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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.

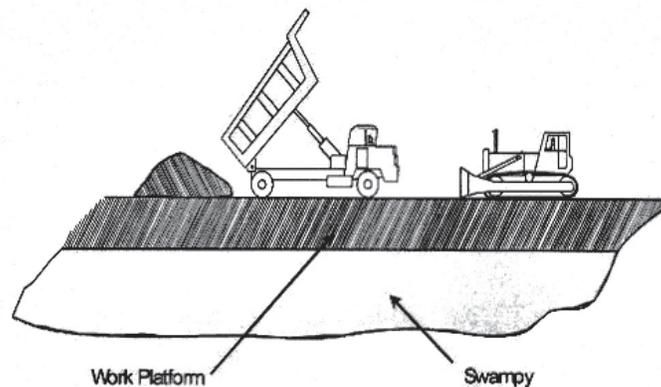


Figure 2.1: Illustration of Bridging Lifts

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

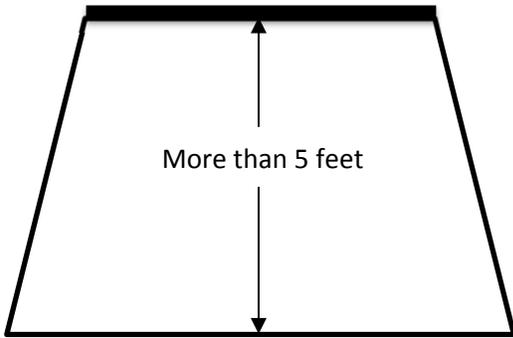


Figure 2.2: Stumps, Roots, Topsoil, and other materials must be left in place

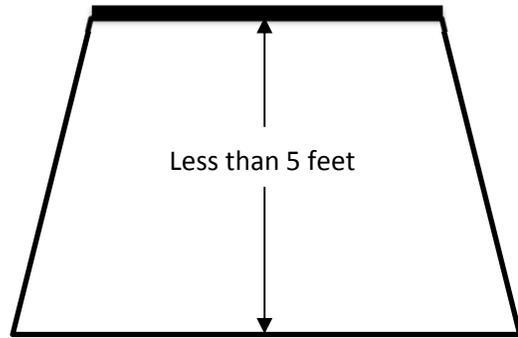


Figure 2.3: Stumps, Roots, Topsoil, and other materials must be removed

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.

