.4	70.7	48.6	94.6
5.6	6.2	12.8	14.7	20.0	25.1	27.2	37.8	34.4	52.5	41.6	71.3	48.8	95.3
5.8	6.4	13.0	15.0	20.2				34.6	52.9	41.8	71.9	49.0	96.1
6.0	6.6	13.2	15.3 ◄	20.4				34.8	53.4	42.0	72.5	49.2	96.9
6.2	6.8	13.4	15.5	20.6				35.0	53.9	42.2	73.0	49.4	97.6
6.4	7.0	13.6	15.8	20.8	26.3	28.0	39.3	35.2	54.4	42.4	73.6	49.6	98.4
6.6	7.3	13.8	16.1	21.0	26.6	28.2	39.7	35.4	54.8	42.6	74.2	49.8	99.2
6.8	7.5	14.0	16.4	21.2	26.9	28.4	40.1	35.6	55.3	42.8	74.8	50.0	----
7.0	7.7	14.2	16.6	21.4	27.3	28.6	40.5	35.8	55.8	43.0	75.5		
7.2	7.9	14.4	16.9	21.6	27.6	28.8	40.9	36.0	56.3	43.2	76.1		
7.4	8.1	14.6	17.1	21.8	28.0	29.0	41.3	36.2	56.8	43.4	76.7		
7.6	8.4	14.8	17.4	22.0	28.3	29.2	41.5	36.4	57.2	43.6	77.3		
7.8	8.6	15.0	17.7	22.2	28.6	29.4	41.7	36.6	57.5	43.8	78.0		
8.0	8.8	15.2	18.0	22.4	28.9	29.6	42.1	36.8	58.3	44.0	78.6		

Speedy Reading for Proctor

Dial Reading = 13.2
Moisture Content = 15.3%



Curve	Max. Dry Weight	Optimum Moisture
	lb/ft³	%
A	141.8	6.1
B	139.1	6.7
C	136.3	7.4
D	134.1	8.0
E	132.0	8.5
F	129.3	9.2
G	126.6	10.0
H	124.2	10.7
I	121.7	11.4
J	119.3	12.2
K	117.0	13.0
L	114.6	14.1
M	112.0	15.2
N	109.6	16.4
O	107.1	17.6
P	104.7	19.2
Q	102.4	20.3
R	99.9	21.5
S	97.4	22.7
T	94.6	24.4
U	92.1	25.8
V	89.9	27.4
W	87.5	29.5
X	85.0	30.5
Y	83.0	31.5
Z	81.1	32.5

CHAPTER 5 – ANSWERS TO STUDY QUESTIONS (CONT.)

Chapter 5 – Practice Problem Number 2
Establishing Target Densities (One-Point Proctor)

A. Complete the one-point proctor form (Form TL-125A) on soil using the information provided.

Date: Today's Date
Compacted Depth of Lift: 6"

Weight of Mold + Weight of Soil = 13.56 lbs.
Weight of Mold = 9.51 lbs.
Speedy Dial Reading = 16.0

B. Answer the following questions.

a) What is the maximum dry density? <u>102.4 lb/ft^3</u>

b) What is the optimum moisture and optimum moisture range? <u>20.3% (Range = 16.2% to 24.4%)</u>

20.3 x 0.20 = 4.06
20.3 – 4.06 = 16.2
20.3 + 4.06 = 24.4

c) A nuclear density test determines the dry density to be 96.2 lb/ft^3 with a moisture content of 15.8%. Does this test pass? <u>No, it does not meet density and moisture requirements.</u>

1) (96.2 ÷ 102.4) x 100 = 93.9% (which is less than the minimum required density of 95.0%)
2) Moisture content of 15.8% does not fall within the optimum moisture range of 16.2% to 24.4%

Form TL-125A (Rev. 07/15)

CHAPTER 5 – ANSWERS TO STUDY QUESTIONS (CONT.)
PRACTICE PROBLEM #2

Route No. 635 **County** Amherst

Project No. 0635-005-187, C501 **Inspector** ________

FHWA No. FH-151(102)

Field Test No.		1	2	3
Date of Test				
Location of Test	Station Number – ft. (m)	87+50		
	Reference to Center Line – ft. (m)	10’ Rt. C/L		
Reference Elevation	Original Ground – ft. (m)	+20 ft.		
	Finished Grade – ft. (m)	-23 ft.		
Type of Roller		Sheepsfoot		
A. Weight (mass) of mold and wet soil – lb. (kg)		13.56		
B. Weight (mass) of mold – lb. (kg)		9.51		
C. Weight (mass) of wet soil (A - B) – lb. (kg)		4.05		
D. Wet density of soil (Line C x 30 lb/ft^3) or (Line C x 1060 kg/m^3)		121.5		
E. “Speedy” Dial Reading		16.0		
F. Moisture Content (%) from Speedy Chart		19.1		
G. Maximum Dry Density – lb/ft^3 (kg/m^3)		102.4		
H. Optimum Moisture (%)		20.3		
I. Field Density – lb/ft^3 (kg/m^3) from TL-125				
J. No. 4 (+4.75 mm) material from field density hole				
K. Corrected Maximum Density – lb/ft^3 (kg/m^3)				
L. Compaction (%)				

Comments:

BY: ________

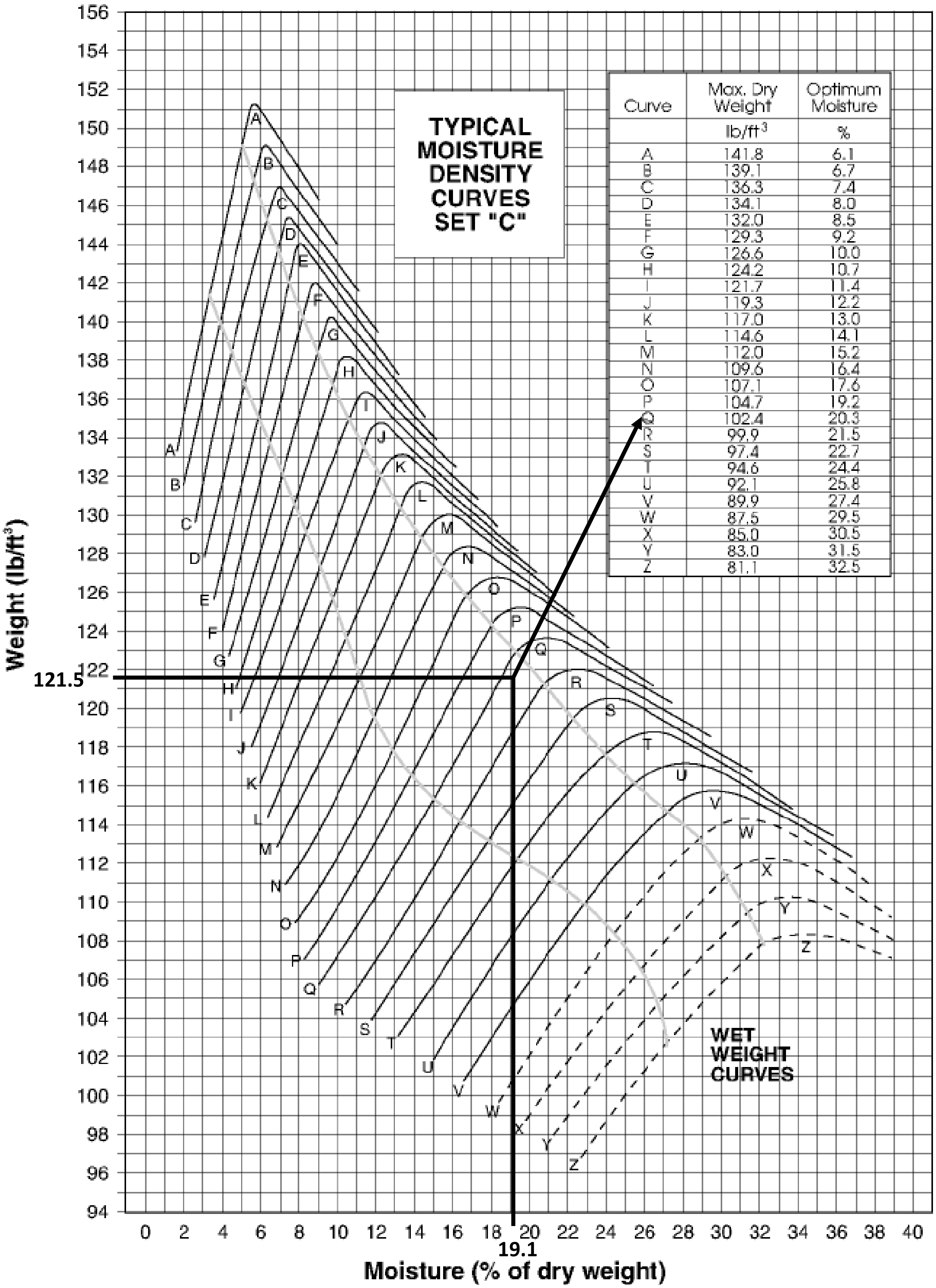
TITLE: ________

SPEEDY MOISTURE CHART

SPEEDY MOIST.		SPEEDY MOIST.		SPEEDY MOIST.		SPEEDY MOIST.		SPEEDY MOIST.		SPEEDY MOIST.		SPEEDY MOIST.	
READ.	CONT.	READ.	CONT.	READ.	CONT.	READ.	CONT.	READ.	CONT.	READ.	CONT.	READ.	CONT.
1.0	1.0	8.2	9.0	15.4	18.3	22.6	29.2	29.8	42.5	37.0	58.8	44.2	79.2
1.2	1.3	8.4	9.2	15.6	18.5	22.8	29.6	30.0	42.9	37.2	59.3	44.4	79.9
1.4	1.5	8.6	9.5	15.8	18.8	23.0				37.4	59.8	44.6	80.5
1.6	1.8	8.8	9.7	16.0	19.1	23.2				37.6	60.3	44.8	81.2
1.8	2.0	9.0	9.9	16.2	19.4	23.4				37.8	60.8	45.0	81.8
2.0	2.2	9.2	10.1	16.4	19.6	23.6	31.3	30.8	44.6	38.0	61.3	45.2	82.5
2.2	2.4	9.4	10.4	16.6	19.9	23.8	31.6	31.0	45.0	38.2	61.8	45.4	83.2
2.4	2.6	9.6	10.6	16.8	20.2	24.0	31.9	31.2	45.4	38.4	62.4	45.6	83.1
2.6	2.9	9.8	10.8	17.0	20.5	24.2	32.3	31.4	45.8	38.6	62.9	45.8	84.5
2.8	3.1	10.0	11.1	17.2	20.8	24.4	32.7	31.6	46.2	38.8	63.5	46.0	85.2
3.0	3.3	10.2	11.4	17.4	21.1	24.6	33.0	31.8	46.7	39.0	64.0	46.2	85.9
3.2	3.5	10.4	11.6	17.6	21.4	24.8	33.4	32.0	47.1	39.2	64.5	46.4	86.6
3.4	3.7	10.6	11.9	17.8	21.7	25.0	33.7	32.2	47.5	39.4	65.0	46.6	87.3
3.6	4.0	10.8	12.1	18.0	22.0	25.2	34.1	32.4	48.0	39.6	65.6	46.8	88.0
3.8	4.2	11.0	12.4	18.2	22.3	25.4	34.5	32.6	48.4	39.8	66.1	47.0	88.7
4.0	4.4	11.2	12.7	18.4	22.6	25.6	34.9	32.8	48.8	40.0	66.7	47.2	89.4
4.2	4.6	11.4	12.9	18.6	23.0	25.8	35.4	33.0	49.3	40.2	67.2	47.4	90.2
4.4	4.8	11.6	13.2	18.8	23.2	26.0	35.7	33.2	49.7	40.4	67.8	47.6	90.8
4.6	5.1	11.8	13.4	19.0	23.5	26.2	35.9	33.4	50.2	40.6	68.4	47.8	91.6
4.8	5.3	12.0	13.7	19.2	23.8	26.4	36.3	33.6	50.6	40.8	68.9	48.0	92.3
5.0	5.5	12.2	13.9	19.4	24.1	26.6	36.6	33.8	51.1	41.0	69.5	48.2	93.1
5.2	5.7	12.4	14.2	19.6	24.4	26.8	37.0	34.0	51.6	41.2	70.1	48.4	93.8
5.4	5.9	12.6	14.4	19.8	24.8	27.0	37.4	34.2	52.0	41.4	70.7	48.6	94.6
5.6	6.2	12.8	14.7	20.0	25.1	27.2	37.8	34.4	52.5	41.6	71.3	48.8	95.3
5.8	6.4	13.0	15.0	20.2	25.4	27.4	38.2	34.6	52.9	41.8	71.9	49.0	96.1
6.0	6.6	13.2	15.3	20.4	25.7	27.6	38.5	34.8	53.4	42.0	72.5	49.2	96.9
6.2	6.8	13.4	15.5	20.6	26.0	27.8	38.9	35.0	53.9	42.2	73.0	49.4	97.6
6.4	7.0	13.6	15.8	20.8	26.3	28.0	39.3	35.2	54.4	42.4	73.6	49.6	98.4
6.6	7.3	13.8	16.1	21.0	26.6	28.2	39.7	35.4	54.8	42.6	74.2	49.8	99.2
6.8	7.5	14.0	16.4	21.2	26.9	28.4	40.1	35.6	55.3	42.8	74.8	50.0	----
7.0	7.7	14.2	16.6	21.4	27.3	28.6	40.5	35.8	55.8	43.0	75.5		
7.2	7.9	14.4	16.9	21.6	27.6	28.8	40.9	36.0	56.3	43.2	76.1		
7.4	8.1	14.6	17.1	21.8	28.0	29.0	41.3	36.2	56.8	43.4	76.7		
7.6	8.4	14.8	17.4	22.0	28.3	29.2	41.5	36.4	57.2	43.6	77.3		
7.8	8.6	15.0	17.7	22.2	28.6	29.4	41.7	36.6	57.5	43.8	78.0		
8.0	8.8	15.2	18.0	22.4	28.9	29.6	42.1	36.8	58.3	44.0	78.6		

Speedy Reading for Proctor

Dial Reading = 16.0
Moisture Content = 19.1%



Curve	Max. Dry Weight lb/ft³	Optimum Moisture %
A	141.8	6.1
B	139.1	6.7
C	136.3	7.4
D	134.1	8.0
E	132.0	8.5
F	129.3	9.2
G	126.6	10.0
H	124.2	10.7
I	121.7	11.4
J	119.3	12.2
K	117.0	13.0
L	114.6	14.1
M	112.0	15.2
N	109.6	16.4
O	107.1	17.6
P	104.7	19.2
Q	102.4	20.3
R	99.9	21.5
S	97.4	22.7
T	94.6	24.4
U	92.1	25.8
V	89.9	27.4
W	87.5	29.5
X	85.0	30.5
Y	83.0	31.5
Z	81.1	32.5

CHAPTER 5 – ANSWERS TO STUDY QUESTIONS (CONT.)