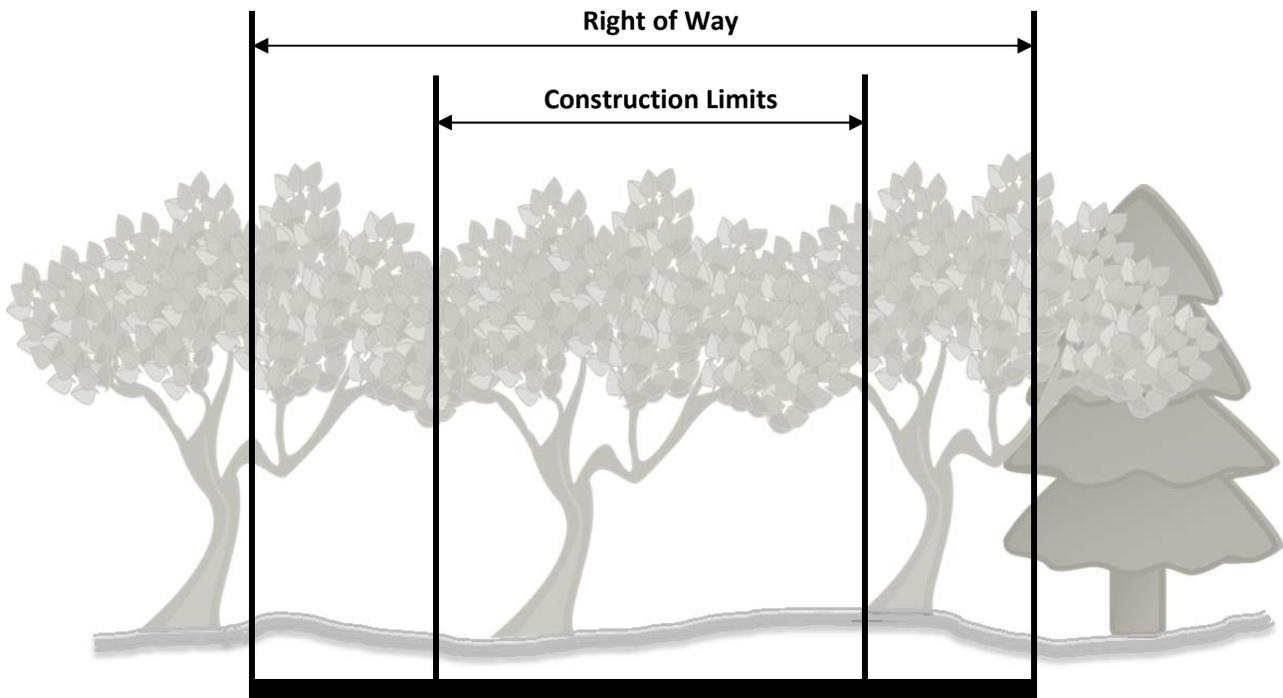


Figure 2.4: Illustration of Standard Right of Way and Construction Limits

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

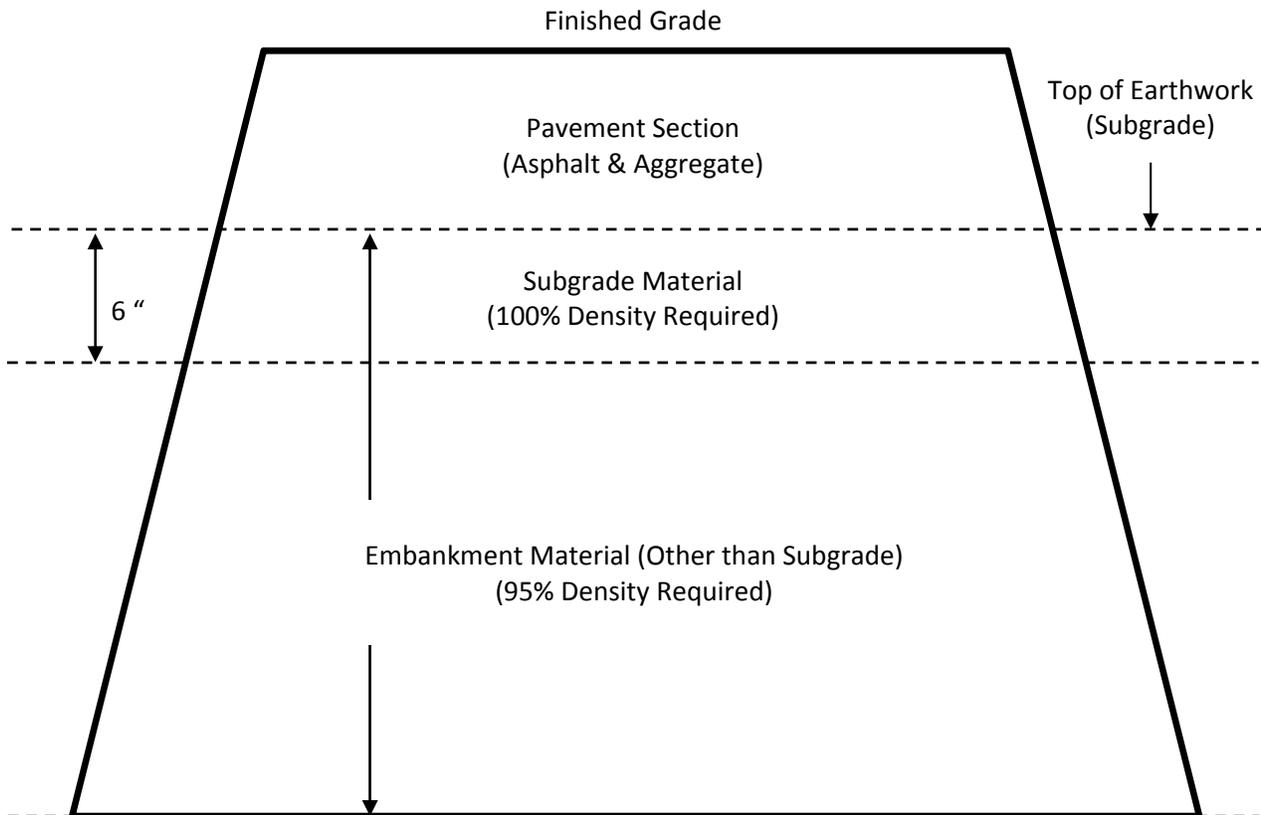


Figure 2.5: Typical Embankment Section

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.