Chapter 5 – Practice Problem Number 3
Establishing Target Densities (One-Point Proctor)

A. Complete the one-point proctor form (Form TL-125A) on soil using the information provided.

Date: Today's Date
Compacted Depth of Lift: 6"

Weight of Mold + Weight of Soil = 8.43 lbs.
Weight of Mold = 4.40 lbs.
Speedy Dial Reading = 14.0

B. Answer the following questions.

a) What is the maximum dry density? 104.7 lb/ft^3

b) What is the optimum moisture and optimum moisture range? 19.2% (Range = 15.4% to 23.0%)

19.2 x 0.20 = 3.84
19.2 – 3.84 = 15.4
19.2 + 3.84 = 23.0

Form TL-125A (Rev. 07/15)

CHAPTER 5 – ANSWERS TO STUDY QUESTIONS (CONT.)
PRACTICE PROBLEM #3

Route No. 615 **County** Campbell

Project No. 0615-015-186, C501 **Inspector**

FHWA No. FH-132(104)

Field Test No.		1	2	3
Date of Test				
Location of Test	Station Number – ft. (m)	87+40		
	Reference to Center Line – ft. (m)	10’ Rt. C/L		
Reference Elevation	Original Ground – ft. (m)	+13 ft.		
	Finished Grade – ft. (m)	-7 ft.		
Type of Roller		Sheepsfoot		
A. Weight (mass) of mold and wet soil – lb. (kg)		8.43		
B. Weight (mass) of mold – lb. (kg)		4.40		
C. Weight (mass) of wet soil (A - B) – lb. (kg)		4.03		
D. Wet density of soil (Line C x 30 lb/ft^3) or (Line C x 1060 kg/m^3)		120.9		
E. “Speedy” Dial Reading		14.0		
F. Moisture Content (%) from Speedy Chart		16.4		
G. Maximum Dry Density – lb/ft^3 (kg/m^3)		104.7		
H. Optimum Moisture (%)		19.2		
I. Field Density – lb/ft^3 (kg/m^3) from TL-125				
J. No. 4 (+4.75 mm) material from field density hole				
K. Corrected Maximum Density – lb/ft^3 (kg/m^3)				
L. Compaction (%)				

Comments:

BY:

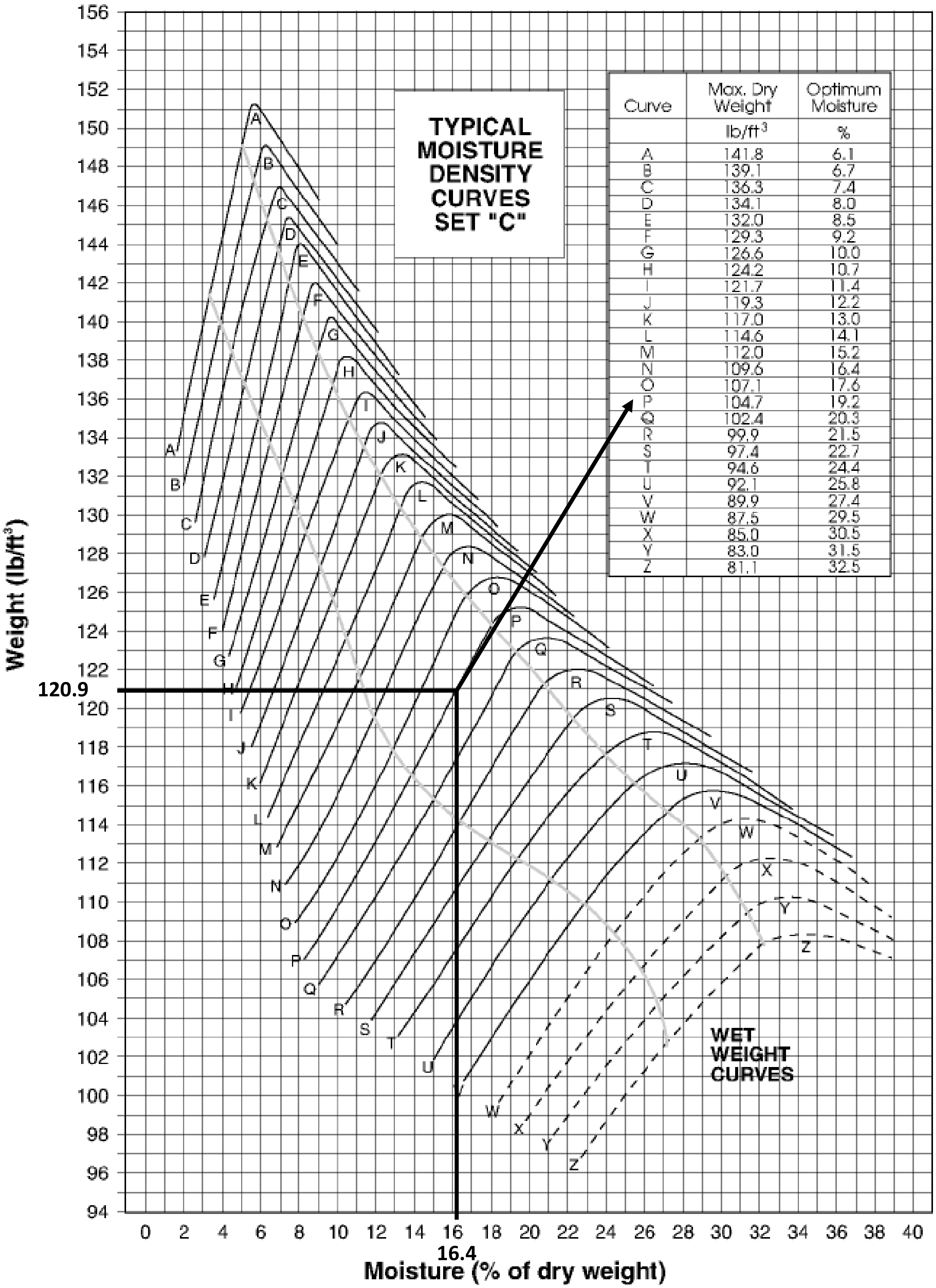
TITLE:

SPEEDY MOISTURE CHART

SPEEDY MOIST.		SPEEDY MOIST.		SPEEDY MOIST.		SPEEDY MOIST.		SPEEDY MOIST.		SPEEDY MOIST.		SPEEDY MOIST.	
READ.	CONT.	READ.	CONT.	READ.	CONT.	READ.	CONT.	READ.	CONT.	READ.	CONT.	READ.	CONT.
1.0	1.0	8.2	9.0	15.4	18.3	22.6	29.2	29.8	42.5	37.0	58.8	44.2	79.2
1.2	1.3	8.4	9.2	15.6	18.5	22.8	29.6	30.0	42.9	37.2	59.3	44.4	79.9
1.4	1.5	8.6	9.5	15.8	18.8	23.0	30.2	30.2	43.3	37.4	59.8	44.6	80.5
1.6	1.8	8.8	9.7	16.0	19.1	23.2	30.6	30.4	43.8	37.6	60.3	44.8	81.2
1.8	2.0	9.0	9.9	16.2	19.4	23.4	30.9	30.6	44.2	37.8	60.8	45.0	81.8
2.0	2.2	9.2	10.1	16.4	19.6	23.6	31.3	30.8	44.6	38.0	61.3	45.2	82.5
2.2	2.4	9.4	10.4	16.6	19.9	23.8	31.6	31.0	45.0	38.2	61.8	45.4	83.2
2.4	2.6	9.6	10.6	16.8	20.2	24.0	31.9	31.2	45.4	38.4	62.4	45.6	83.1
2.6	2.9	9.8	10.8	17.0	20.5	24.2	32.3	31.4	45.8	38.6	62.9	45.8	84.5
2.8	3.1	10.0	11.1	17.2	20.8	24.4	32.7	31.6	46.2	38.8	63.5	46.0	85.2
3.0	3.3	10.2	11.4	17.4	21.1	24.6	33.0	31.8	46.7	39.0	64.0	46.2	85.9
3.2	3.5	10.4	11.6	17.6	21.4	24.8	33.4	32.0	47.1	39.2	64.5	46.4	86.6
3.4	3.7	10.6	11.9	17.8	21.7	25.0	33.7	32.2	47.5	39.4	65.0	46.6	87.3
3.6	4.0	10.8	12.1	18.0	22.0	25.2	34.1	32.4	48.0	39.6	65.6	46.8	88.0
3.8	4.2	11.0	12.4	18.2	22.3	25.4	34.5	32.6	48.4	39.8	66.1	47.0	88.7
4.0	4.4	11.2	12.7	18.4	22.6	25.6	34.9	32.8	48.8	40.0	66.7	47.2	89.4
4.2	4.6	11.4	12.9	18.6	23.0	25.8	35.4	33.0	49.3	40.2	67.2	47.4	90.2
4.4	4.8	11.6	13.2	18.8	23.2	26.0	35.7	33.2	49.7	40.4	67.8	47.6	90.8
4.6	5.1	11.8	13.4	19.0	23.5	26.2	35.9	33.4	50.2	40.6	68.4	47.8	91.6
4.8	5.3	12.0	13.7	19.2	23.8	26.4	36.3	33.6	50.6	40.8	68.9	48.0	92.3
5.0	5.5	12.2	13.9	19.4	24.1	26.6	36.6	33.8	51.1	41.0	69.5	48.2	93.1
5.2	5.7	12.4	14.2	19.6	24.4	26.8	37.0	34.0	51.6	41.2	70.1	48.4	93.8
5.4	5.9	12.6	14.4	19.8	24.8	27.0	37.4	34.2	52.0	41.4	70.7	48.6	94.6
5.6	6.2	12.8	14.7	20.0	25.1	27.2	37.8	34.4	52.5	41.6	71.3	48.8	95.3
5.8	6.4	13.0	15.0	20.2	25.4	27.4	38.2	34.6	52.9	41.8	71.9	49.0	96.1
6.0	6.6	13.2	15.3	20.4	25.7	27.6	38.5	34.8	53.4	42.0	72.5	49.2	96.9
6.2	6.8	13.4	15.5	20.6	26.0	27.8	38.9	35.0	53.9	42.2	73.0	49.4	97.6
6.4	7.0	13.6	15.8	20.8	26.3	28.0	39.3	35.2	54.4	42.4	73.6	49.6	98.4
6.6	7.3	13.8	16.1	21.0				35.4	54.8	42.6	74.2	49.8	99.2
6.8	7.5	14.0	16.4	21.2				35.6	55.3	42.8	74.8	50.0	----
7.0	7.7	14.2	16.6	21.4				35.8	55.8	43.0	75.5		
7.2	7.9	14.4	16.9	21.6	27.6	28.8	40.9	36.0	56.3	43.2	76.1		
7.4	8.1	14.6	17.1	21.8	28.0	29.0	41.3	36.2	56.8	43.4	76.7		
7.6	8.4	14.8	17.4	22.0	28.3	29.2	41.5	36.4	57.2	43.6	77.3		
7.8	8.6	15.0	17.7	22.2	28.6	29.4	41.7	36.6	57.5	43.8	78.0		
8.0	8.8	15.2	18.0	22.4	28.9	29.6	42.1	36.8	58.3	44.0	78.6		

Speedy Reading for Proctor

Dial Reading = 14.0
Moisture Content = 16.4%



Curve	Max. Dry Weight	Optimum Moisture
	lb/ft^3	%
A	141.8	6.1
B	139.1	6.7
C	136.3	7.4
D	134.1	8.0
E	132.0	8.5
F	129.3	9.2
G	126.6	10.0
H	124.2	10.7
I	121.7	11.4
J	119.3	12.2
K	117.0	13.0
L	114.6	14.1
M	112.0	15.2
N	109.6	16.4
O	107.1	17.6
P	104.7	19.2
Q	102.4	20.3
R	99.9	21.5
S	97.4	22.7
T	94.6	24.4
U	92.1	25.8
V	89.9	27.4
W	87.5	29.5
X	85.0	30.5
Y	83.0	31.5
Z	81.1	32.5

CHAPTER 5 – ANSWERS TO STUDY QUESTIONS (CONT.)

Chapter 5 – Practice Problem Number 4
Establishing Target Densities (One-Point Proctor)

A. Complete the one-point proctor form (Form TL-125A) on soil using the information provided.

Date: Today's Date
Compacted Depth of Lift: 6"

Weight of Mold + Weight of Soil = 13.56 lbs.
Weight of Mold = 9.51 lbs.
Speedy Dial Reading = 16.2

B. Answer the following questions.

a) What is the maximum dry density? 102.4 lb/ft^3

b) What is the optimum moisture and optimum moisture range? 20.3% (Range = 16.2% to 24.4%)

20.3 x 0.20 = 4.06
20.3 – 4.06 = 16.2
20.3 + 4.06 = 24.4

Form TL-125A (Rev. 07/15)

CHAPTER 5 – ANSWERS TO STUDY QUESTIONS (CONT.)
PRACTICE PROBLEM #4

Route No. 632 **County** Amherst

Project No. 0632-005-184, C501 **Inspector** ______

FHWA No. FH-130(101)

Field Test No.		7		
Date of Test				
Location of Test	Station Number – ft. (m)	120+40		
	Reference to Center Line – ft. (m)	13’ Rt. C/L		
Reference Elevation	Original Ground – ft. (m)	+16 ft.		
	Finished Grade – ft. (m)	-7 ft.		
Type of Roller		Sheepsfoot		
A. Weight (mass) of mold and wet soil – lb. (kg)		13.56		
B. Weight (mass) of mold – lb. (kg)		9.51		
C. Weight (mass) of wet soil (A - B) – lb. (kg)		4.05		
D. Wet density of soil (Line C x 30 lb/ft^3) or (Line C x 1060 kg/m^3)		121.5		
E. “Speedy” Dial Reading		16.2		
F. Moisture Content (%) from Speedy Chart		19.4		
G. Maximum Dry Density – lb/ft^3 (kg/m^3)		102.4		
H. Optimum Moisture (%)		20.3		
I. Field Density – lb/ft^3 (kg/m^3) from TL-125				
J. No. 4 (+4.75 mm) material from field density hole				
K. Corrected Maximum Density – lb/ft^3 (kg/m^3)				
L. Compaction (%)				

Comments:

BY: ______

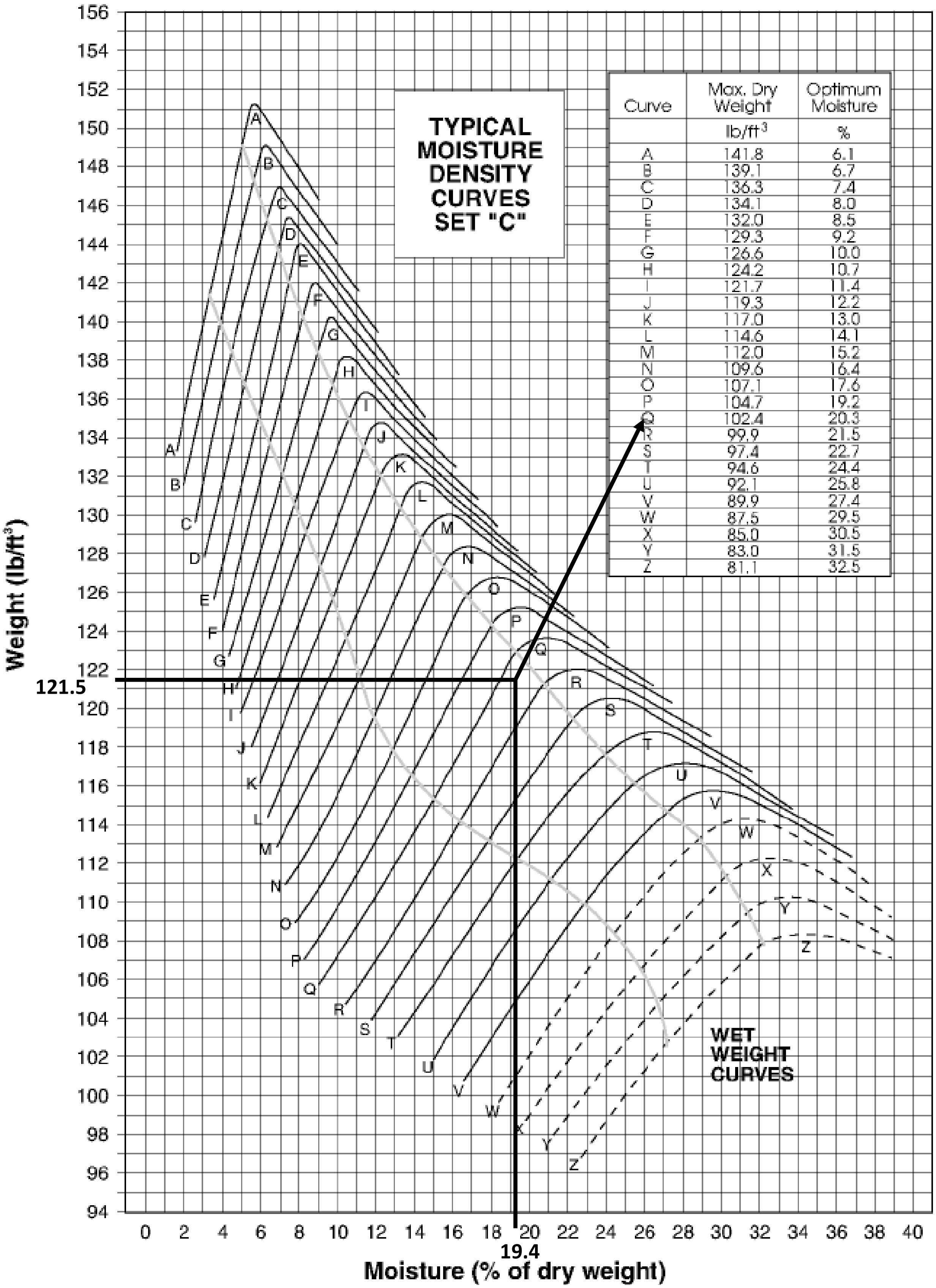
TITLE: ______

SPEEDY MOISTURE CHART

SPEEDY MOIST.		SPEEDY MOIST.		SPEEDY MOIST.		SPEEDY MOIST.		SPEEDY MOIST.		SPEEDY MOIST.		SPEEDY MOIST.	
READ.	CONT.	READ.	CONT.	READ.	CONT.	READ.	CONT.	READ.	CONT.	READ.	CONT.	READ.	CONT.
1.0	1.0	8.2	9.0	15.4	18.3	22.6	29.2	29.8	42.5	37.0	58.8	44.2	79.2
1.2	1.3	8.4	9.2	15.6	18.5	22.8	29.6	30.0	42.9	37.2	59.3	44.4	79.9
1.4	1.5	8.6	9.5	15.8	18.8	23.0	30.2	30.2	43.3	37.4	59.8	44.6	80.5
1.6	1.8	8.8	9.7	16.0	19.1	23.2				37.6	60.3	44.8	81.2
1.8	2.0	9.0	9.9	16.2	19.4	23.4				37.8	60.8	45.0	81.8
2.0	2.2	9.2	10.1	16.4	19.6	23.6				38.0	61.3	45.2	82.5
2.2	2.4	9.4	10.4	16.6	19.9	23.8	31.6	31.0	45.0	38.2	61.8	45.4	83.2
2.4	2.6	9.6	10.6	16.8	20.2	24.0	31.9	31.2	45.4	38.4	62.4	45.6	83.1
2.6	2.9	9.8	10.8	17.0	20.5	24.2	32.3	31.4	45.8	38.6	62.9	45.8	84.5
2.8	3.1	10.0	11.1	17.2	20.8	24.4	32.7	31.6	46.2	38.8	63.5	46.0	85.2
3.0	3.3	10.2	11.4	17.4	21.1	24.6	33.0	31.8	46.7	39.0	64.0	46.2	85.9
3.2	3.5	10.4	11.6	17.6	21.4	24.8	33.4	32.0	47.1	39.2	64.5	46.4	86.6
3.4	3.7	10.6	11.9	17.8	21.7	25.0	33.7	32.2	47.5	39.4	65.0	46.6	87.3
3.6	4.0	10.8	12.1	18.0	22.0	25.2	34.1	32.4	48.0	39.6	65.6	46.8	88.0
3.8	4.2	11.0	12.4	18.2	22.3	25.4	34.5	32.6	48.4	39.8	66.1	47.0	88.7
4.0	4.4	11.2	12.7	18.4	22.6	25.6	34.9	32.8	48.8	40.0	66.7	47.2	89.4
4.2	4.6	11.4	12.9	18.6	23.0	25.8	35.4	33.0	49.3	40.2	67.2	47.4	90.2
4.4	4.8	11.6	13.2	18.8	23.2	26.0	35.7	33.2	49.7	40.4	67.8	47.6	90.8
4.6	5.1	11.8	13.4	19.0	23.5	26.2	35.9	33.4	50.2	40.6	68.4	47.8	91.6
4.8	5.3	12.0	13.7	19.2	23.8	26.4	36.3	33.6	50.6	40.8	68.9	48.0	92.3
5.0	5.5	12.2	13.9	19.4	24.1	26.6	36.6	33.8	51.1	41.0	69.5	48.2	93.1
5.2	5.7	12.4	14.2	19.6	24.4	26.8	37.0	34.0	51.6	41.2	70.1	48.4	93.8
5.4	5.9	12.6	14.4	19.8	24.8	27.0	37.4	34.2	52.0	41.4	70.7	48.6	94.6
5.6	6.2	12.8	14.7	20.0	25.1	27.2	37.8	34.4	52.5	41.6	71.3	48.8	95.3
5.8	6.4	13.0	15.0	20.2	25.4	27.4	38.2	34.6	52.9	41.8	71.9	49.0	96.1
6.0	6.6	13.2	15.3	20.4	25.7	27.6	38.5	34.8	53.4	42.0	72.5	49.2	96.9
6.2	6.8	13.4	15.5	20.6	26.0	27.8	38.9	35.0	53.9	42.2	73.0	49.4	97.6
6.4	7.0	13.6	15.8	20.8	26.3	28.0	39.3	35.2	54.4	42.4	73.6	49.6	98.4
6.6	7.3	13.8	16.1	21.0	26.6	28.2	39.7	35.4	54.8	42.6	74.2	49.8	99.2
6.8	7.5	14.0	16.4	21.2	26.9	28.4	40.1	35.6	55.3	42.8	74.8	50.0	----
7.0	7.7	14.2	16.6	21.4	27.3	28.6	40.5	35.8	55.8	43.0	75.5		
7.2	7.9	14.4	16.9	21.6	27.6	28.8	40.9	36.0	56.3	43.2	76.1		
7.4	8.1	14.6	17.1	21.8	28.0	29.0	41.3	36.2	56.8	43.4	76.7		
7.6	8.4	14.8	17.4	22.0	28.3	29.2	41.5	36.4	57.2	43.6	77.3		
7.8	8.6	15.0	17.7	22.2	28.6	29.4	41.7	36.6	57.5	43.8	78.0		
8.0	8.8	15.2	18.0	22.4	28.9	29.6	42.1	36.8	58.3	44.0	78.6		

Speedy Reading for Proctor

Dial Reading = 16.2
Moisture Content = 19.4%



Curve	Max. Dry Weight	Optimum Moisture
	lb/ft³	%
A	141.8	6.1
B	139.1	6.7
C	136.3	7.4
D	134.1	8.0
E	132.0	8.5
F	129.3	9.2
G	126.6	10.0
H	124.2	10.7
I	121.7	11.4
J	119.3	12.2
K	117.0	13.0
L	114.6	14.1
M	112.0	15.2
N	109.6	16.4
O	107.1	17.6
P	104.7	19.2
Q	102.4	20.3
R	99.9	21.5
S	97.4	22.7
T	94.6	24.4
U	92.1	25.8
V	89.9	27.4
W	87.5	29.5
X	85.0	30.5
Y	83.0	31.5
Z	81.1	32.5

CHAPTER 6 – ANSWERS TO STUDY QUESTIONS

1) Batteries should be charged when the battery indicator light comes on.

2) True or False. The nuclear gauge should be warmed-up first thing in the morning before using it. True.

3) True or False. The only maintenance performed in the field is cleaning the nuclear gauge and charging the batteries. True.

4) When taking a standard count, the nuclear gauge should be a minimum of 10 ft. from any structure and 33 ft. from any other radioactive source.

5) True or False. Cesium-137 is located in the tip of the stainless steel rod which is used in taking moisture determinations and Americium-241:Beryllium is located inside the nuclear gauge and is used for density testing. False – Cesium-137 is located in the tip of the stainless steel rod and is used for density determinations and the Americium-241:Beryllium is located inside the gauge and is used for moisture determinations.

6) When taking Standard Counts the Reference Standard should be placed on what type of surface? Smooth, flat, and dry surface with a minimum density of 100 lb/ft^3.

7) Three ways to limit exposure to radiation are time, distance, and shielding.

8) If the soil material fails a nuclear test because of excessive moisture, the first step taken is to run another test, while checking test methods to ensure they are correct.

9) A testing method for testing densities whereby the source rod is inserted into the material to be tested at a depth of 4, 6, or 8 inches is direct transmission method.

10) If, during construction, the density results either change suddenly, or simply don't make sense, you should check your math and the test itself, including test procedures to ensure that the test was run properly.

11) If the moisture results from the nuclear test appear high, the "Speedy" Moisture Test could be used to check the moisture.

12) When a nuclear gauge is operated within 24" of a vertical structure, the moisture and density readings are influenced by the structure.

Form TL-124 (Rev. 07/15)

CHAPTER 6 – ANSWERS TO STUDY QUESTIONS (CONT.)