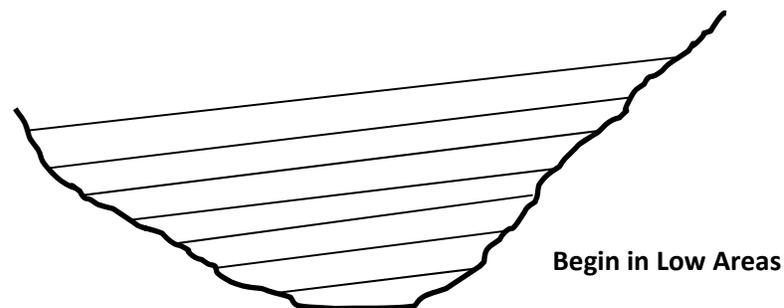


Figure 2.6: Illustration of Layer Placement

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.

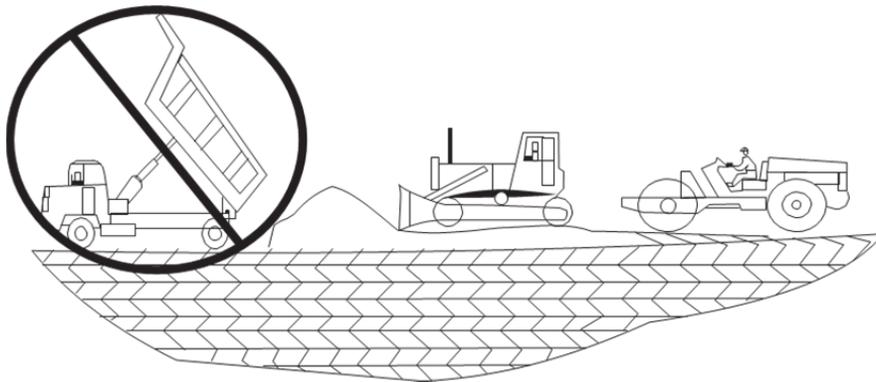


Figure 2.7: Illustration of Incorrect Layer Placement

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

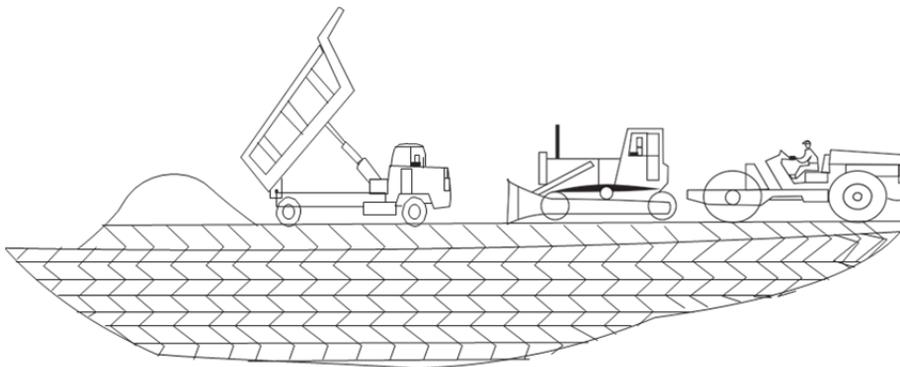


Figure 2.8: Illustration of Correct Layer Placement

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.