REPORT ON NUCLEAR EMBANKMENT DENSITIES (UNIT MASSES)

Report No. 45 **Date** 06/22/2015 **Sheet No.** 1 **of** 1
Route No. 252 **County** Augusta
Project No. 0252-132-101, C501
FHWA No. None
Testing for Embankment
Model No. 3440 **Serial No.** 23456 **Calibration Date** 02/10/2015

STANDARD COUNT DATA

Density 2844 **Moisture** 701

Test No.			**1**	**2**	**3**	**4**
Location	Station ft. (m)		305+00	305+60	306+20	
of	Ref. to center line ft. (m)		at. C/L	10’ Lt.	7’ Lt.	
Test	Elevation		+10 / -7	+3 / -10	+3 / -3	
Compaction Depth of Lift in. (mm)			6”	6”	6”	
Method of Compaction			Sheepsfoot	Sheepsfoot	Sheepsfoot	
A. Wet Density (lbs/ft^3), Wet Unit Mass (kg/m^3)		=	133.3	123.6	128.2	
B. Moisture Unit Mass (lbs/ft^3 or kg/m^3)		=	19.1	17.9	18.6	
C. Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) (A-B)		=	114.2	105.7	109.6	
D. Moisture Content (B ÷ C) x 100		=	16.7	16.9	17.0	
E. Maximum Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) Lab Proctor or One Point Proctor		=	114.6	106.9	112.1	
F. Percent Optimum Moisture from Lab or One Point Proctor		=	14.1 11.3 – 16.9	17.6 14.1 – 21.1	15.2 12.2 – 18.2	
G. Percent of Plus #4, (plus 4.75 mm)		=				
H. Corrected Max. Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3)		=				
I. Corrected Optimum Moisture		=				
J. Percent Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) (C ÷ E) x 100 or (C ÷ H) x 100		=	99.7	98.9	97.8	
K. Percent Minimum Density Required		=	95.0	95.0	95.0	

Comments: All density test results are above the minimum 95% requirement, and all moisture test results are within the acceptable optimum moisture ranges

BY: ____________________

TITLE: ____________________

Form TL-124 (Rev. 07/15)

CHAPTER 6 – ANSWERS TO STUDY QUESTIONS (CONT.)

REPORT ON NUCLEAR EMBANKMENT DENSITIES (UNIT MASSES)

Report No. 1-17-1 **Date** 06/22/2015 **Sheet No.** 1 **of** 1
Route No. 17 **County** Campbell
Project No. 0017-015-104, C503
FHWA No. None
Testing for Embankment
Model No. 3440 **Serial No.** 23456 **Calibration Date** 02/10/2015

STANDARD COUNT DATA

Density 2830 **Moisture** 701

			1	2	3	4
Location		Station ft. (m)	85+00			
of		ter line ft. (m)	at. C/L			
Test		Elevation	+9 / -3			
Compaction Depth of			6”			
Method of Compaction			Sheepsfoot			
A. Wet Density		=	141.0	141.0		
B. Moisture Un		=	~~23.1~~	13.5		
C. Dry Density		=	~~117.9~~	127.5		
D. Moisture Co		=	~~19.6~~	10.6		
E. Maximum D n^3) Lab Proctor or One Point Proctor		=	132.4	132.4		
F. Percent Optimu r		=	9.2 7.4 – 11.0	9.2 7.4 – 11.0		
G. Percent of Plus		=				
H. Corrected Max. Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3)		=				
I. Corrected Optimum Mo		=				
J. Percent Dry Density (lbs (C ÷ E) x 100 or (C ÷ H)		=	~~89.0~~	96.3		
K. Percent Minimum Dens		=	95.0	95.0		

Step 3 - Adjust Moisture Mass

MM = WD - DD

MM = 141.0 – 127.5

MM = 13.5 lbs/ft^3

Step 2 – Adjust Dry Density

DD = WD ÷ (1 + M%)

DD = 141.0 ÷ (1 + 0.106)

DD = 127.5 lbs/ft^3

Step 1 – Conduct a Speedy Moisture Test to correct Moisture Content

Step 4 – Correct Percent Density

%PR = (DD ÷ Max. DD) x 100

%PR = (127.5 ÷ 132.4) x 100

%PR = 96.3%

Comments:

BY: ________________

TITLE: ________________

Form TL-124 (Rev. 07/15)

CHAPTER 7 – ANSWERS TO STUDY QUESTIONS
PRACTICE PROBLEM #1

Report No. 1-117-1 **Date** 06/22/2015 **Sheet No.** 1 **of** 1
Route No. 117 **County** Roanoke
Project No. 0117-080-105, C501
FHWA No. None
Testing for Embankment
Model No. 3440 **Serial No.** 23456 **Calibration Date** 02/10/2015

STANDARD COUNT DATA

Density 2844 **Moisture** 701

Test No.			**1**	**2**	**3**	**4**
Location	Station ft. (m)		90+45			
of	Ref. to center line ft. (m)		6’ Rt. C/L			
Test	Elevation		+8 / -6			
Compaction Depth of Lift in. (mm)			6”			
Method of Compaction			Sheepsfoot			
A. Wet Density (lbs/ft^3), Wet Unit Mass (kg/m^3)		=	127.4			
B. Moisture Unit Mass (lbs/ft^3 or kg/m^3)		=	12.6			
C. Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) (A-B)		=	114.8			
D. Moisture Content (B ÷ C) x 100		=	11.0			
E. Maximum Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) Lab Proctor or One Point Proctor		=	112.6			
F. Percent Optimum Moisture from Lab or One Point Proctor		=	14.5 11.6 – 17.4			
G. Percent of Plus #4, (plus 4.75 mm)		=	15.0			
H. Corrected Max. Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3)		=	118.1			
I. Corrected Optimum Moisture		=	12.8 10.2 – 15.4			
J. Percent Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) (C ÷ E) x 100 or (C ÷ H) x 100		=	97.2			
K. Percent Minimum Density Required		=	95.0			

Comments: Moisture content of 11.0% falls within the optimum moisture range of 10.2% to 15.4%
Density achieved 97.2% and minimum density required is 95.0%

BY: ____________________

TITLE: ____________________

CALCULATION #1

Amount of +4 Material in Total Soil

	Weight of Dry Soil + Dish	9.29	lb.	Weight of +4 Material + Dish	3.63	lb.
-	Weight of Dish Only	2.62	lb.	Weight of Dish Only	2.62	lb.
	Total Weight of Dry Soil	6.67	lb.	Total Weight of +4 Material	1.01	lb.

$$\frac{\text{Total Weight of +4 Material}}{\text{Total Weight of Dry Soil}} = \frac{\underline{1.01}}{\underline{6.67}} = \underline{0.151} \times 100 = \underline{15\%} \text{ (Enter on Line G)}$$

CALCULATION #2

Total Density of Soils with +4 Material

Needed Information:

P_c = Percent of +4 material expressed as a decimal = 0.15 (Taken from Sieve Analysis)

D_c = 2.63 Sp. Gr. of +4 Material x 62.4 lbs/ft^3 = 164.1 lbs/ft^3

P_f = Percent of -4 material expressed as a decimal = 0.85 (Taken from Sieve Analysis)

D_f = Maximum Dry Density of the -4 material = 112.6 (Taken from Proctor)

$$\frac{D_f \times D_c}{(P_c \times D_f) + (P_f \times D_c)} = \underbrace{\frac{\underline{112.6} \times \underline{164.1}}{(\underline{0.15} \times \underline{112.6}) + (\underline{0.85} \times \underline{164.1})}}_{\text{Step 1}} = \underbrace{\frac{\underline{18477.7}}{(\underline{16.9}) + (\underline{139.5})}}_{\text{Step 2}} = \underbrace{\frac{\underline{18477.7}}{\underline{156.4}}}_{\text{Step 3}} = \underline{118.1}$$

Maximum Dry Density of Total Soil = <u>118.1 lb/ft^3</u> (Enter on Line H)

CALCULATION #3

Optimum Moisture Content of Soils with +4 Material

Needed Information:

P_c = Percent of +4 material expressed as a decimal = 0.15 (Taken from Sieve Analysis)

W_c =Absorption of the +4 Material expressed as a decimal = 0.03 (Taken from Material Division)

P_f = Percent of -4 material expressed as a decimal = 0.85 (Taken from Sieve Analysis)

W_f = Optimum Moisture of the -4 material expressed as a decimal = 0.145 (Taken from Proctor)

$$(P_cW_c + P_fW_f) \times 100 = \underbrace{[(\underline{0.15} \times \underline{0.03}) + (\underline{0.85} \times \underline{0.145})] \times 100}_{\text{Step 1}} = \underbrace{[(\underline{0.005}) + (\underline{0.123})] \times 100}_{\text{Step 2}} = \underbrace{(\underline{0.128}) \times 100}_{\text{Step 3}} = \underline{12.8}$$

Optimum Moisture Content of Total Soil = <u>12.8%</u> (Enter on Line I)

Form TL-124 (Rev. 07/15)

CHAPTER 7 – ANSWERS TO STUDY QUESTIONS (CONT.)
PRACTICE PROBLEM #2

Report No. 1-117-1 **Date** 06/22/2015 **Sheet No.** 1 **of** 1

Route No. 117 **County** Roanoke

Project No. 0117-080-105, C501

FHWA No. None

Testing for Embankment

Model No. 3440 **Serial No.** 23456 **Calibration Date** 02/10/2015

STANDARD COUNT DATA

Density 2844 **Moisture** 701

Test No.			**1**	**2**	**3**	**4**
Location	Station ft. (m)		90+45			
of	Ref. to center line ft. (m)		6’ Rt. C/L			
Test	Elevation		+8 / -6			
Compaction Depth of Lift in. (mm)			6”			
Method of Compaction			Sheepsfoot			
A. Wet Density (lbs/ft³), Wet Unit Mass (kg/m³)		=	127.9			
B. Moisture Unit Mass (lbs/ft³ or kg/m³)		=	12.2			
C. Dry Density (lbs/ft³), Dry Unit Mass (kg/m³) (A-B)		=	115.7			
D. Moisture Content (B ÷ C) x 100		=	10.5			
E. Maximum Dry Density (lbs/ft³), Dry Unit Mass (kg/m³) Lab Proctor or One Point Proctor		=	110.5			
F. Percent Optimum Moisture from Lab or One Point Proctor		=	14.3 11.4 – 17.2			
G. Percent of Plus #4, (plus 4.75 mm)		=	15.0			
H. Corrected Max. Dry Density (lbs/ft³), Dry Unit Mass (kg/m³)		=	116.5			
I. Corrected Optimum Moisture		=	12.5 10.0 – 15.0			
J. Percent Dry Density (lbs/ft³), Dry Unit Mass (kg/m³) (C ÷ E) x 100 or (C ÷ H) x 100		=	99.3			
K. Percent Minimum Density Required		=	95.0			

Comments: Moisture content of 10.5% falls within the optimum moisture range of 10.0% to 15.0%
Density achieved 99.3% and minimum density required is 95.0%

BY: ______________________

TITLE: ______________________

CALCULATION #1

Amount of +4 Material in Total Soil

	Weight of Dry Soil + Dish	9.30	lb.	Weight of +4 Material + Dish	3.65	lb.
-	Weight of Dish Only	2.62	lb.	Weight of Dish Only	2.62	lb.
	Total Weight of Dry Soil	6.68	lb.	Total Weight of +4 Material	1.03	lb.

$$\frac{\text{Total Weight of +4 Material}}{\text{Total Weight of Dry Soil}} = \frac{\underline{1.03}}{\underline{6.68}} = \underline{0.154} \text{ x } 100 = \underline{15\%} \text{ (Enter on Line G)}$$

CALCULATION #2

Total Density of Soils with +4 Material

Needed Information:

P_c = Percent of +4 material expressed as a decimal = 0.15 (Taken from Sieve Analysis)

D_c = 2.70 Sp. Gr. of +4 Material x 62.4 lbs/ft^3 = 168.5 lbs/ft^3

P_f = Percent of -4 material expressed as a decimal = 0.85 (Taken from Sieve Analysis)

D_f = Maximum Dry Density of the -4 material = 110.5 (Taken from Proctor)

$$\frac{D_f \text{ x } D_c}{(P_c \text{ x } D_f) + (P_f \text{ x } D_c)} = \underset{\text{Step 1}}{\frac{\underline{110.5} \text{ x } \underline{168.5}}{(\underline{0.15} \text{ x } \underline{110.5}) + (\underline{0.85} \text{ x } \underline{168.5})}} = \underset{\text{Step 2}}{\frac{\underline{18619.3}}{(\underline{16.6}) + (\underline{143.2})}} = \underset{\text{Step 3}}{\frac{\underline{18619.3}}{\underline{159.8}}} = \underline{116.5}$$

Maximum Dry Density of Total Soil = <u>116.5 lb/ft^3</u> (Enter on Line H)

CALCULATION #3

Optimum Moisture Content of Soils with +4 Material

Needed Information:

P_c = Percent of +4 material expressed as a decimal = 0.15 (Taken from Sieve Analysis)

W_c =Absorption of the +4 Material expressed as a decimal = 0.02 (Taken from Material Division)

P_f = Percent of -4 material expressed as a decimal = 0.85 (Taken from Sieve Analysis)

W_f = Optimum Moisture of the -4 material expressed as a decimal = 0.143 (Taken from Proctor)

$$(P_cW_c + P_fW_f) \text{ x } 100 = \underset{\text{Step 1}}{[(\underline{0.15} \text{ x } \underline{0.02}) + (\underline{0.85} \text{ x } \underline{0.143})] \text{ x } 100} = \underset{\text{Step 2}}{[(\underline{0.003}) + (\underline{0.122})] \text{ x } 100} = \underset{\text{Step 3}}{(\underline{0.125}) \text{ x } 100} = \underline{12.5}$$

Optimum Moisture Content of Total Soil = <u>12.5%</u> (Enter on Line I)

Form TL-124 (Rev. 07/15)

CHAPTER 7 – ANSWERS TO STUDY QUESTIONS (CONT.)
PRACTICE PROBLEM #3

Report No. 1-117-1 **Date** 06/22/2015 **Sheet No.** 1 **of** 1
Route No. 117 **County** Roanoke
Project No. 0117-080-105, C501
FHWA No. None
Testing for Embankment
Model No. 3440 **Serial No.** 23456 **Calibration Date** 02/10/2015

STANDARD COUNT DATA

Density 2844 **Moisture** 701

Test No.			**1**	**2**	**3**	**4**
Location	Station ft. (m)		90+45			
of	Ref. to center line ft. (m)		6’ Rt. C/L			
Test	Elevation		+8 / -6			
Compaction Depth of Lift in. (mm)			6”			
Method of Compaction			Sheepsfoot			
A. Wet Density (lbs/ft³), Wet Unit Mass (kg/m³)		=	127.5			
B. Moisture Unit Mass (lbs/ft³ or kg/m³)		=	12.8			
C. Dry Density (lbs/ft³), Dry Unit Mass (kg/m³) (A-B)		=	114.7			
D. Moisture Content (B ÷ C) x 100		=	11.2			
E. Maximum Dry Density (lbs/ft³), Dry Unit Mass (kg/m³) Lab Proctor or One Point Proctor		=	109.9			
F. Percent Optimum Moisture from Lab or One Point Proctor		=	13.9 11.1 – 16.7			
G. Percent of Plus #4, (plus 4.75 mm)		=	13.0			
H. Corrected Max. Dry Density (lbs/ft³), Dry Unit Mass (kg/m³)		=	115.0			
I. Corrected Optimum Moisture		=	12.4 9.9 – 14.9			
J. Percent Dry Density (lbs/ft³), Dry Unit Mass (kg/m³) (C ÷ E) x 100 or (C ÷ H) x 100		=	99.7			
K. Percent Minimum Density Required		=	95.0			

Comments: Moisture content of 11.2% falls within the optimum moisture range of 9.9% to 14.9%
Density achieved 99.7% and minimum density required is 95.0%

BY: ____________________

TITLE: ____________________

CALCULATION #1

Amount of +4 Material in Total Soil

	Weight of Dry Soil + Dish	9.29	lb.	Weight of +4 Material + Dish	3.51	lb.
-	Weight of Dish Only	2.62	lb.	Weight of Dish Only	2.62	lb.
	Total Weight of Dry Soil	6.67	lb.	Total Weight of +4 Material	0.89	lb.

$$\frac{\text{Total Weight of +4 Material}}{\text{Total Weight of Dry Soil}} = \frac{\underline{0.89}}{\underline{6.67}} = \underline{0.133} \times 100 = \underline{13\%}\text{ (Enter on Line G)}$$

CALCULATION #2

Total Density of Soils with +4 Material

Needed Information:

P_c = Percent of +4 material expressed as a decimal = 0.13 (Taken from Sieve Analysis)

D_c = 2.68 Sp. Gr. of +4 Material x 62.4 lbs/ft^3 = 167.2 lbs/ft^3

P_f = Percent of -4 material expressed as a decimal = 0.87 (Taken from Sieve Analysis)

D_f = Maximum Dry Density of the -4 material = 109.9 (Taken from Proctor)

$$\frac{D_f \times D_c}{(P_c \times D_f) + (P_f \times D_c)} = \underset{\text{Step 1}}{\frac{\underline{109.9} \times \underline{167.2}}{(\underline{0.13} \times \underline{109.9}) + (\underline{0.87} \times \underline{167.2})}} = \underset{\text{Step 2}}{\frac{\underline{18375.3}}{(\underline{14.3}) + (\underline{145.5})}} = \underset{\text{Step 3}}{\frac{\underline{18375.3}}{\underline{159.8}}} = \underline{115.0}$$

Maximum Dry Density of Total Soil = $\underline{115.0\ \text{lb/ft}^3}$ (Enter on Line H)

CALCULATION #3

Optimum Moisture Content of Soils with +4 Material

Needed Information:

P_c = Percent of +4 material expressed as a decimal = 0.13 (Taken from Sieve Analysis)

W_c =Absorption of the +4 Material expressed as a decimal = 0.02 (Taken from Material Division)

P_f = Percent of -4 material expressed as a decimal = 0.87 (Taken from Sieve Analysis)

W_f = Optimum Moisture of the -4 material expressed as a decimal = 0.139 (Taken from Proctor)

$$(P_cW_c + P_fW_f) \times 100 = \underset{\text{Step 1}}{[(\underline{0.13} \times \underline{0.02}) + (\underline{0.87} \times \underline{0.139})] \times 100} = \underset{\text{Step 2}}{[(\underline{0.003}) + (\underline{0.121})] \times 100} = \underset{\text{Step 3}}{(\underline{0.124}) \times 100} = \underline{12.4}$$

Optimum Moisture Content of Total Soil = $\underline{12.4\%}$ (Enter on Line I)

Form TL-124 (Rev. 07/15)

CHAPTER 7 – ANSWERS TO STUDY QUESTIONS (CONT.)
PRACTICE PROBLEM #4

Report No. 1-21A-1 **Date** 06/22/2015 **Sheet No.** 1 **of** 1
Route No. 95 **County** Fairfax
Project No. 0095-029-F15, C502
FHWA No. None
Testing for Direct Transmission on Aggregate Base Type I (21A)
Model No. 3440 **Serial No.** 23456 **Calibration Date** 02/10/2015

STANDARD COUNT DATA

Density 2844 **Moisture** 701

Test No.			**1**	**2**	**3**	**4**
Location	Station ft. (m)		24+35			
of	Ref. to center line ft. (m)		5’ Rt. C/L			
Test	Elevation					
Compaction Depth of Lift in. (mm)			6”			
Method of Compaction			Vibratory			
A. Wet Density (lbs/ft³), Wet Unit Mass (kg/m³)		=	140.0			
B. Moisture Unit Mass (lbs/ft³ or kg/m³)		=	6.9			
C. Dry Density (lbs/ft³), Dry Unit Mass (kg/m³) (A-B)		=	133.1			
D. Moisture Content (B ÷ C) x 100		=	5.2			
E. Maximum Dry Density (lbs/ft³), Dry Unit Mass (kg/m³) Lab Proctor or One Point Proctor		=	124.4			
F. Percent Optimum Moisture from Lab or One Point Proctor		=	7.4 5.4 – 9.4			
G. Percent of Plus #4, (plus 4.75 mm)		=	37.0			
H. Corrected Max. Dry Density (lbs/ft³), Dry Unit Mass (kg/m³)		=	138.2			
I. Corrected Optimum Moisture		=	5.2 3.2 – 7.2			
J. Percent Dry Density (lbs/ft³), Dry Unit Mass (kg/m³) (C ÷ E) x 100 or (C ÷ H) x 100		=	96.3			
K. Percent Minimum Density Required		=	95.0			

Comments: Moisture content of 5.2% falls within the optimum moisture range of 3.2% to 7.2%
Density achieved 96.3% and minimum density required is 95.0%

BY: ______________________

TITLE: ______________________

CALCULATION #1

Amount of +4 Material in Total Soil

	Weight of Dry Soil + Dish	5.41	lb.	Weight of +4 Material + Dish	3.01	lb.
-	Weight of Dish Only	1.61	lb.	Weight of Dish Only	1.61	lb.
	Total Weight of Dry Soil	3.80	lb.	Total Weight of +4 Material	1.40	lb.

$$\frac{\text{Total Weight of +4 Material}}{\text{Total Weight of Dry Soil}} = \frac{\underline{1.40}}{\underline{3.80}} = \underline{0.368} \times 100 = \underline{37\%}\text{ (Enter on Line G)}$$

CALCULATION #2

Total Density of Soils with +4 Material

Needed Information:

P_c = Percent of +4 material expressed as a decimal = 0.37 (Taken from Sieve Analysis)

D_c = 2.73 Sp. Gr. of +4 Material x 62.4 lbs/ft^3 = 170.4 lbs/ft^3

P_f = Percent of -4 material expressed as a decimal = 0.63 (Taken from Sieve Analysis)

D_f = Maximum Dry Density of the -4 material = 124.4 (Taken from Proctor)

$$\frac{D_f \times D_c}{(P_c \times D_f) + (P_f \times D_c)} = \underset{\text{Step 1}}{\frac{\underline{124.4} \times \underline{170.4}}{(\underline{0.37} \times \underline{124.4}) + (\underline{0.63} \times \underline{170.4})}} = \underset{\text{Step 2}}{\frac{\underline{21197.8}}{(\underline{46.0}) + (\underline{107.4})}} = \underset{\text{Step 3}}{\frac{\underline{21197.8}}{\underline{153.4}}} = \underline{138.2}$$

Maximum Dry Density of Total Soil = $\underline{138.2 \text{ lb/ft}^3}$ (Enter on Line H)

CALCULATION #3

Optimum Moisture Content of Soils with +4 Material

Needed Information:

P_c = Percent of +4 material expressed as a decimal = 0.37 (Taken from Sieve Analysis)

W_c = Absorption of the +4 Material (+1) expressed as a decimal = 0.013 (Taken from Material Division)

P_f = Percent of -4 material expressed as a decimal = 0.63 (Taken from Sieve Analysis)

W_f = Optimum Moisture of the -4 material expressed as a decimal = 0.074 (Taken from Proctor)

$$(P_cW_c + P_fW_f) \times 100 = \underset{\text{Step 1}}{[(\underline{0.37} \times \underline{0.013}) + (\underline{0.63} \times \underline{0.074})] \times 100} = \underset{\text{Step 2}}{[(\underline{0.005}) + (\underline{0.047})] \times 100} = \underset{\text{Step 3}}{(\underline{0.052}) \times 100} = \underline{5.2}$$

Optimum Moisture Content of Total Soil = $\underline{5.2\%}$ (Enter on Line I)

Form TL-124 (Rev. 07/15)

CHAPTER 7 – ANSWERS TO STUDY QUESTIONS (CONT.)
PRACTICE PROBLEM #5

Report No. 1-21A-1 **Date** 06/22/2015 **Sheet No.** 1 **of** 1
Route No. 7 **County** Loudon
Project No. 0007-053-121, C501
FHWA No. None
Testing for Direct Transmission on Aggregate Base Type I (21A)
Model No. 3440 **Serial No.** 23456 **Calibration Date** 02/10/2015

STANDARD COUNT DATA

Density 2864 **Moisture** 709

Test No.			**1**	**2**	**3**	**4**
Location	Station ft. (m)		901+25			
of	Ref. to center line ft. (m)		3' Lt. C/L			
Test	Elevation					
Compaction Depth of Lift in. (mm)			6"			
Method of Compaction			Vibratory			
A. Wet Density (lbs/ft³), Wet Unit Mass (kg/m³)		=	155.3			
B. Moisture Unit Mass (lbs/ft³ or kg/m³)		=	5.1			
C. Dry Density (lbs/ft³), Dry Unit Mass (kg/m³) (A-B)		=	150.2			
D. Moisture Content (B ÷ C) x 100		=	3.4			
E. Maximum Dry Density (lbs/ft³), Dry Unit Mass (kg/m³) Lab Proctor or One Point Proctor		=	134.6			
F. Percent Optimum Moisture from Lab or One Point Proctor		=	8.4 6.4 – 10.4			
G. Percent of Plus #4, (plus 4.75 mm)		=	60.0			
H. Corrected Max. Dry Density (lbs/ft³), Dry Unit Mass (kg/m³)		=	156.4			
I. Corrected Optimum Moisture		=	4.2 2.2 – 6.2			
J. Percent Dry Density (lbs/ft³), Dry Unit Mass (kg/m³) (C ÷ E) x 100 or (C ÷ H) x 100		=	96.0			
K. Percent Minimum Density Required		=	90.0			

Comments: Moisture content of 3.4% falls within the optimum moisture range of 2.2% to 6.2%
Density achieved 96.0% and minimum density required is 90.0%

BY: ____________________

TITLE: ____________________

CALCULATION #1
Amount of +4 Material in Total Soil

	Weight of Dry Soil + Dish	8.43	lb.	Weight of +4 Material + Dish	5.71	lb.
-	Weight of Dish Only	1.61	lb.	Weight of Dish Only	1.61	lb.
	Total Weight of Dry Soil	6.82	lb.	Total Weight of +4 Material	4.10	lb.

$$\frac{\text{Total Weight of +4 Material}}{\text{Total Weight of Dry Soil}} = \frac{\underline{4.10}}{\underline{6.82}} = \underline{0.601} \text{ x } 100 = \underline{60\%} \text{ (Enter on Line G)}$$

CALCULATION #2
Total Density of Soils with +4 Material

Needed Information:

P_c = Percent of +4 material expressed as a decimal = 0.60 (Taken from Sieve Analysis)

D_c = 2.81 Sp. Gr. of +4 Material x 62.4 lbs/ft^3 = 175.3 lbs/ft^3

P_f = Percent of -4 material expressed as a decimal = 0.40 (Taken from Sieve Analysis)

D_f = Maximum Dry Density of the -4 material = 134.6 (Taken from Proctor)

$$\frac{D_f \text{ x } D_c}{(P_c \text{ x } D_f) + (P_f \text{ x } D_c)} = \underset{\text{Step 1}}{\frac{\underline{134.6} \text{ x } \underline{175.3}}{(\underline{0.60} \text{ x } \underline{134.6}) + (\underline{0.40} \text{ x } \underline{175.3})}} = \underset{\text{Step 2}}{\frac{\underline{23595.4}}{(\underline{80.8}) + (\underline{70.1})}} = \underset{\text{Step 3}}{\frac{\underline{23595.4}}{\underline{150.9}}} = \underline{156.4}$$

Maximum Dry Density of Total Soil = $\underline{156.4 \text{ lb/ft}^3}$ (Enter on Line H)

CALCULATION #3
Optimum Moisture Content of Soils with +4 Material

Needed Information:

P_c = Percent of +4 material expressed as a decimal = 0.60 (Taken from Sieve Analysis)

W_c = Absorption of the +4 Material (+1) expressed as a decimal = 0.013 (Taken from Material Division)

P_f = Percent of -4 material expressed as a decimal = 0.40 (Taken from Sieve Analysis)

W_f = Optimum Moisture of the -4 material expressed as a decimal = 0.084 (Taken from Proctor)

$$(P_cW_c + P_fW_f) \text{ x } 100 = \underset{\text{Step 1}}{[(\underline{0.60} \text{ x } \underline{0.013}) + (\underline{0.40} \text{ x } \underline{0.084})] \text{ x } 100} = \underset{\text{Step 2}}{[(\underline{0.008}) + (\underline{0.034})] \text{ x } 100} = \underset{\text{Step 3}}{(\underline{0.042}) \text{ x } 100} = \underline{4.2}$$

Optimum Moisture Content of Total Soil = $\underline{4.2\%}$ (Enter on Line I)

Form TL-124 (Rev. 07/15)