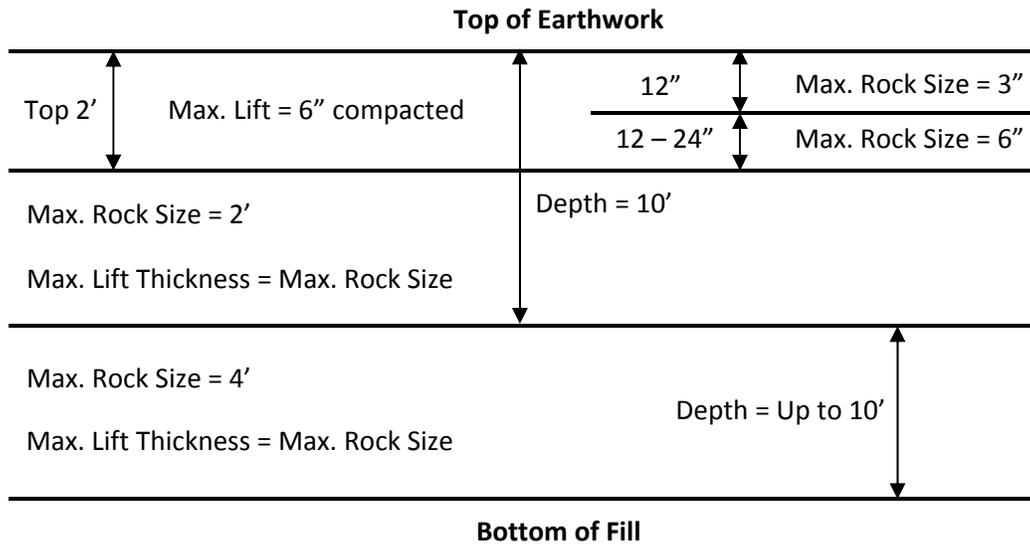


Figure 2.11: Requires for Rock Size and Lift Thickness

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.