CHAPTER 7 – ANSWERS TO STUDY QUESTIONS (CONT.)
PRACTICE PROBLEM #6

Report No. 1-21A-1 **Date** 06/22/2015 **Sheet No.** 1 **of** 1
Route No. 265 **County** Pittsylvania
Project No. 6265-071-102, G302
FHWA No. None
Testing for Direct Transmission on Aggregate Base Type I (21A)
Model No. 3440 **Serial No.** 23456 **Calibration Date** 02/10/2015

STANDARD COUNT DATA

Density 2844 **Moisture** 701

Test No.			**1**	**2**	**3**	**4**
Location	Station ft. (m)		609+10			
of	Ref. to center line ft. (m)		6' Rt. C/L			
Test	Elevation					
Compaction Depth of Lift in. (mm)			6"			
Method of Compaction			Vibratory			
A. Wet Density (lbs/ft^3), Wet Unit Mass (kg/m^3)		=	150.2			
B. Moisture Unit Mass (lbs/ft^3 or kg/m^3)		=	6.1			
C. Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) (A-B)		=	144.1			
D. Moisture Content (B ÷ C) x 100		=	4.2			
E. Maximum Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) Lab Proctor or One Point Proctor		=	132.1			
F. Percent Optimum Moisture from Lab or One Point Proctor		=	7.2 5.2 – 9.2			
G. Percent of Plus #4, (plus 4.75 mm)		=	46.0			
H. Corrected Max. Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3)		=	148.8			
I. Corrected Optimum Moisture		=	4.6 2.6 – 6.6			
J. Percent Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3) (C ÷ E) x 100 or (C ÷ H) x 100		=	96.8			
K. Percent Minimum Density Required		=	95.0			

Comments: Moisture content of 4.2% falls within the optimum moisture range of 2.6% to 6.6%
Density achieved 96.8% and minimum density required is 95.0%

BY: ________________

TITLE: ________________

CALCULATION #1

Amount of +4 Material in Total Soil

	Weight of Dry Soil + Dish	8.40	lb.	Weight of +4 Material + Dish	4.75	lb.
-	Weight of Dish Only	1.63	lb.	Weight of Dish Only	1.63	lb.
	Total Weight of Dry Soil	6.77	lb.	Total Weight of +4 Material	3.12	lb.

$$\frac{\text{Total Weight of +4 Material}}{\text{Total Weight of Dry Soil}} = \frac{\underline{3.12}}{\underline{6.77}} = \underline{0.461} \text{ x } 100 = \underline{46\%} \text{ (Enter on Line G)}$$

CALCULATION #2

Total Density of Soils with +4 Material

Needed Information:

P_c = Percent of +4 material expressed as a decimal = 0.46 (Taken from Sieve Analysis)

D_c = 2.80 Sp. Gr. of +4 Material x 62.4 lbs/ft^3 = 174.7 lbs/ft^3

P_f = Percent of -4 material expressed as a decimal = 0.54 (Taken from Sieve Analysis)

D_f = Maximum Dry Density of the -4 material = 132.1 (Taken from Proctor)

$$\frac{D_f \text{ x } D_c}{(P_c \text{ x } D_f) + (P_f \text{ x } D_c)} = \underset{\text{Step 1}}{\frac{\underline{132.1} \text{ x } \underline{174.7}}{(\underline{0.46} \text{ x } \underline{132.1}) + (\underline{0.54} \text{ x } \underline{174.7})}} = \underset{\text{Step 2}}{\frac{\underline{23077.9}}{(\underline{60.8}) + (\underline{94.3})}} = \underset{\text{Step 3}}{\frac{\underline{23077.9}}{\underline{155.1}}} = \underline{148.8}$$

Maximum Dry Density of Total Soil = <u>148.8 lb/ft^3</u> (Enter on Line H)

CALCULATION #3

Optimum Moisture Content of Soils with +4 Material

Needed Information:

P_c = Percent of +4 material expressed as a decimal = 0.46 (Taken from Sieve Analysis)

W_c = Absorption of the +4 Material (+1) expressed as a decimal = 0.016 (Taken from Material Division)

P_f = Percent of -4 material expressed as a decimal = 0.54 (Taken from Sieve Analysis)

W_f = Optimum Moisture of the -4 material expressed as a decimal = 0.072 (Taken from Proctor)

$$(P_cW_c + P_fW_f) \text{ x } 100 = \underset{\text{Step 1}}{[(\underline{0.46} \text{ x } \underline{0.016}) + (\underline{0.54} \text{ x } \underline{0.072})] \text{ x } 100} = \underset{\text{Step 2}}{[(\underline{0.007}) + (\underline{0.039})] \text{ x } 100} = \underset{\text{Step 3}}{(\underline{0.046}) \text{ x } 100} = \underline{4.6}$$

Optimum Moisture Content of Total Soil = <u>4.6%</u> (Enter on Line I)

CHAPTER 8 – ANSWERS TO STUDY QUESTIONS

1) True or False. Before a Roller Pattern can be set the subgrade must be approved, compaction equipment must be approved and material to be tested must be placed at uniform depth. True.

2) Roller pattern compares compactive effort vs. density.

3) When must a new Roller Pattern be set up?
   - Multiple lifts of material
   - Change in source of material
   - Change in compaction equipment
   - Visual change in the subsurface or subgrade
   - Change in the gradation or type of material

4) Backscatter method is the testing method in which the gauge is placed on the surface of the material to be tested and the source rod is lowered to the first notch.

5) When taking a nuclear reading near an unsupported edge, 18 inches is the minimum distance from the edge that an accurate nuclear reading can be taken.

6) A direct transmission test is taken at the end of the control strip to verify the results.

7) The control strip dry density must be within 3.0 lb/ft^3 of the roller pattern peak density.

8) A roller pattern on aggregate covers 75 feet, a control strip covers 300 feet and a test section covers half a mile per paver width.

9) The Contractor has applied the dense graded aggregate layer to the right lane of a two-lane roadway beginning at Station 25 + 25. Using the numbers from the Random Number Table given below, calculate and determine the test location for each density and moisture reading for this test section, which is 12 feet wide. Remember not to test any closer than 18 inches to an unsupported edge.

Distance from Start of Sublot	Distance from Reference Line
181	3
252	3
96	2
43	6
71	4

There are 5,280 feet in a mile. A Test Section is 0.5 mile per paver width or 2640 feet. Five (5) tests will be performed in the test section. 2640 ÷ 5 = 528 feet.

Beginning Station No. 25+25

Sublot 1 528 Feet

Station No. 30+53

Sublot 2 528 Feet

Station No. 35+81

Sublot 3 528 Feet

Station No. 41+09

Sublot 4 528 Feet

Station No. 46+37

Sublot 5 528 Feet

Ending Station No. 51+65

Test No.	Station No. at Start of Each Sublot	+	Distance from Start of Sublot	=	Station No. of Each Test Location	Distance from Reference Line (ft)
1	25+25	+	181	=	27+06	3
2	30+53	+	252	=	33+05	3
3	35+81	+	96	=	36+77	2
4	41+09	+	43	=	41+52	6
5	46+37	+	71	=	47+08	4

CHAPTER 8 – ANSWERS TO STUDY QUESTIONS (CONT.)

NOTE: Each Practice Problem contains 4 Parts

Chapter 8 – Practice Problem Number 1
Nuclear Density Testing of Aggregates
Step 1 – Roller Pattern

A. Given the following information, complete the following worksheet (Form TL-53)

B. How many passes should be made for Test 5? Why?

Two more passes should be made for Test 5 for a total of 10V passes because the increase in density was greater than 1 lb/ft^3 between Test 3 and Test 4

How many passes should be made for Test 6? Why?

One more pass should be made for Test 6 for a total of 11 passes (10V, 1S) because the increase in density was less than 1 lb/ft^3 between Test 4 and Test 5

C. Should this be considered an acceptable Roller Pattern? Why?

Yes, the density curve drops off properly without dropping over 1.5 lb/ft^3

Form TL-53 (Rev. 07/15)

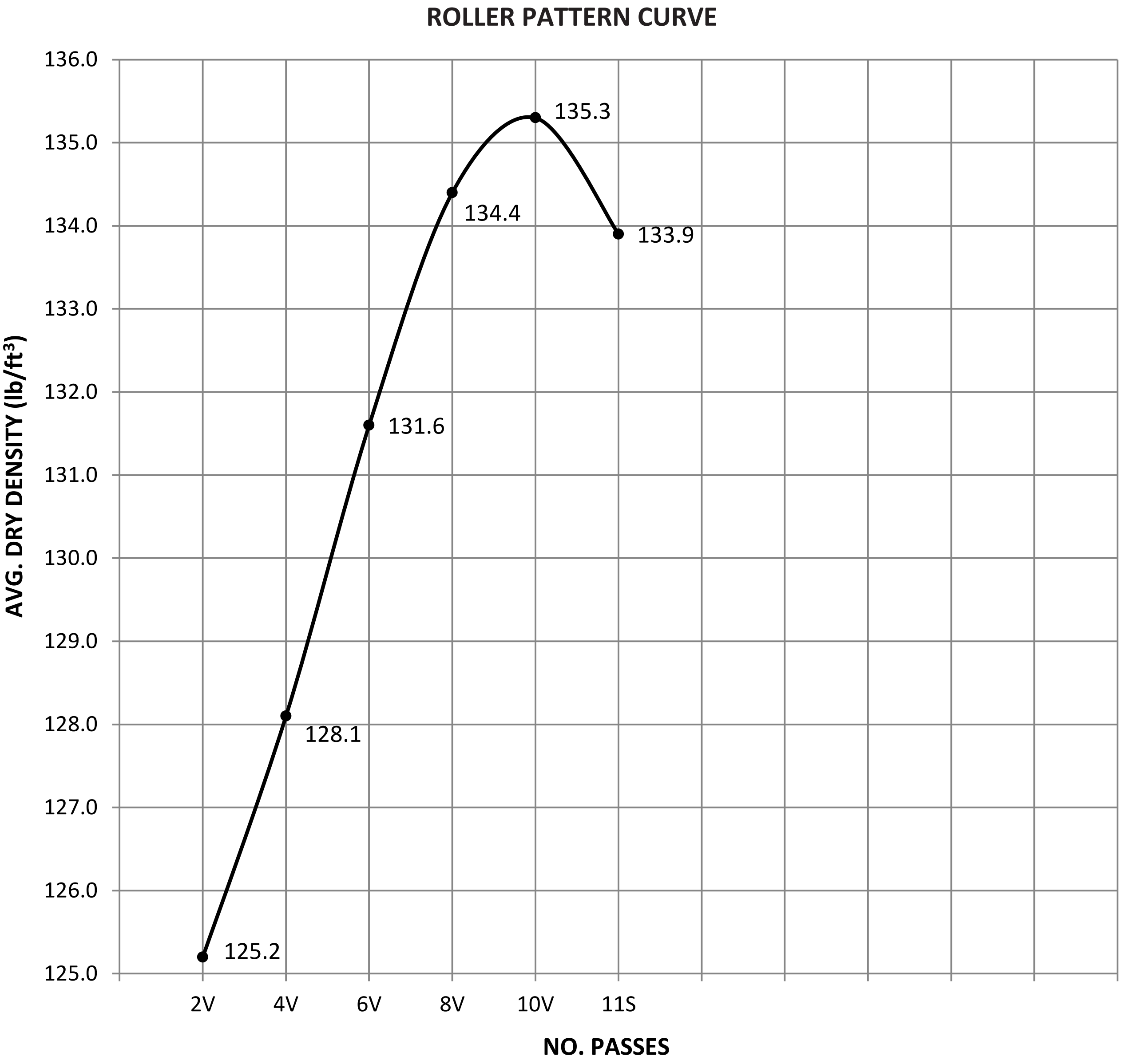
VIRGINIA DEPARTMENT OF TRANPORTATION
MATERIALS DIVISION
REPORT ON NUCLEAR ROLLER PATTERN

Report No. 1-21A-1 **Nuclear Gauge Model No.** 3440 **Serial No.** 23456
Date 06/22/2015 **Project No.** 0095-029-F14, C502 **Route No.** 95
FHWA No. NH (95) - 1 **County** Fairfax
Section No. 1 **Station No.** 21+00 **ft. (m.) to Station** 21+75 **ft. (m.)**
Type Material Aggregate Base Type I (21A) **Width** 12 **ft. (m.)**
Optimum Moisture ____ **Optimum Moisture Range** ____
Remarks ____

STANDARD COUNT DATA

Density 2847 **Moisture** 695

TEST NO.	DRY DENSITY	MOISTURE	TEST NO.	DRY DENSITY	MOISTURE
Test No. 1 **No. of Passes 2V**			**Test No. 6** **No. of Passes 11S**		
Sta. 21+00	125.4	5.1	**Sta. 21+00**	134.0	4.9
Sta. 21+35	124.9	5.2	**Sta. 21+35**	133.5	5.0
Sta. 21+75	125.3	5.6	**Sta. 21+75**	134.1	5.1
Total	375.6	15.9	**Total**	401.6	15.0
Average	125.2	5.3	**Average**	133.9	5.0
Test No. 2 **No. of Passes 4V**			**Test No. 7** **No. of Passes**		
Sta. 21+00	128.4	5.4	**Sta.**		
Sta. 21+35	127.5	5.1	**Sta.**		
Sta. 21+75	128.5	4.9	**Sta.**		
Total	384.4	15.4	**Total**		
Average	128.1	5.1	**Average**		
Test No. 3 **No. of Passes 6V**			**Test No. 8** **No. of Passes**		
Sta. 21+00	131.8	5.1	**Sta.**		
Sta. 21+35	131.0	5.0	**Sta.**		
Sta. 21+75	132.1	4.9	**Sta.**		
Total	394.9	15.0	**Total**		
Average	131.6	5.0	**Average**		
Test No. 4 **No. of Passes 8V**			**Test No. 9** **No. of Passes**		
Sta. 21+00	134.7	5.5	**Sta.**		
Sta. 21+35	133.7	4.9	**Sta.**		
Sta. 21+75	134.8	5.1	**Sta.**		
Total	403.2	15.5	**Total**		
Average	134.4	5.2	**Average**		
Test No. 5 **No. of Passes 10V**			**Test No. 10** **No. of Passes**		
Sta. 21+00	135.5	5.2	**Sta.**		
Sta. 21+35	135.0	5.1	**Sta.**		
Sta. 21+75	135.4	4.9	**Sta.**		
Total	405.9	15.2	**Total**		
Average	135.3	5.1	**Average**		



Comments:

By: ______________________________

Title: ______________________________

CHAPTER 8 – ANSWERS TO STUDY QUESTIONS (CONT.)

NOTE: Each Practice Problem contains 4 Parts

Chapter 8 – Practice Problem Number 1
Nuclear Density Testing of Aggregates
Step 2 – Control Strip

A. Complete the following worksheet (Form TL-54) using the data below and answer the following questions.

B. How many roller passes were required to attain the maximum density on the Control Strip (Use the information from Step 1 – Form TL-53)
10V – determined by the roller pattern

C. Does the test pass the moisture criteria?
Yes, all moisture contents fall within ±2 percentage points of the optimum moisture (3.2% to 7.2%)

D. Is the Control Strip within tolerance of the Roller Pattern?
Yes, the maximum dry density of 135.3 lb/ft^3 is within 3.0 lb/ft^3 of the roller pattern peak density

Form TL-54 (Rev. 07/15)

VIRGINIA DEPARTMENT OF TRANPORTATION
MATERIALS DIVISION
REPORT ON NUCLEAR CONTROL STRIP

Report No. 1-21A-2 **Date** 06/22/2015

Route No. 95 **Project No.** 0095-029-F14, C502

FHWA No. NH(95)-1 **County** Fairfax

Type Material Aggregate Base Type I (21A) **Width** 12

Station No. 22+25 **ft. (m.) to Station** 25+25 **ft. (m.) to Nuclear Gauge**

Model No. 3440 **Serial No.** 23456

Remarks

STANDARD COUNT DATA

Density 2847 **Moisture** 695

	STATION	REFERENCE TO CENTER LINE FT. (M)	LANE	DRY DENSITY (LB/FT^3) DRY UNIT MASS (KG/M^3)	MOISTURE CONTENT
1	22+25	3 FT. RT.	WBL	134.8	5.4
2	22+65	9 FT. RT.	WBL	135.2	5.3
3	23+00	6 FT. RT.	WBL	135.6	5.4
4	23+35	9 Ft. Rt.	WBL	135.5	5.4
5	23+70	3 Ft. Rt.	WBL	135.3	5.4
6	24+00	9 Ft. Rt.	WBL	135.3	5.1
7	24+35	6 Ft. Rt.	WBL	135.2	5.5
8	24+70	9 Ft. Rt.	WBL	135.8	5.4
9	25+00	6 Ft. Rt.	WBL	135.3	5.1
10	25+25	3 Ft. Rt.	WBL	134.7	5.0
			TOTAL:	1352.7	
			AVERAGE:	135.3	

5.2 **OPTIMUM MOSTURE REQUIRED (From Producer or Materials Division)**

3.2 – 7.2 **OPTIMUM MOISTURE RANGE**

(135.3) x 0.95 = Dens. Avg. 128.5 **INDIVIDUAL DRY DENSITY (lbs/ft^3), DRY UNIT MASS (kg/m^3) REQUIREMENT FOR TEST SECTION**

(135.3) x 0.98 = Dens. Avg. 132.6 **AVERAGE DRY DENSITY (lbs/ft^3), DRY UNIT MASS (kg/m^3) REQUIREMENT FOR TEST SECTION**

BY:

TITLE:

CHAPTER 8 – ANSWERS TO STUDY QUESTIONS (CONT.)

NOTE: Each Practice Problem contains 4 Parts

Chapter 8 – Practice Problem Number 1
Nuclear Density Testing of Aggregates
Step 3 – Control Strip (Direct Transmission Test)

A. Use the information below to complete the following worksheet (Form TL-124) and answer the following questions.

Information from Quarry or Materials Lab:

Percent Passing the No. 4 Sieve = 46%
Therefore, the percent of +4 Material = 54%

Specific Gravity of the +4 Material = 2.40
Therefore, the density of the +4 Material = 149.8

Absorption Rate of the +4 Material = 0.2%

Lab Proctor Information
Maximum Dry Density of the -4 Material = 133.0 lbs/ft^3
Optimum Moisture of the -4 Material = 10.1%

Nuclear Gauge Display Panel

% PR = 97.9%

DD = 130.2
WD = 137.1

M = 6.9 M% = 5.3

B. What is the minimum density required?
The minimum density required is 90.0% because 54% of the material was retained on the No. 4 Sieve

C. Does the test pass?
Yes, the actual density was 91.9%, which was above the minimum of 90.0%

D. Does this test validate the Control Strip?
Yes

Form TL-124 (Rev. 07/15)

VIRGINIA DEPARTMENT OF TRANPORTATION
MATERIALS DIVISION
REPORT ON NUCLEAR EMBANKMENT DENSITIES (UNIT MASSES)

Report No. 1-21A-3 **Date** 06/22/2015 **Sheet No.** 1 **of** 1
Route No. 95 **County** Fairfax
Project No. 0095-029-F14, C502
FHWA No. NH(95)-1
Testing for Aggregate Base Type I (21A)
Model No. 3440 **Serial No.** 23456 **Calibration Date** 02/10/2015

STANDARD COUNT DATA

Density 2847 **Moisture** 695

Test No.			**1**	**2**	**3**	**4**
Location	Station ft. (m)		22+25			
of	Ref. to center line ft. (m)		2’ Rt. C/L			
Test	Elevation					
Compaction Depth of Lift in. (mm)			6”			
Method of Compaction			Vibratory			
A. V		=	137.1			
B. (		=	6.9			
C. (		=	130.2			
D.		=	5.3			
E. (	m³)	=	133.0			
F.	Proctor	=	10.1			
G. Percent of Plus #4, (plus 4.75 mm)		=	54			
H. (	s (kg/m³)	=	141.6			
I. (		=	5.2 3.2 – 7.2			
J. I (	³)	=	91.9			
K. I		=	90.0			

Corrected Dry Density for +4 Aggregate

$$\frac{D_f \times D_c}{(P_c \times D_f) + (P_f \times D_c)}$$

$$\frac{133.0 \times 149.8}{(0.54 \times 133.0) + (0.46 \times 149.8)}$$

$$\frac{19{,}923}{(71.8 + 68.9)} = \frac{19{,}923}{140.7} = 141.6 \text{ lbs/ft}^3$$

Corrected Moisture for +4 Aggregate

$$(P_cW_c + P_fW_f) \times 100$$
$$[(0.54 \times 0.012) + (0.46 \times 0.101)] \times 100$$
$$[(0.006) + (0.046)] \times 100$$
$$[0.052] \times 100 = 5.2\%$$

Corrected Percent Density

(Dry Density ÷ Corrected +4 Density) x 100

(130.2 ÷ 141.7) x 100

(0.919) x 100

% Density = 91.9%

Comments:

BY: ____________________

TITLE: ____________________

CHAPTER 8 – ANSWERS TO STUDY QUESTIONS (CONT.)

NOTE: Each Practice Problem contains 4 Parts

Chapter 8 – Practice Problem Number 1
Nuclear Density Testing of Aggregates
Step 4 – Test Section

A. Transfer the Optimum Moisture, Optimum Moisture Range, Individual Dry Density Requirement, and Average Dry Density Requirement from the Control Strip (Form TL-54) to the proper place on the Test Section worksheet (Form TL-55).

B. Given the following nuclear density and moisture readings, complete the Form TL-55.

C. Does this test pass? Why?
Yes, each of the moisture contents falls within the optimum moisture range. Each individual density test exceeds 95%, and the overall average of the 5 density readings exceed 98%

D. If the test does not pass, what corrective action should be taken?
Retest the area, checking math and testing procedures before advising the contractor.

E. What are the beginning and ending station numbers of the first Test Section?
Beginning Station Number = 25+25; Ending Station Number is 51+65

Form TL-55 (Rev. 07/15)

VIRGINIA DEPARTMENT OF TRANPORTATION
MATERIALS DIVISION
REPORT ON NUCLEAR TEST SECTION

Report No. 1-21A-4 **Date** 06/22/2015
Route No. 95 **Project No.** 0095-029-F14, C502
FHWA No. NH(95)-1 **County** Fairfax
Type Material Aggregate Base Type I (21A) **Width** 12
Section No. 1 **Station No.** 25+25 **ft. (m.) to Station** 51+65 **ft. (m.)**
Model No. 3440 **Serial No.** 23456
Remarks

STANDARD COUNT DATA

Density 2830 **Moisture** 701

5.2 **OPTIMUM MOISTURE REQUIRED % (From Producer or Materials Division)**

3.2 – 7.2 **OPTIMUM MOISTURE RANGE**

128.5 **INDIVIDUAL DRY DENSITY (lbs/ft^3), DRY UNIT MASS (kg/m^3) REQUIRED (95% of Control Strip Density from TL-54A)**

132.6 **AVERAGE DRY DENSITY (lbs/ft^3), DRY UNIT MASS (kg/m^3) REQUIRED (98% of Control Strip Density from TL-54A)**

Test No.	Station ft. (m)	Lane	Dry Density (lbs/ft^3), Dry Unit Mass (kg/m^3)	Moisture Content	Pass (P) Fail (F)
1	27+06	WBL	136.4	5.1	P
2	33+05	WBL	135.0	5.4	P
3	36+77	WBL	136.5	5.0	P
4	41+52	WBL	133.2	5.3	P
5	47+08	WBL	136.0	5.1	P
Average			135.4		P

Comments:

BY:

TITLE:

CHAPTER 8 – ANSWERS TO STUDY QUESTIONS (CONT.)

NOTE: Each Practice Problem contains 4 Parts

Chapter 8 – Practice Problem Number 2
Nuclear Density Testing of Aggregates
Step 1 – Roller Pattern

A. Given the following information, complete the following worksheet (Form TL-53)

B. Should this be considered an acceptable Roller Pattern? Why?
Yes, the density curve drops off properly without dropping over 1.5 lb/ft^3

Form TL-53 (Rev. 07/15)

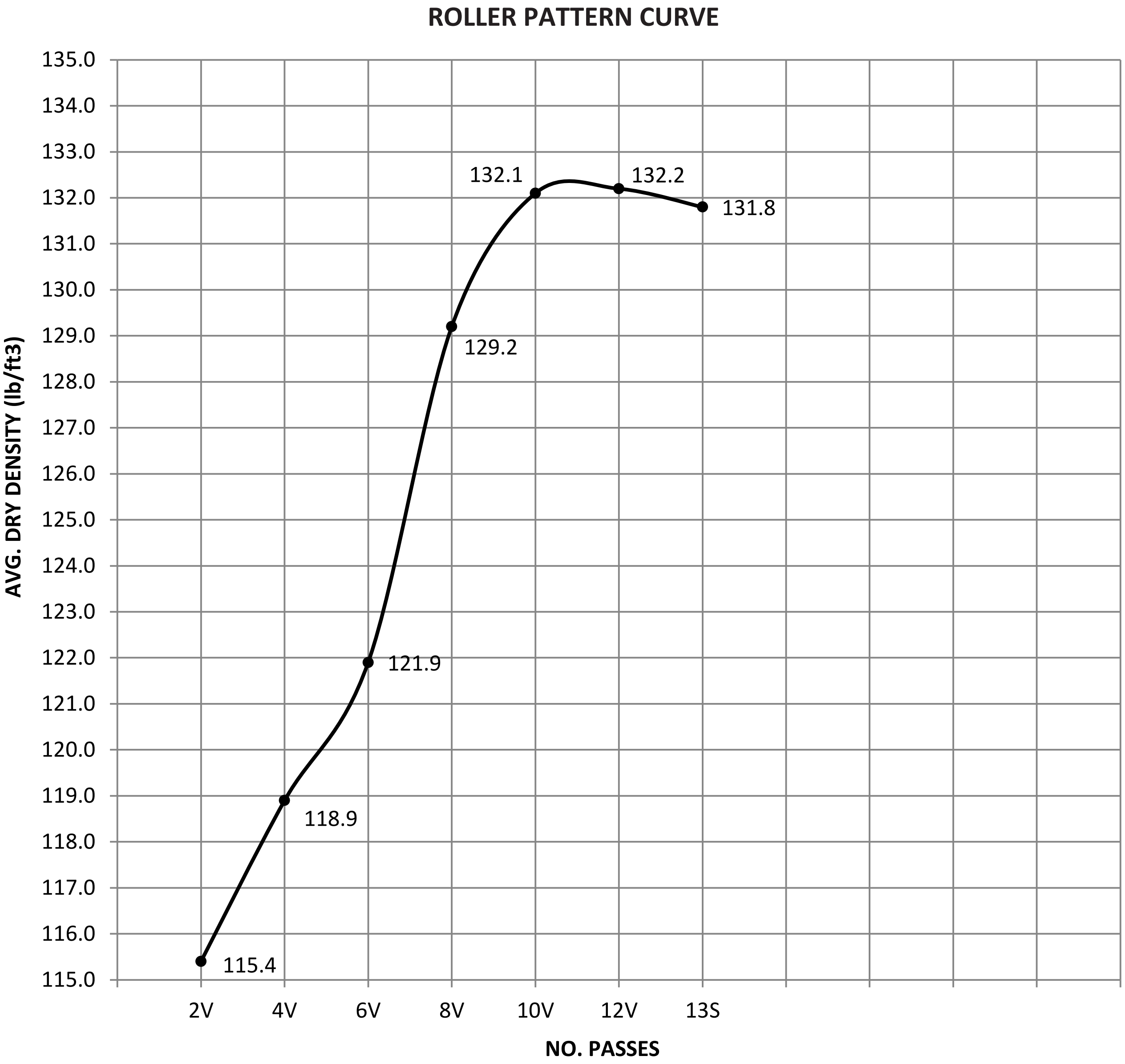
VIRGINIA DEPARTMENT OF TRANPORTATION
MATERIALS DIVISION
REPORT ON NUCLEAR ROLLER PATTERN