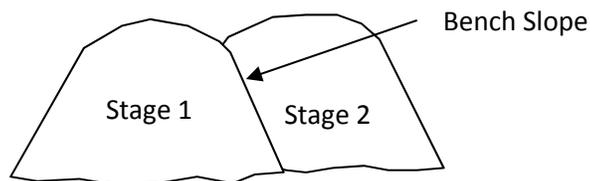


Figure 2.12: Benching 1/2 Width at a Time

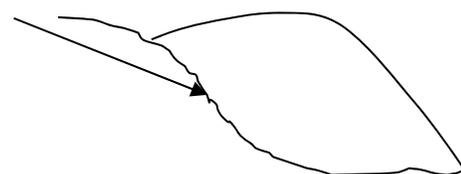


Figure 2.13: Benching Against Hillside

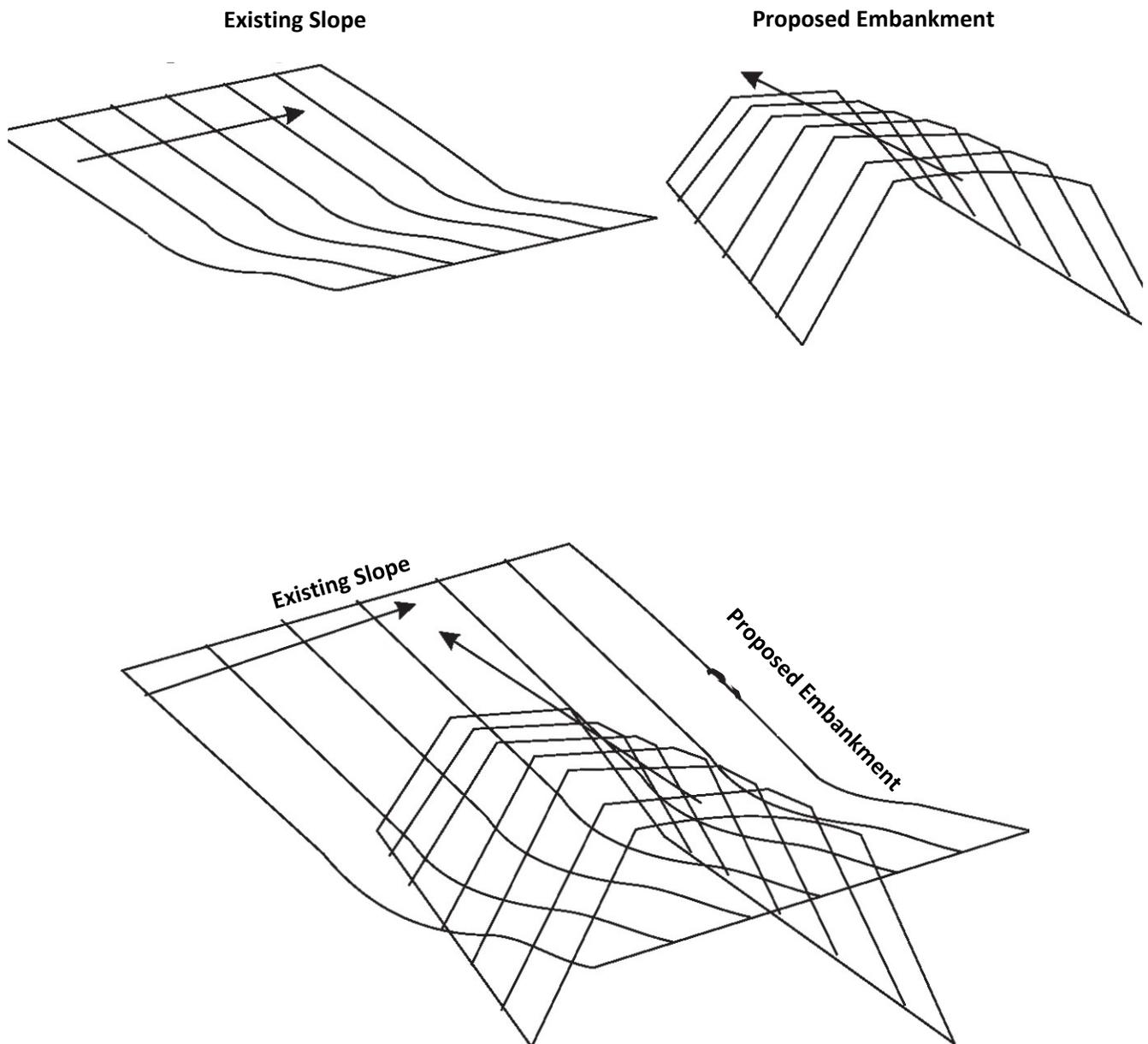


Figure 2.14: Benching Against an Existing Slope

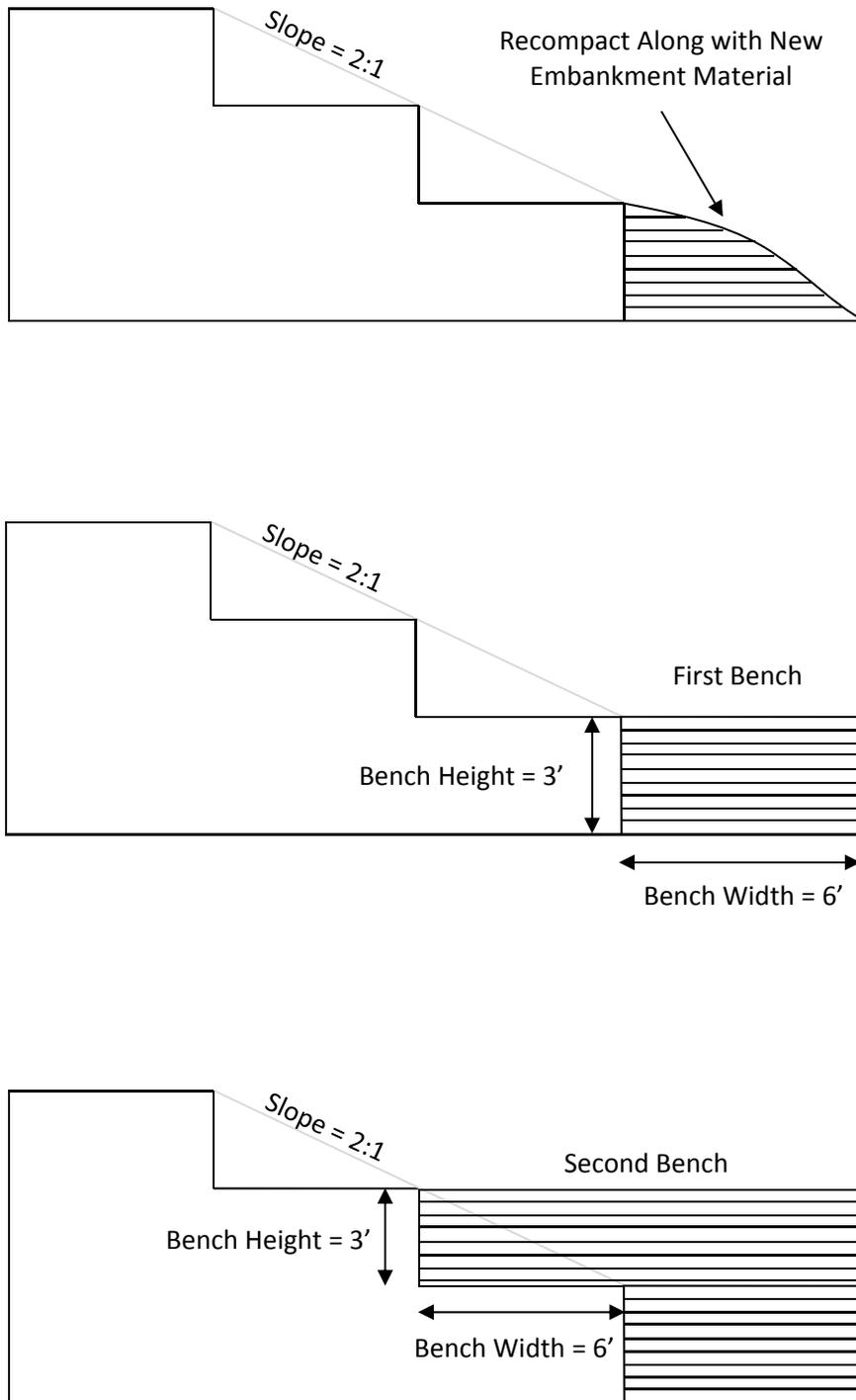


Figure 2.15: Proper Methods and Requirements for Benching

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:

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

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

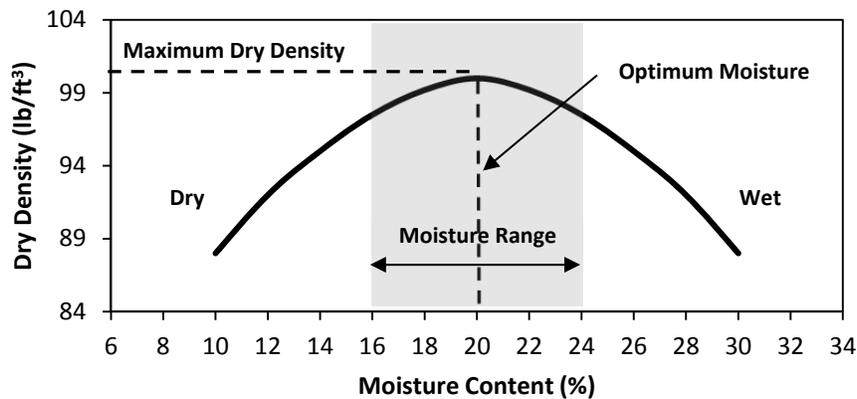


Figure 2.16: Moisture-Density Relationship

Moisture Specifications

For both the subgrade and embankment, the specifications require that each lift be compacted at optimum moisture, with a tolerance of $\pm 20\%$ 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 ($\pm 20\%$): $15\% \times 0.20 = 3\%$
- 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 its 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 construction 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 yd³ 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 yd³ from the bottom to the top of the fill, plus one field density test for every other 6" lift starting with the second lift.

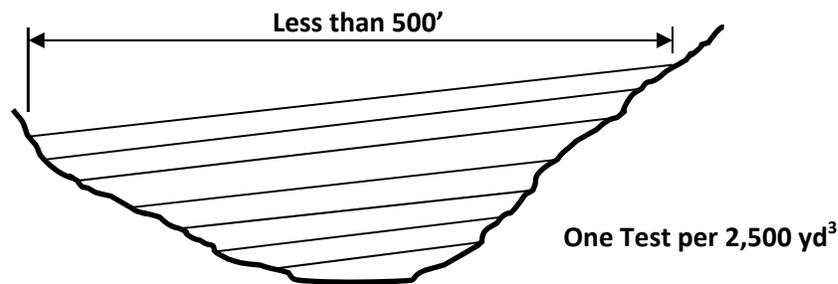


Figure 2.17: Typical Fill Section Less than 500'

For fill areas from 500 to 2,000 feet, one field density test for each 2,500 yd³ from the bottom to the top of the fill, plus two field density tests for every 6" lift within the top 5' of fill.

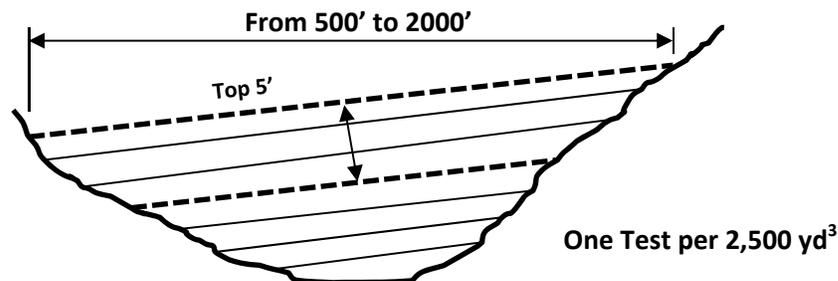


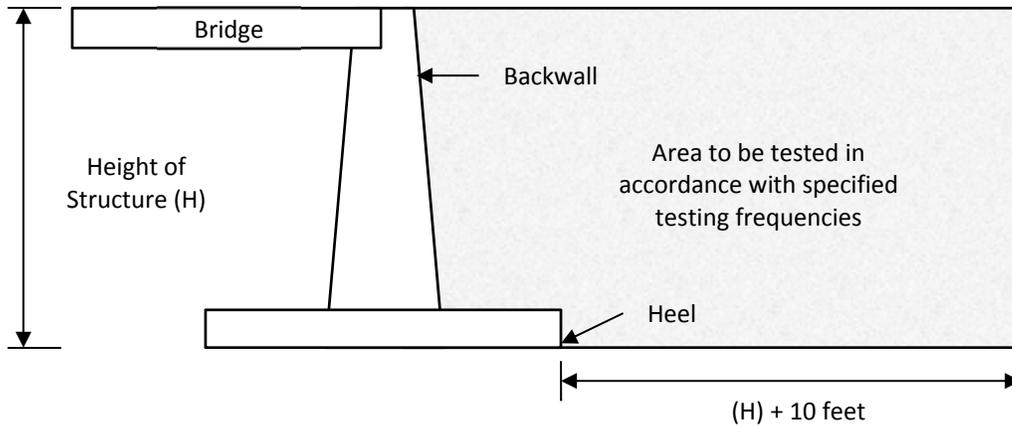
Figure 2.18: Typical Fill Section from 500' to 2000'

Abutments, Gravity and Cantilver Retaining Walls

The testing frequencies for backfill behind Abutments, Gravity and Cantiliver 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

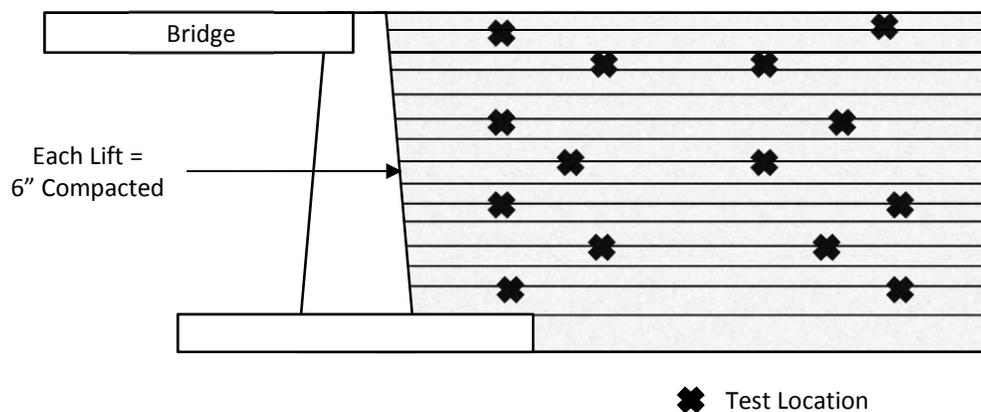
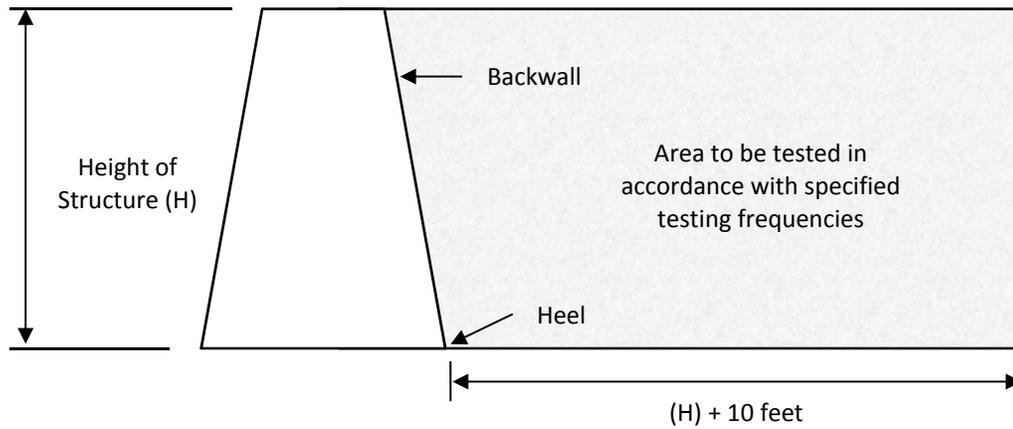


Figure 2.19: Testing Frequencies and Locations for Bridge Abutments

Testing Frequencies and Locations for Gravity Retaining Walls



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

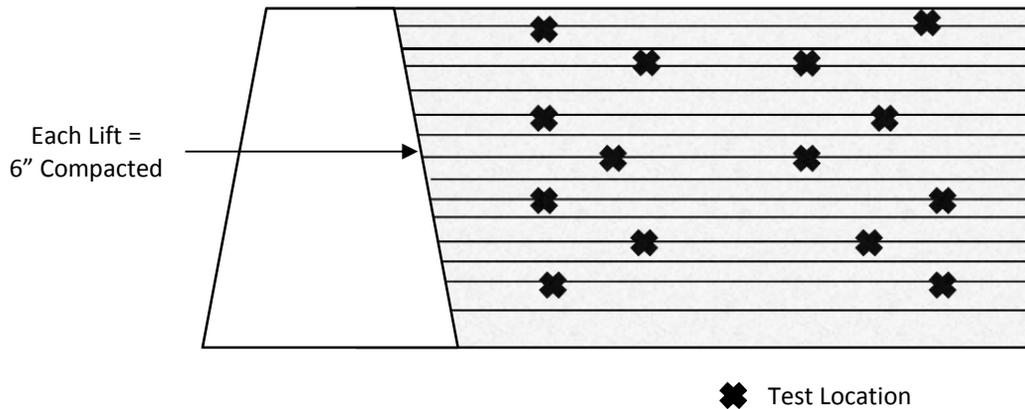


Figure 2.20: Testing Frequencies and Locations for Gravity Retaining Walls

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.

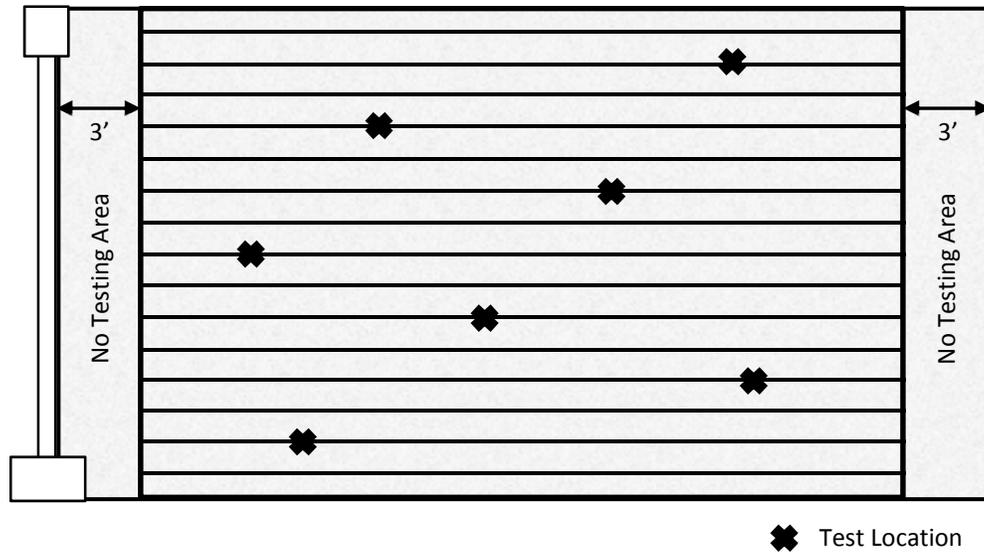


Figure 2.21: Testing Frequencies and Locations for MSE Walls (less than 100')

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 $\pm 40\%$.
- 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 _____.