Report No. 3-21ACTA-1 **Nuclear Gauge Model No.** 3440 **Serial No.** 23456
Date Today **Project No.** 0007-053-121, C501 **Route No.** 7
FHWA No. None **County** Loudon
Section No. 1 **Station No.** 900+00 **ft. (m.) to Station** 900+75 **ft. (m.)**
Type Material Type 21A with 4% cement **Width** 12 **ft. (m.)**
Optimum Moisture 5.1 **Optimum Moisture Range** 3.1 – 7.1
Remarks

STANDARD COUNT DATA

Density 2864 **Moisture** 709

TEST NO.	DRY DENSITY	MOISTURE	TEST NO.	DRY DENSITY	MOISTURE
Test No. 1 **No. of Passes 2V**			**Test No. 6** **No. of Passes 12V**		
Sta. 900+00	115.4	5.3	**Sta. 900+00**	132.2	5.2
Sta. 900+35	114.6	5.1	**Sta. 900+35**	131.7	5.0
Sta. 900+75	116.1	4.9	**Sta. 900+75**	132.8	5.2
Total	346.1	15.3	**Total**	396.7	15.4
Average	115.4	5.1	**Average**	132.2	5.1
Test No. 2 **No. of Passes 4V**			**Test No. 7** **No. of Passes 13S**		
Sta. 900+00	118.9	5.3	**Sta. 900+00**	131.8	4.4
Sta. 900+35	118.6	5.2	**Sta. 900+35**	131.7	5.2
Sta. 900+75	119.1	5.3	**Sta. 900+75**	131.8	5.8
Total	356.6	15.8	**Total**	395.3	15.4
Average	118.9	5.3	**Average**	131.8	5.1
Test No. 3 **No. of Passes 6V**			**Test No. 8** **No. of Passes**		
Sta. 900+00	121.9	5.1	**Sta.**		
Sta. 900+35	121.0	4.9	**Sta.**		
Sta. 900+75	122.9	5.3	**Sta.**		
Total	365.8	15.3	**Total**		
Average	121.9	5.1	**Average**		
Test No. 4 **No. of Passes 8V**			**Test No. 9** **No. of Passes**		
Sta. 900+00	129.2	5.5	**Sta.**		
Sta. 900+35	128.1	4.8	**Sta.**		
Sta. 900+75	130.2	5.0	**Sta.**		
Total	387.5	15.3	**Total**		
Average	129.2	5.1	**Average**		
Test No. 5 **No. of Passes 10V**			**Test No. 10** **No. of Passes**		
Sta. 900+00	132.1	5.3	**Sta.**		
Sta. 900+35	131.6	4.3	**Sta.**		
Sta. 900+75	132.6	5.9	**Sta.**		
Total	396.3	15.5	**Total**		
Average	132.1	5.2	**Average**		



Comments:

By: ______________________

Title: ______________________

CHAPTER 8 – ANSWERS TO STUDY QUESTIONS (CONT.)

NOTE: Each Practice Problem contains 4 Parts

Chapter 8 – Practice Problem Number 2
Nuclear Density Testing of Aggregates
Step 2 – Control Strip

A. Using the same “header” information in Step 1, as well as the given below, complete the Control Strip (Form TL-54) and Direct Transmission (Form TL-124) worksheets.

B. How many roller passes were required to attain the maximum density on the Control Strip (Use the information from Step 1 – Form TL-53)

12V – that is the optimum number determined by the roller pattern

C. Does the test pass the moisture criteria?

Yes, the individual moisture contents fall within the optimum moisture range of 3.0% to 7.0%

D. Is the Control Strip within tolerance of the Roller Pattern?

Yes, the max. dry density of 132.7 lb/ft^3 is within 3.0 lb/ft^3 of the roller pattern peak density

E. Does the Direct Transmission Test validate the Control Strip Dry Density? (See Page 8-49)

Yes

Form TL-54 (Rev. 07/15)

VIRGINIA DEPARTMENT OF TRANPORTATION
MATERIALS DIVISION
REPORT ON NUCLEAR CONTROL STRIP

Report No. 3-21ACTA-2 **Date** Today
Route No. 7 **Project No.** 0007-053-121, C501
FHWA No. None **County** Loudon
Type Material Type 21A w/ 4% cement **Width** 12
Station No. 901+25 **ft. (m.) to Station** 904+25 **ft. (m.) to Nuclear Gauge**
Model No. 3440 **Serial No.** 23456
Remarks 6” Depth, Roller Pattern No. 3

STANDARD COUNT DATA

Density 2864 **Moisture** 709

	STATION	**REFERENCE TO CENTER LINE FT. (M)**	**LANE**	**DRY DENSITY (LB/FT^3) DRY UNIT MASS (KG/M^3)**	**MOISTURE CONTENT**
1	901+25	3’ LT.	WBL	132.8	5.6
2	901+75	9’ LT.	WBL	132.7	5.7
3	902+00	6’ LT.	WBL	132.9	5.6
4	902+30	3’ LT.	WBL	132.6	5.8
5	902+70	6’ LT.	WBL	133.0	5.2
6	903+00	9’ LT.	WBL	132.5	5.7
7	903+35	9’ LT.	WBL	132.7	5.1
8	903+70	3’ LT.	WBL	132.7	5.8
9	904+00	6’ LT.	WBL	132.5	5.2
10	904+25	9’ LT.	WBL	132.8	5.5
			TOTAL:	1327.2	
			AVERAGE:	132.7	

5.0 **OPTIMUM MOSTURE REQUIRED (From Producer or Materials Division)**

3.0 – 7.0 **OPTIMUM MOISTURE RANGE**

(132.7) x 0.95 = Dens. Avg. 126.1 **INDIVIDUAL DRY DENSITY (lbs/ft^3), DRY UNIT MASS (kg/m^3) REQUIREMENT FOR TEST SECTION**

(132.7) x 0.98 = Dens. Avg. 130.0 **AVERAGE DRY DENSITY (lbs/ft^3), DRY UNIT MASS (kg/m^3) REQUIREMENT FOR TEST SECTION**

BY: __________

TITLE: __________

CHAPTER 8 – ANSWERS TO STUDY QUESTIONS (CONT.)

NOTE: Each Practice Problem contains 4 Parts

Chapter 8 – Practice Problem Number 2
Nuclear Density Testing of Aggregates
Step 3 – Control Strip (Direct Transmission Test)

A. Use the information below to complete the following worksheet (Form TL-124) and answer the following questions.

Information from Quarry or Materials Lab:

Percent Passing the No. 4 Sieve = 43%
Therefore, the percent of +4 Material = 57%

Specific Gravity of the +4 Material = 2.50
Therefore, the density of the +4 Material = 156.0

Absorption Rate of the +4 Material = 0.3%

Lab Proctor Information
Maximum Dry Density of the -4 Material = 133.0 lbs/ft^3
Optimum Moisture of the -4 Material = 10.1%

Nuclear Gauge Display Panel

% PR = 100.5%

DD = 133.6
WD = 140.8

M = 7.2 M% = 5.4

B. What is the minimum density required?
The minimum density required is 90.0%

C. Does the test pass?
Yes.

Form TL-124 (Rev. 07/15)

VIRGINIA DEPARTMENT OF TRANPORTATION
MATERIALS DIVISION
REPORT ON NUCLEAR EMBANKMENT DENSITIES (UNIT MASSES)

Report No. 3-21ACTA-2 **Date** Today **Sheet No.** 1 **of** 1
Route No. 7 **County** Loudon
Project No. 0007-053-121, C501
FHWA No. None
Testing for Aggregate Subbase
Model No. 3440 **Serial No.** 23456 **Calibration Date** 12/10/2015

STANDARD COUNT DATA

Density __________ **Moisture** __________

Test No.			**1**	**2**	**3**	**4**
Location	Station ft. (m)		902+70			
of	Ref. to center line ft. (m)		9' Lt.			
Test	Elevation					
Compaction Depth of Lift in. (mm)			6"			
Method of Compaction			Vibratory			
A.		=	140.8			
B.		=	7.2			
C.		=	133.6			
D.		=	5.4			
E.	/m³)	=	133.0			
F.	t Proctor	=	10.1			
G. Percent of Plus #4, (plus 4.75 mm)		=	57			
H.	s (kg/m³)	=	145.2			
I.		=	5.0 3.0 – 7.0			
J.	³)	=	92.0			
K.		=	90.0			

Corrected Dry Density for +4 Aggregate

$$\frac{D_f \times D_c}{(P_c \times D_f) + (P_f \times D_c)}$$

$$\frac{133.0 \times 156.0}{(0.57 \times 133.0) + (0.43 \times 156.0)}$$

$$\frac{20{,}748}{(75.8 + 67.1)} = \frac{20{,}748}{142.9} = 145.2 \text{ lbs/ft}^3$$

Corrected Moisture for +4 Aggregate

$$(P_cW_c + P_fW_f) \times 100$$

$$[(0.57 \times 0.013) + (0.43 \times 0.101)] \times 100$$

$$[(0.007) + (0.043)] \times 100$$

$$[0.050] \times 100 = 5.0\%$$

Corrected Percent Density

(Dry Density ÷ Corrected +4 Density) x 100

(133.6 ÷ 145.2) x 100

(0.920) x 100

% Density = 92.0%

Comments:

BY: __________

TITLE: __________

CHAPTER 8 – ANSWERS TO STUDY QUESTIONS (CONT.)

NOTE: Each Practice Problem contains 4 Parts

Chapter 8 – Practice Problem Number 2
Nuclear Density Testing of Aggregates
Step 4 – Test Section

A. Testing at the minimum frequency: With the Test Section beginning at Station No. 904+25 and having a paving width 12 feet, choose five (5) test site location using the following random numbers.

Distance from Start of Sublot	Distance from Reference Line
101	4
106	8
27	3
140	3
182	10

There are 5,280 feet in a mile. A Test Section is 0.5 mile per paver width or 2640 feet. Five (5) tests will be performed in the test section. 2640 ÷ 5 = 528.

Beginning Station No. 904+25

Sublot 1 528 Feet

Station No. 909+53

Sublot 2 528 Feet

Station No. 914+81

Sublot 3 528 Feet

Station No. 920+09

Sublot 4 528 Feet

Station No. 925+37

Sublot 5 528 Feet

Ending Station No. 930+65

Test No.	Station No. at Start of Each Sublot	+	Distance from Start of Sublot	=	Station No. of Each Test Location	Distance from Reference Line (ft)
1	904+25	+	101	=	905+26	4
2	909+53	+	106	=	910+59	8
3	914+81	+	27	=	915+08	3
4	920+09	+	140	=	921+49	3
5	925+37	+	182	=	927+19	10

B. Transfer the Optimum Moisture, Optimum Moisture Range, Individual Dry Density Requirement, and Average Dry Density Requirement from the Control Strip (Form TL-54) to the proper place on the Test Section worksheet (Form TL-55).

C. Given the following nuclear density and moisture readings, complete the Form TL-55 using the same header information from the preceding problems (except use the correct Report Number: 3-21ACTA-4).

Test 1

Nuclear Gauge Display Panel

% PR = _____%

DD = 132.3
WD = 139.8

M = 7.5 M% = 5.7

Test 2

Nuclear Gauge Display Panel

% PR = _____%

DD = 131.2
WD = 138.4

M = 7.2 M% = 5.5

Test 3

Nuclear Gauge Display Panel

% PR = _____%

DD = 130.6
WD = 137.4

M = 6.8 M% = 5.2

Test 4

Nuclear Gauge Display Panel

% PR = _____%

DD = 131.3
WD = 138.0

M = 6.7 M% = 5.1

Test 5

Nuclear Gauge Display Panel

% PR = _____%

DD = 129.6
WD = 137.4

M = 7.8 M% = 6.0

D. Does this test pass? Why?
Yes, each of the individual density test exceed the minimum density requirement, and the average of the 5 readings exceeds the average requirement and all moisture contents fall within the optimum range

E. At what station is Test 4 to be taken from?
921+49

F. At what station does Sublot 2 begin?
909+53

G. How many feet from the reference line is Test 5 to be taken?
10 feet

Form TL-55 (Rev. 07/15)

VIRGINIA DEPARTMENT OF TRANPORTATION
MATERIALS DIVISION
REPORT ON NUCLEAR TEST SECTION

Report No. 3-21ACTA-4 **Date** Today
Route No. 7 **Project No.** 0007-053-121, C501
FHWA No. None **County** Loudon
Type Material Type 21A w/ 4% cement **Width** 12
Section No. 1 **Station No.** 904+25 **ft. (m.) to Station** 930+65 **ft. (m.)**
Model No. 3440 **Serial No.** 23456
Remarks 6” Depth, Roller Pattern No 3

STANDARD COUNT DATA

Density 2864 **Moisture** 709

5.0 **OPTIMUM MOISTURE REQUIRED % (From Producer or Materials Division)**

5.0 – 7.0 **OPTIMUM MOISTURE RANGE**

126.1 **INDIVIDUAL DRY DENSITY (lbs/ft³), DRY UNIT MASS (kg/m³) REQUIRED**
(95% of Control Strip Density from TL-54A)

130.0 **AVERAGE DRY DENSITY (lbs/ft³), DRY UNIT MASS (kg/m³) REQUIRED**
(98% of Control Strip Density from TL-54A)

Test No.	Station ft. (m)	Lane	Dry Density (lbs/ft³), Dry Unit Mass (kg/m³)	Moisture Content	Pass (P) Fail (F)
1	905+26	WBL	132.3	5.7	p
2	910+59	WBL	131.2	5.5	P
3	915+08	WBL	130.6	5.2	P
4	921+49	WBL	131.3	5.1	P
5	927+19	WBL	129.6	6.0	P
Average			131.0		P

Comments:

BY:

TITLE: