

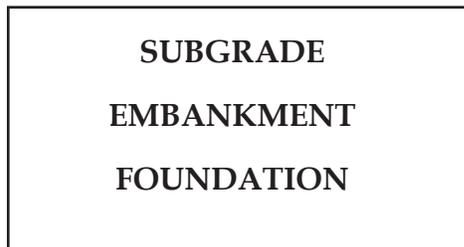
CHAPTER 2

CONSTRUCTION AND TESTING OF EMBANKMENTS

CONSTRUCTION PREPARATION OF EMBANKMENT FOUNDATIONS

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:



- To Prepare for construction of an embankment:**
- **Start with a firm foundation**
 - **Clearing and grubbing**
 - **Erosion controls**
 - **Grading methods**
 - **Placement of layers**

FOUNDATION CONSTRUCTION

- Construction preparation of embankment foundations:**
- **Must ensure firm foundation**
 - **Competent testing and monitoring**
 - **Prepare work platform if needed**

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 it's 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

- | |
|--|
| <p>Work Platform Construction Techniques</p> <ul style="list-style-type: none">• Bridge layer/lift• Geosynthetic reinforcement |
|--|

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.

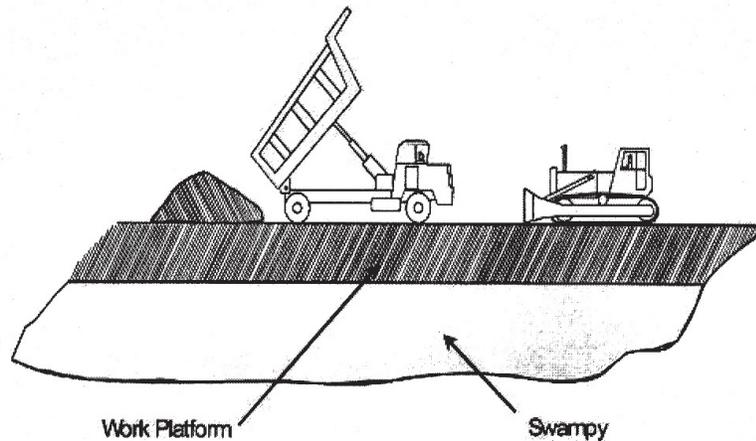


Figure 2.1

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.

CLEARING AND GRUBBING

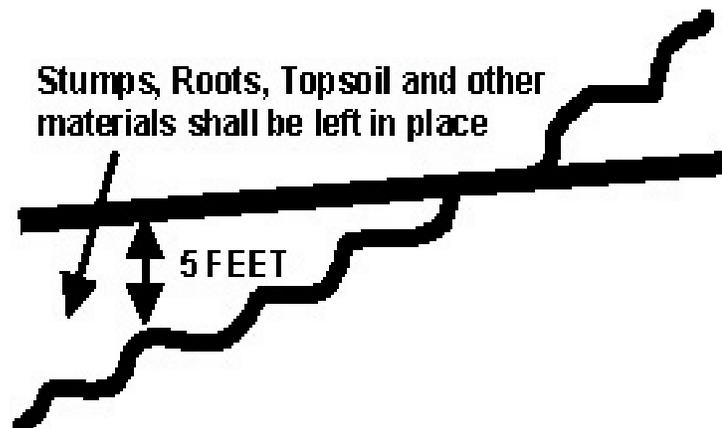
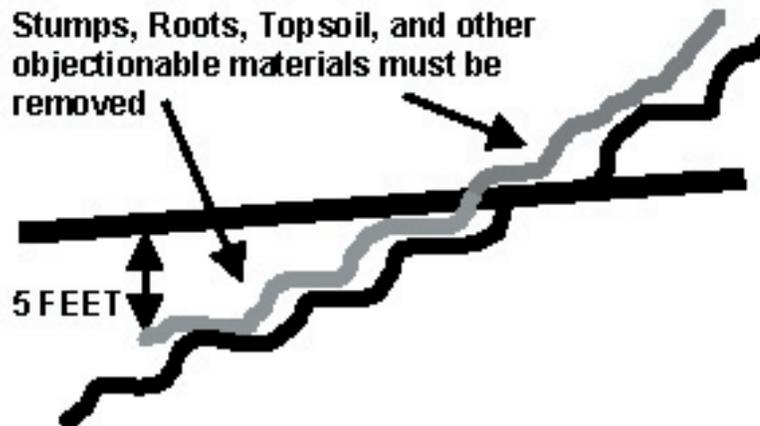
Clearing is the removal of trees, brush, debris, and other large items.

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.

Clearing and grubbing is required in these areas:

- all cut sections (See Fig.2.2)
- fill sections less than 5 feet in depth and directly
- beneath the pavement and shoulders (See Fig.2.3)
- any borrow excavation sites



Purpose of Clearing and Grubbing

Clearing and grubbing is done in 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.

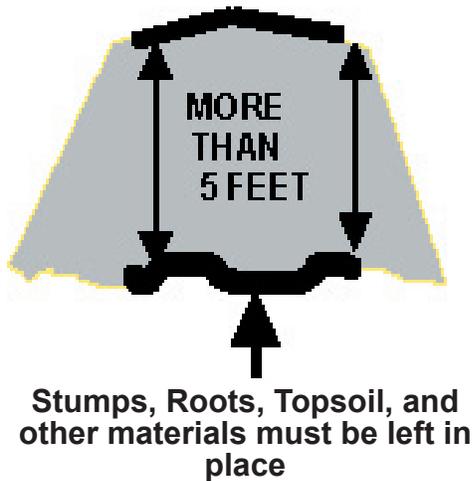


Figure 2.4

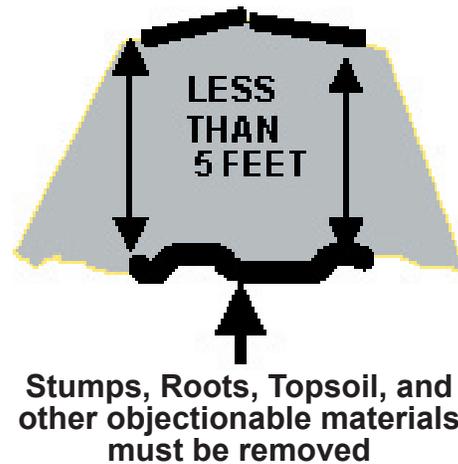


Figure 2.5

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.

When and Where to Clear and Grub

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.

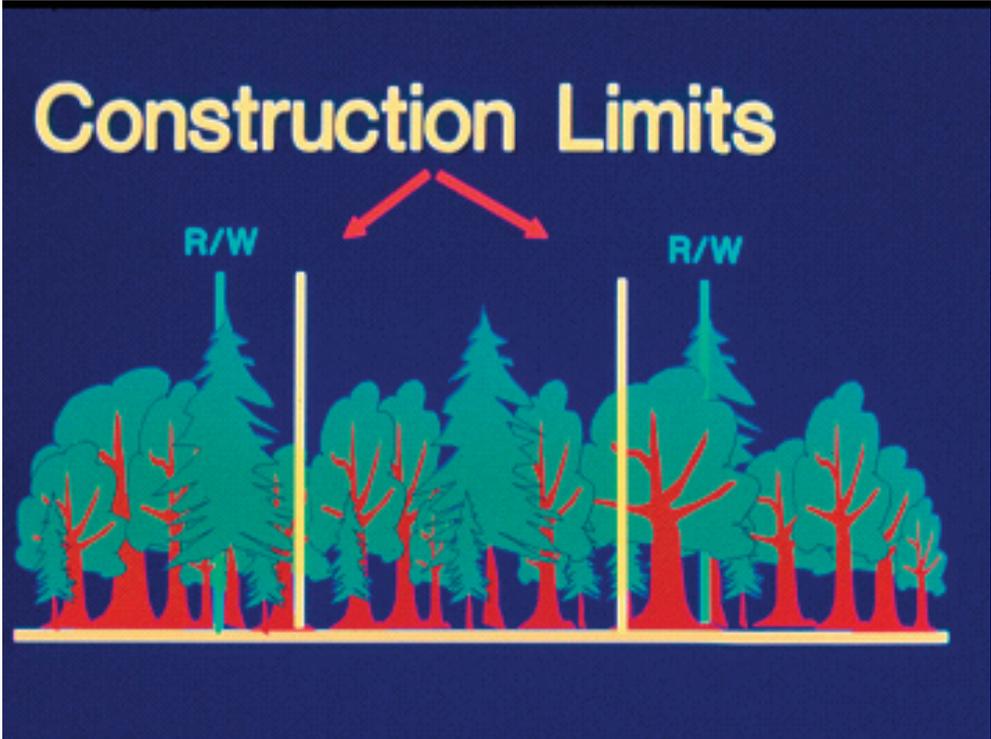
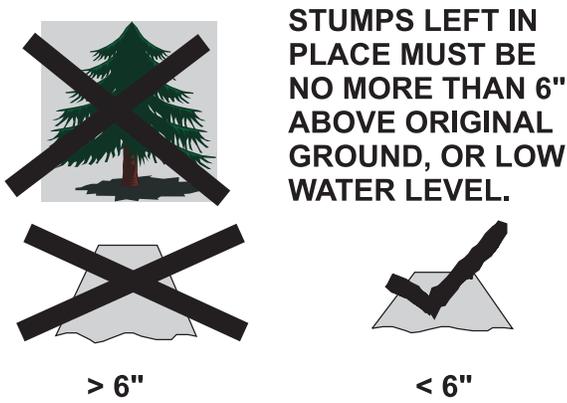


Figure 2.6

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. As previously mentioned, 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.



STUMPS LEFT IN PLACE MUST BE NO MORE THAN 6" ABOVE ORIGINAL GROUND, OR LOW WATER LEVEL.

LIMBS OVERHANGING ROADWAY MUST BE REMOVED

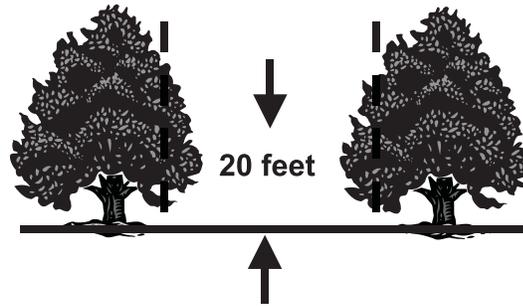


Figure 2.7

Figure 2.8

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.

Disposal of Removed Material

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

- | |
|--|
| <p>Material less than 3" in Diameter</p> <ul style="list-style-type: none"> • 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 107.14(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.

EROSION AND SILTATION CONTROL

Erosion and siltation controls must be installed prior to beginning any construction. 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, fabric silt barriers, and temporary filter barriers.

Baled straw silt barriers may be substituted for temporary filter barriers 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 Siltation Control and designated as the RLD (Responsible Land Disturber). Since Jan. 5, 2005, the RLD certification is to be obtained from the VDOT Environmental Division. 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.

GRADING METHODS AND PRACTICES

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.

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 runoff 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 seedings slopes.

Grade to Drain

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

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

EMBANKMENT

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

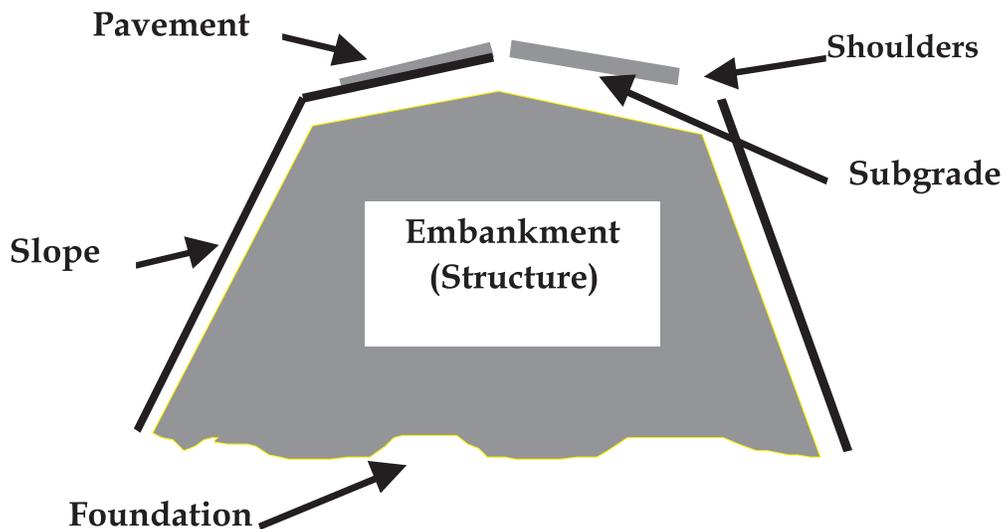


Figure 2.9

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 it's construction. Figure 2.10 illustrates the areas to be cleared, scarified, and compacted prior to placing fill material. 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.

Embankment Construction

- Foundation approved
- Remove loose material from the surface
- Establish work platform on soft, swampy areas
- Bring in approved embankment material
- Shall not be placed on frozen areas or on areas covered with ice or snow
- Shall not be placed on soft, yielding foundation without the Engineer's approval
- Cisterns, septic tanks, and other structures must be filled

AREA MUST BE CLEARED AND GRUBBED, AND THE TOP 6 INCHES COMPACTED

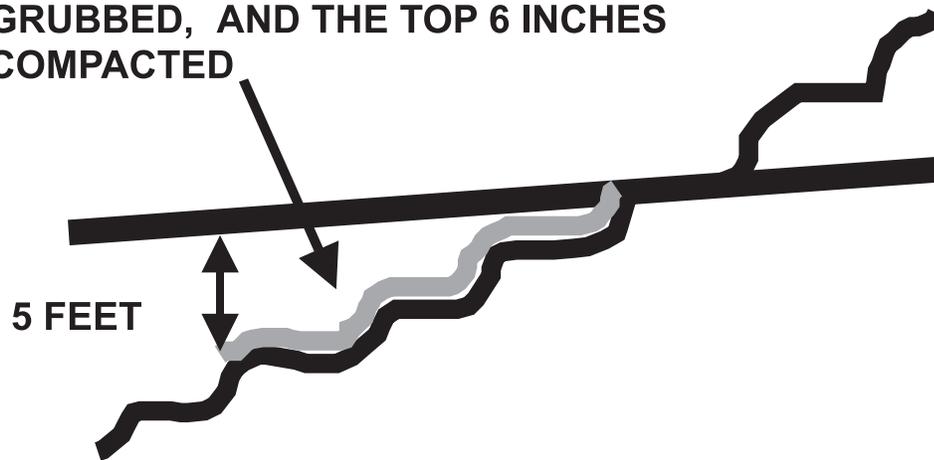


Figure 2.10

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 Fills

- Regular excavation
- Borrow excavation
- Specialized materials
 - o Commercial sources
 - o Tires
 - o Light weight fill
 - Aggregate
 - Flowable fill
 - Cellular concrete fill/foam concrete fill
 - o Flyash and slag

PLACEMENT OF LAYERS

As shown in Fig. 2.11, 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.

- Uniform Layers
- Parallel to Finished Grade

Uniform

- Lift Thickness
- Moisture
- Compactive Effort

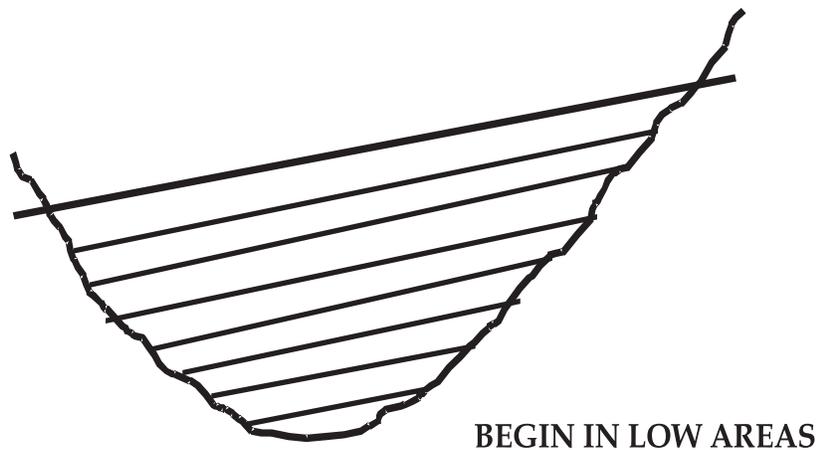


Figure 2.11

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. 2.12 & 2.13 show the incorrect and the correct method respectively.

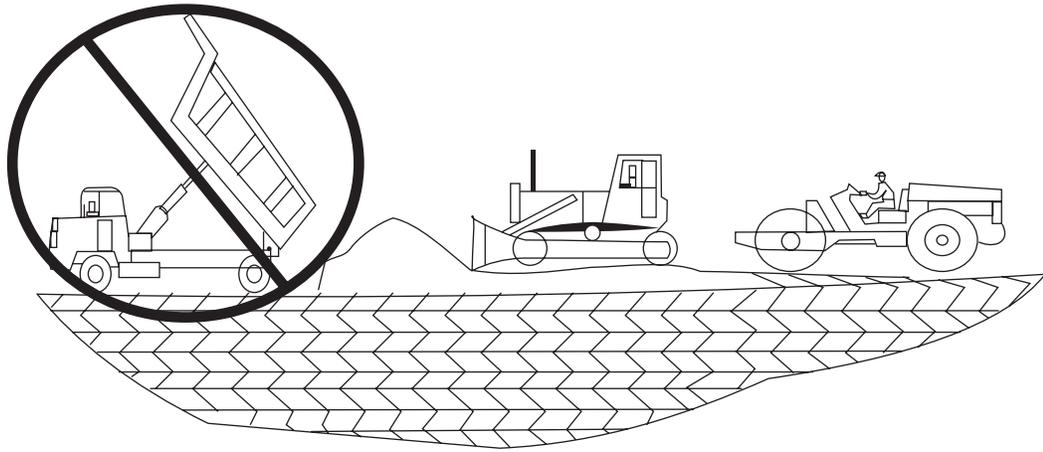


Figure 2.12

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

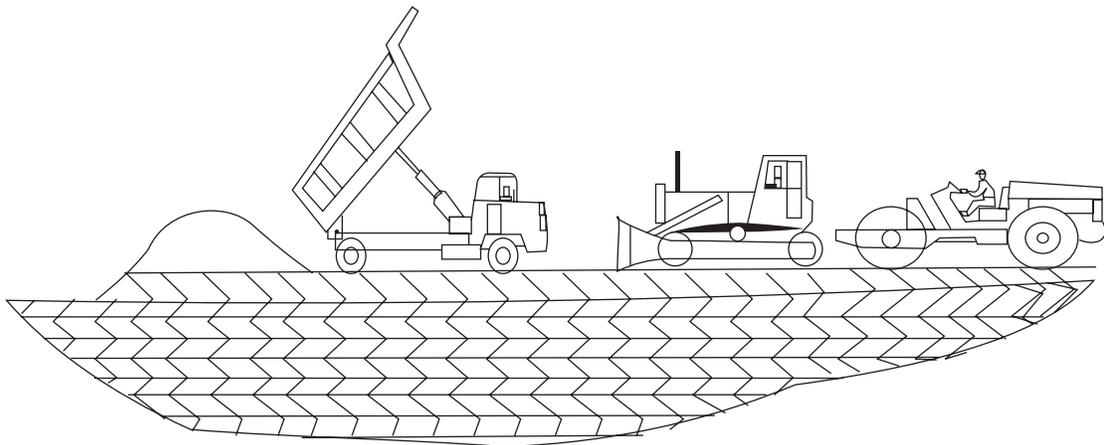


Figure 2.13

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

MONITORING LIFT THICKNESS

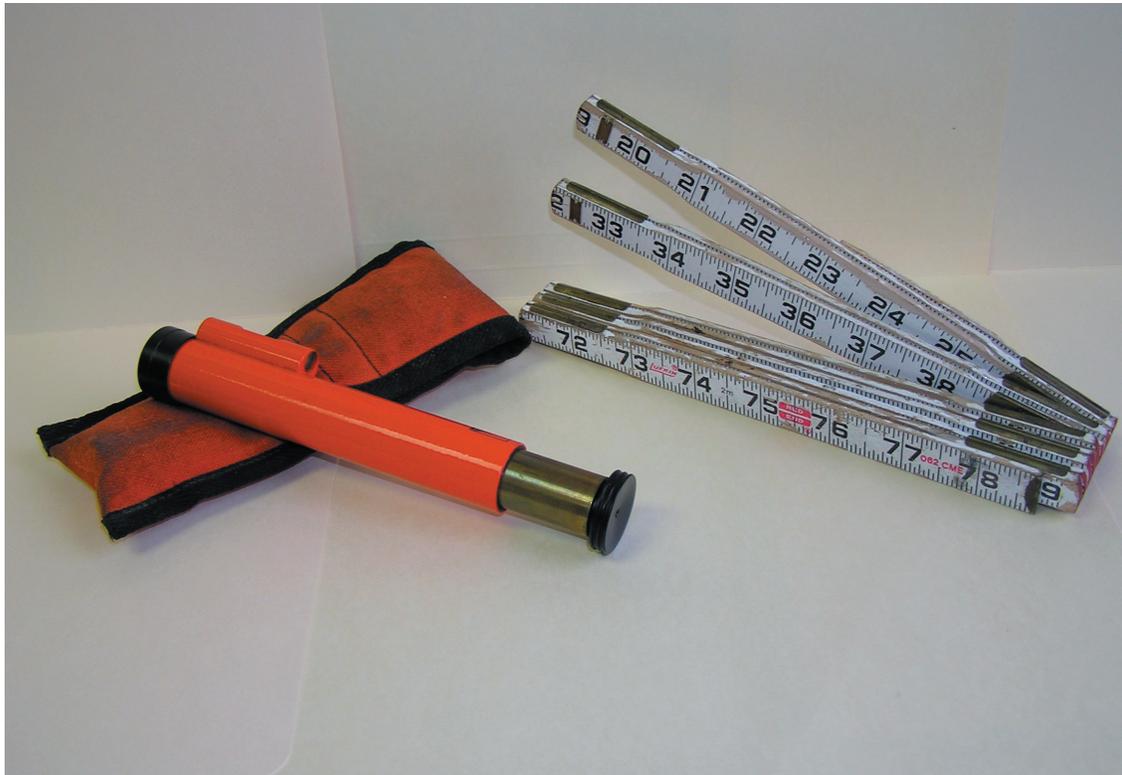
The compaction of soils is influenced by how they are manipulated. Uniform layer or lift thickness is essential in achieving proper compaction. Typical lift thickness for soils in an embankment is eight inches loose, six inches compacted. When lift thickness is increased the actual compaction will decrease 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.



A more accurate method of determining lift thickness is to look at actual ground surface elevations. The ability to determine elevations in the field is key in monitoring lift thickness. By comparing the surface elevation of a new lift to the surface elevation of the previous lift an accurate determination of lift thickness is possible. Surface elevations are required at all density test locations as part of the test location documentation. A common method of determining elevations in the field is to use a Locke level and folding rule to take rudimentary elevations. Lets look at this procedure in more detail.

On some projects the contractor may have a surveying instrument set up near the fill area and can provide the surface elevations to you. If that option is not available, the Locke Level and folding rule will be your common tools for establishing field elevations.



Here is a diagram of a typical Locke level. When sighting through the Locke level the field of view is partially occupied by the reflection of the spirit level in the mirror. The spirit level is used to ensure that the instrument is held level when taking a sighting. A line of levels may be carried with the Locke level for a distance of 400 to 500 feet, provided the length of each sight is not over 50 feet.

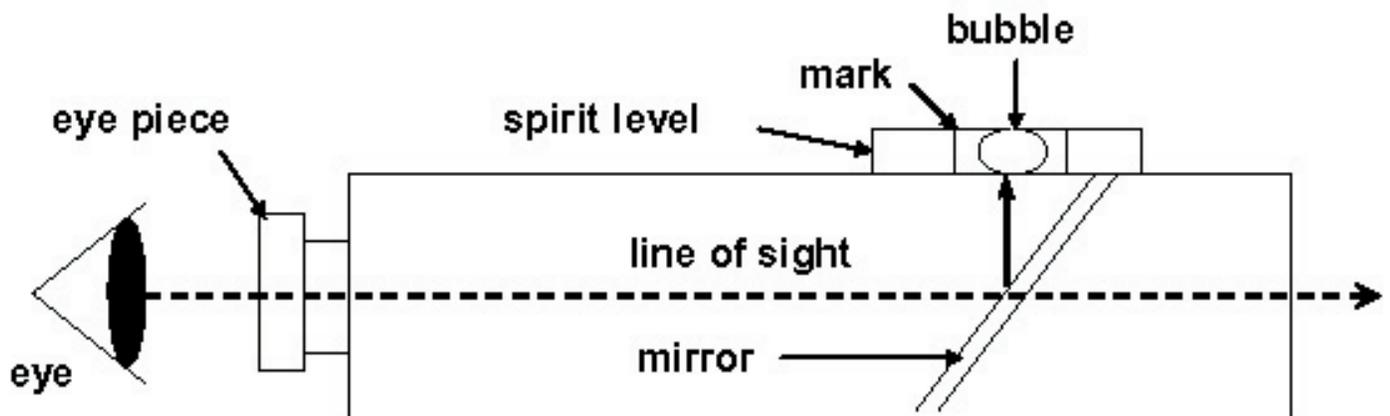
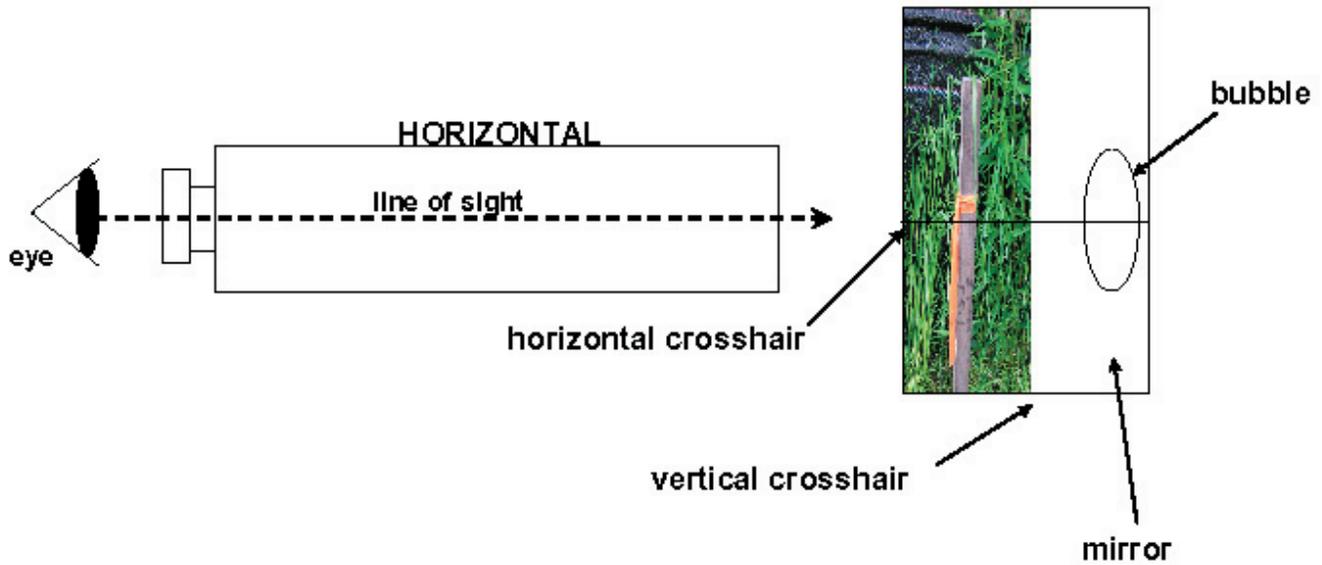


Figure 2.14

When sighting through the Locke level, the bubble should be bisected by the horizontal crosshair to ensure that the instrument is being held level. Move the instrument up and down, keeping the bubble bisected, until the horizontal crosshair is lined up with the target on the stake.

View through the instrument



If the instrument is not being held level, the bubble will not be bisected by the horizontal crosshair.

View through the instrument

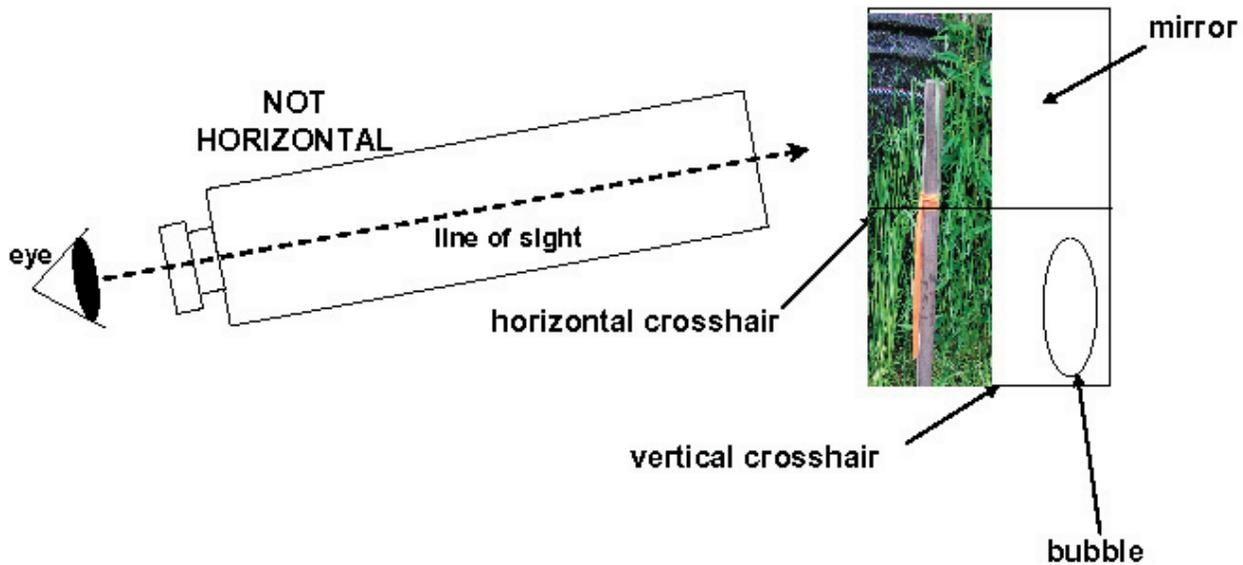


Figure 2.15

DETERMINING FIELD ELEVATIONS

When determining field elevations with a Locke level and folding rule you will typically have two scenarios. If you have a target of known elevation within fifty feet you will be able to take a direct shot with the hand level. If the target is more than fifty feet away you will need to take a series of fifty foot shots to the target.

Now let's go through an example where there is a target of known elevation within fifty feet. A grade stake will most often be the nearest target of known elevation. A grade stake will typically be adjacent to a hub of known elevation or lacking a hub the stake marks the elevation of the ground surface at the base of the stake. Either the hub or the ground surface will be your target.



Hold the six foot folding rule vertically with one end resting on the ground surface where your want to check the elevation.



Use the folding rule as a guide for the Locke level as you sight through it to the mark on the grade stake.



Move the Locke level up or down the rule until the crosshairs in the level are on the target mark and the bubble indicates you are holding the Locke level horizontally.

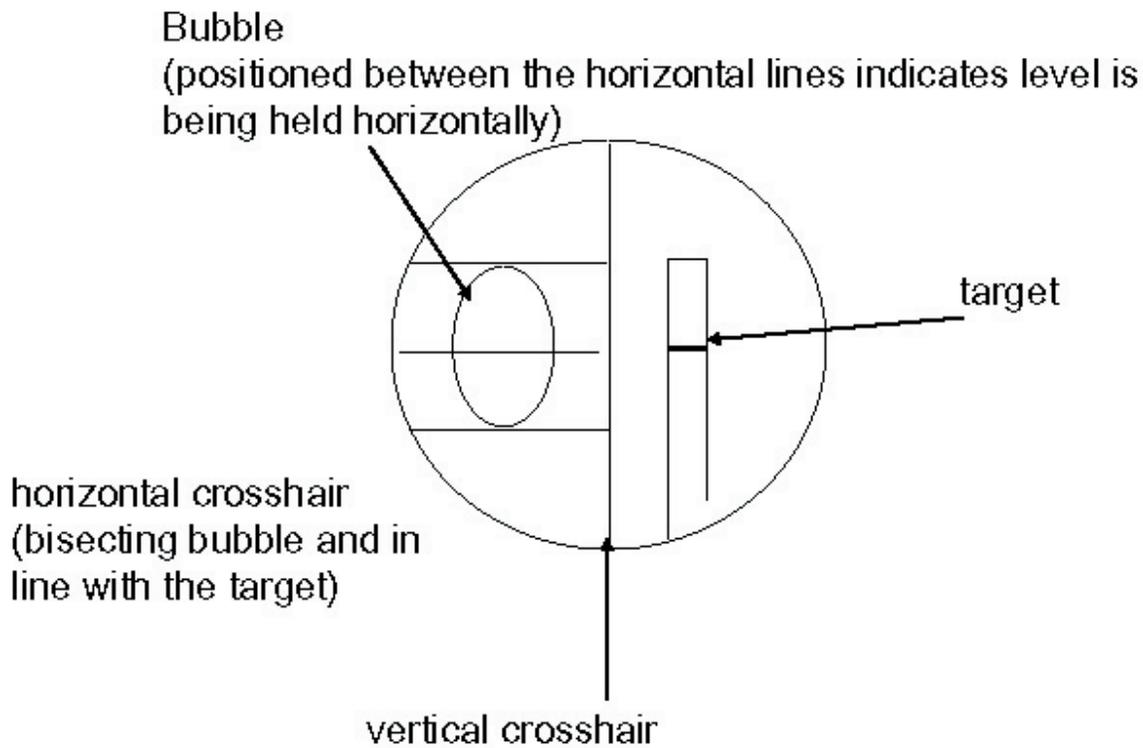


Figure 2.16

Note the reading on the rule adjacent to the Locke level's position when it is horizontal and in line with the target. This reading is your height of instrument (HI), record this reading.

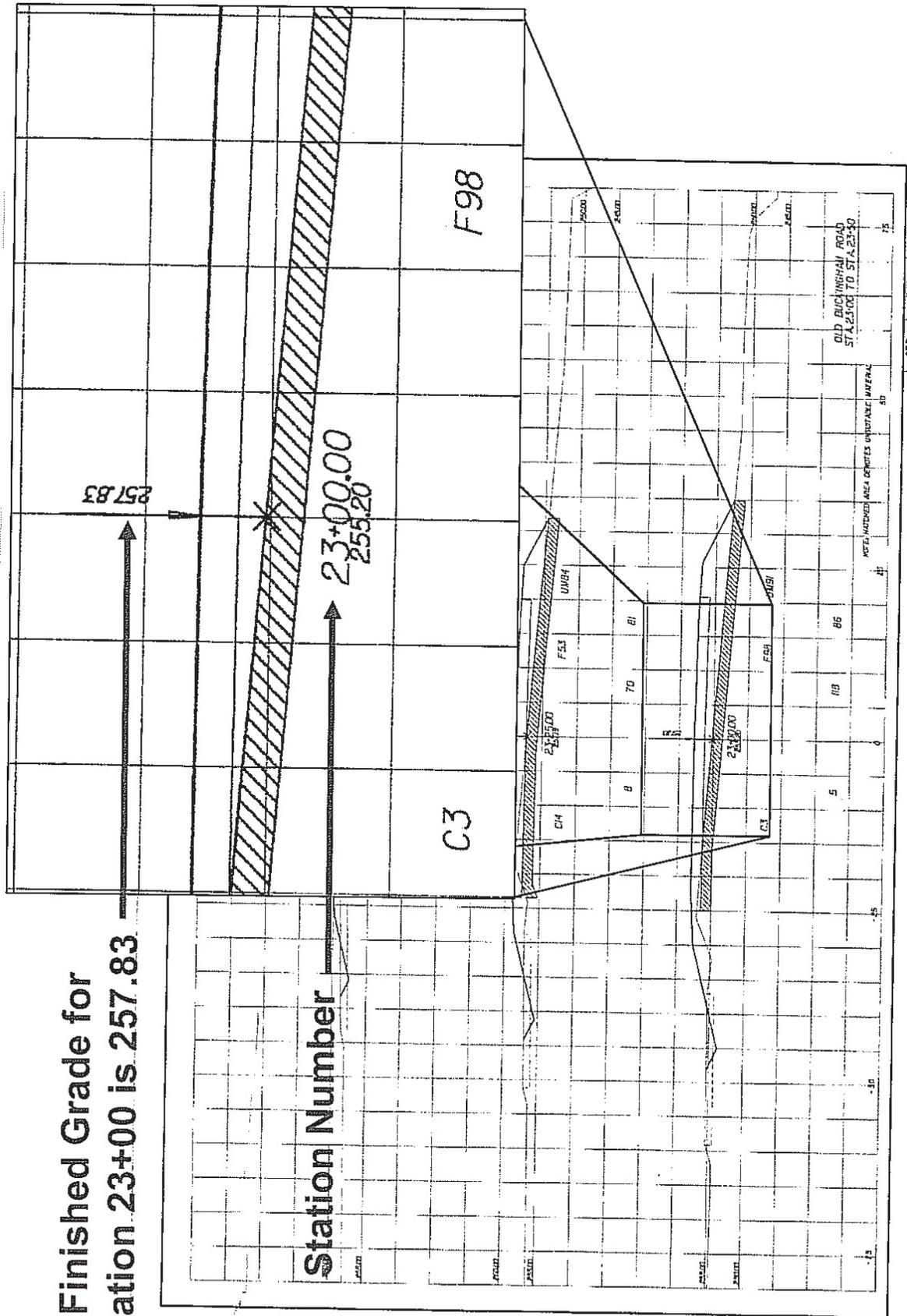


Now you must determine the elevation of your target. Grade stakes will usually have the station number and a reference elevation marked on them. In this example F 5.1 is the reference elevation and tells us finished grade is 5.1 feet above the base of the stake. The station number for this location is 23+00.



Next you will need to find the cross section sheet for Station 23+00. The cross section sheets are located in the project plans. From the cross section sheet we determine that the finished grade elevation at Station 23+00 is 257.83 feet.

Figure 2.17



With the finished grade elevation and the reference elevation from the stake, calculate the elevation of the target at the stake. Once you have the elevation of your target, subtract the reading you obtained from the rule (HI) to give you the actual surface elevation at the site of your elevation check.

Finished Grade Elevation - Reference Elevation = Target Elevation

Target Elevation - Height of Instrument (HI) = Surface Elevation

Lets look at the numbers from our example. Our finished grade elevation from the cross section sheet is 257.83 ft. and our reference elevation from the grade stake is 5.1 ft. Subtract the reference elevation from the finished grade elevation to get a target elevation of 252.73 ft.

Now subtract the HI reading from the target elevation to get a surface elevation of 248.65 ft. at the site of your elevation check.

If your target is further than fifty away, the hand level can not be used to an acceptable degree of accuracy and you must take a series of shots to temporary benchmarks (TBM) you will establish. The TBM's can be stakes driven in the ground with a piece of flagging tied around it or a mark drawn on the stake to serve as your target. They should be spaced about fifty feet apart between the spot where you want to determine the elevation and your point of known elevation.

Starting at the spot where you want to determine the elevation use the hand level and folding rule to shoot forward to the target on the closest TBM and record the HI. Then move up to the TBM, measure the Height of the Target above the ground surface and record. Continue this process until you are able to sight the target of known elevation. You will generate readings similar to the ones in this table from Figure 2-18.

Location	Surface Ele.	HI Reading	Target Height	Target Ele.
Test 201		5.5 ft.	X	X
TBM1	X	5.2 ft.	2.5 ft.	
TBM2	X	3.8 ft.	2.3 ft.	
St. 25+50 O/S Stake	X	X	X	

What is the elevation of test number 201?

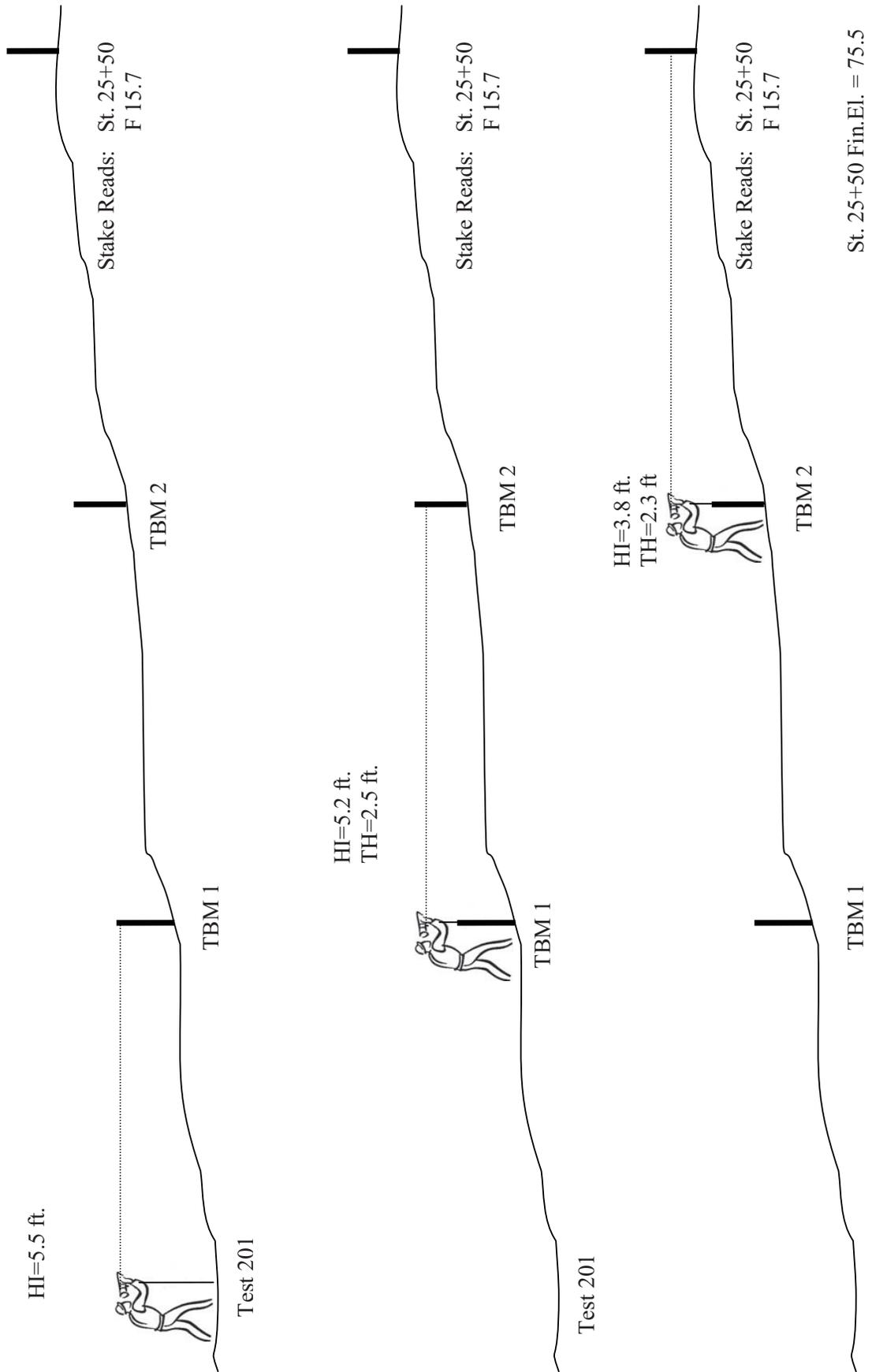


Figure 2.18

From these field readings and the information on the grade stake, the surface elevation at Test 201 can be calculated.

Finished Grade Ele. - Reference Ele. = Target Ele.

Finished Grade @ St. 25+50 = 75.5 ft. (from plans)
Reference Ele. @ St. 25+50 = 15.7 ft. (from stake)

Target Ele. @ St. 25+50 = 75.5 - 15.7 = 59.8 ft.

Location	Surface Ele.	HI Reading	Target Height	Target Ele.
Test 201		5.5 ft.	 	
TBM1	 	5.2 ft.	2.5 ft.	
TBM2	 	3.8 ft.	2.3 ft.	
St. 25+50 O/S Stake	 	 	 	59.8 ft.

Target Ele._{St. 25+50} - (HI_{TBM2} - TH_{TBM2}) = Target Ele._{TBM2}

Target Ele._{St. 25+50} = 59.8 ft.
HI_{TBM2} = 3.8 ft.
TH_{TBM2} = 2.3 ft.

Target Ele._{TBM2} = 59.8 - (3.8 - 2.3) = 58.3 ft.

Location	Surface Ele.	HI Reading	Target Height	Target Ele.
Test 201		5.5 ft.	 	
TBM1	 	5.2 ft.	2.5 ft.	
TBM2	 	3.8 ft.	2.3 ft.	58.3 ft.
St. 25+50 O/S Stake	 	 	 	59.8 ft.

$$\text{Target Ele.}_{\text{TBM2}} - (\text{HI}_{\text{TBM1}} - \text{TH}_{\text{TBM1}}) = \text{Target Ele.}_{\text{TBM1}}$$

$$\text{Target Ele.}_{\text{TBM2}} = 58.3 \text{ ft.}$$

$$\text{HI}_{\text{TBM1}} = 5.2 \text{ ft.}$$

$$\text{TH}_{\text{TBM1}} = 2.5 \text{ ft.}$$

$$\text{Target Ele.}_{\text{TBM1}} = 58.3 - (5.2 - 2.5) = 55.6 \text{ ft.}$$

Location	Surface Ele.	HI Reading	Target Height	Target Ele.
Test 201		5.5 ft.		
TBM1		5.2 ft.	2.5 ft.	55.6 ft.
TBM2		3.8 ft.	2.3 ft.	58.3 ft.
St. 25+50 O/S Stake				59.8 ft.

$$\text{Target Ele.}_{\text{TBM1}} - \text{HI}_{\text{Test 201}} = \text{Surface Ele.}_{\text{Test 201}}$$

$$\text{Target Ele.}_{\text{TBM1}} = 55.6 \text{ ft.}$$

$$\text{HI}_{\text{Test 201}} = 5.5 \text{ ft.}$$

$$\text{Surface Ele.}_{\text{Test 201}} = 55.6 - 5.5 = 50.1 \text{ ft.}$$

Location	Surface Ele.	HI Reading	Target Height	Target Ele.
Test 201	50.1 ft.	5.5 ft.		
TBM1		5.2 ft.	2.5 ft.	55.6 ft.
TBM2		3.8 ft.	2.3 ft.	58.3 ft.
St. 25+50 O/S Stake				59.8 ft.

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 FILLS

What the specifications say about...

- **Placing method**
- **Lift thickness**
- **Rock size**
- **Moisture**
- **Testing**

PLACING ROCK FILLS

- **Use same guidelines as for embankment**
- **Uniform layers**
- **Spread across the entire width of embankment**
- **Surface continuously manipulated and leveled parallel with the finished grade**

PLACING ROCK FILLS

- **End dumping shall be performed by dumping each load on the previously place layer and shoved into place**
- **Dumping material over the edge of the completed work is unacceptable**
- **For uniformity, mix soil, rock spall, and rock dust with large rock**

Rock shall be placed, manipulated, and compacted in uniform layers. Figure 2.19 shows 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.

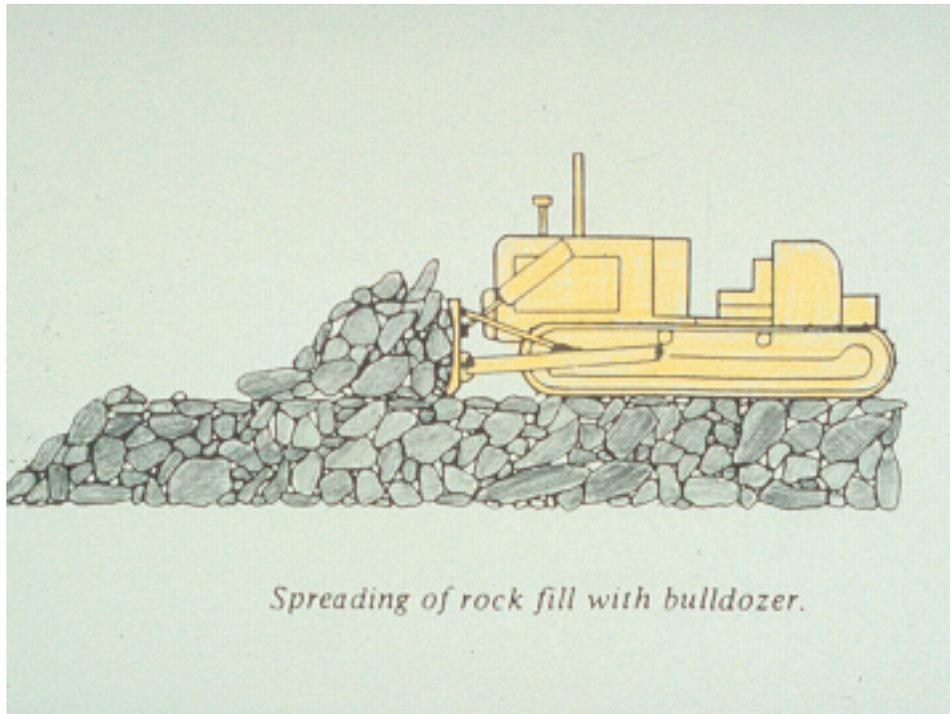


Figure 2.19

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. This is illustrated in Fig. 2.20.

ROCK FILLS

**Lift thickness and rock size depend on where you
are relative to the top of the subgrade**

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.

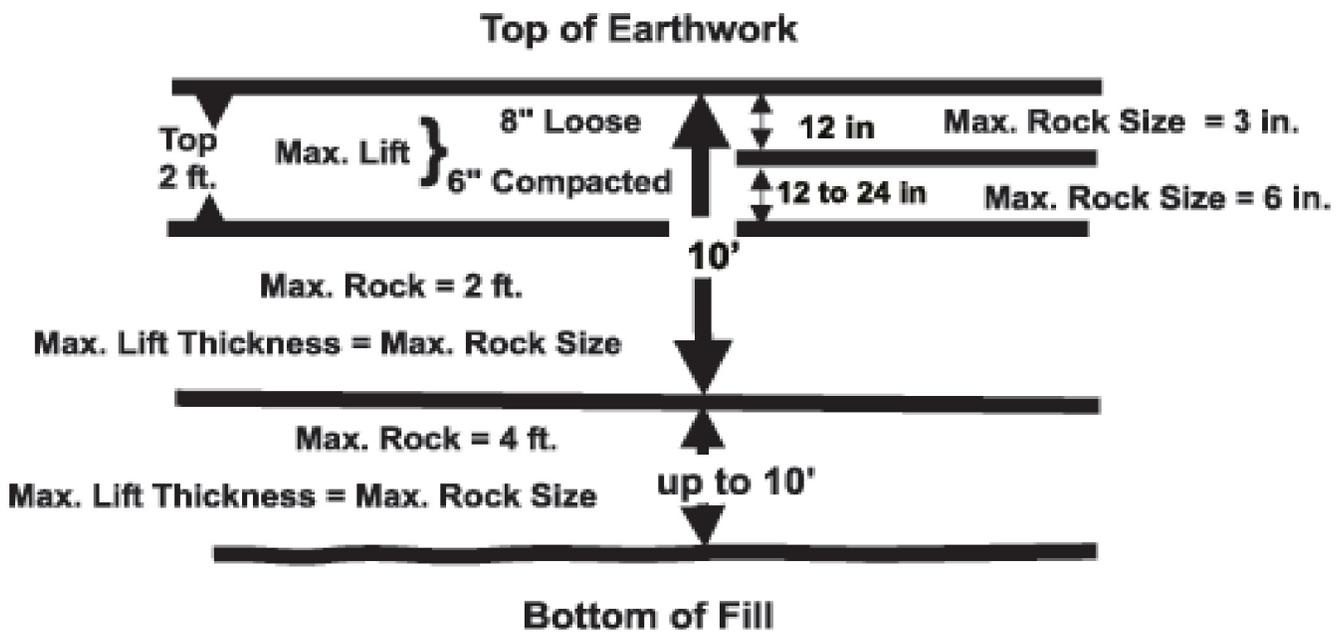


Figure 2.20

ROCK FILLS

- 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.

SLOPES

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.

To Keep Water Out of the Face of the Slope:

- Minimize storm runoff from getting to the slope by using water diversion techniques
- Compact slope face
- Maintain incremental seeding

The problem of water intrusion can be minimized by following sound construction practices. Methods for grading to drain as outlined on page 2-7 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 - 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 EMBANKMENTS ON EXISTING EMBANKMENTS OR HILLSIDES

- **To ensure stability of the new embankment we must provide for a foundation and a 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. Figure 2.21 illustrates 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.

Typical Cross Section Benches at Cut/Fill Transition

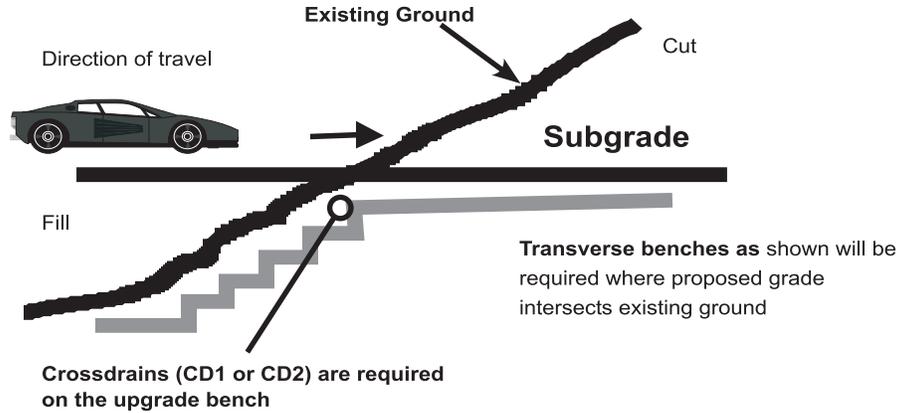


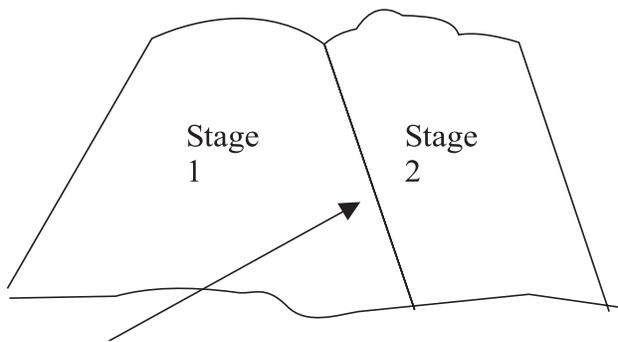
Figure 2.21

BENCHING

Bench old embankment when constructing new embankment...

- 1/2 width at a time
- Against existing embankments/hillsides
- Where new embankment crosses existing embankment at a skew of 30 degrees or more & existing slope is steeper than 4H:1V

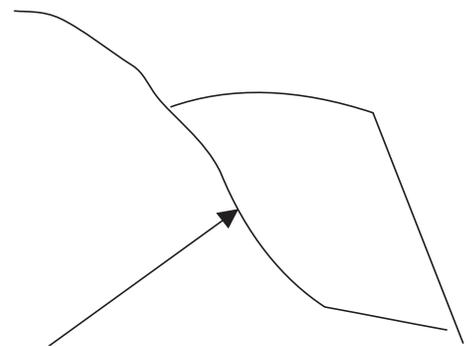
1/2 WIDTH AT A TIME



BENCH THIS SLOPE

Figure 2.22

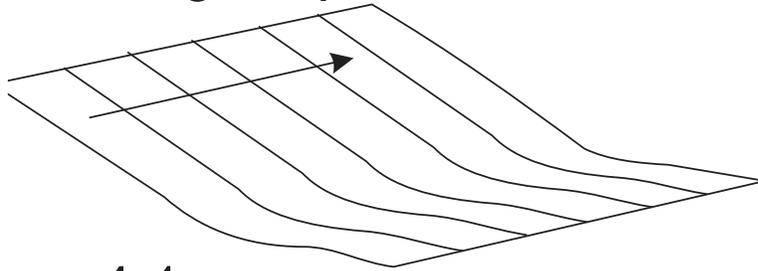
AGAINST EXISTING HILLSIDE



BENCH THIS SLOPE

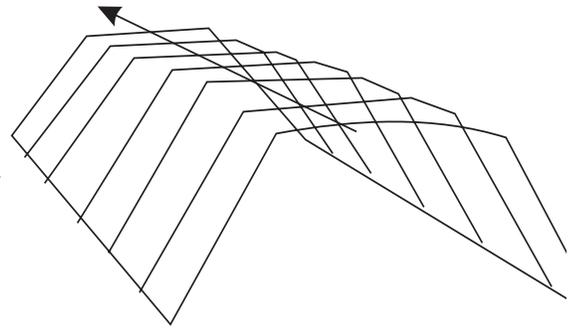
Figure 2.23

Existing Slope

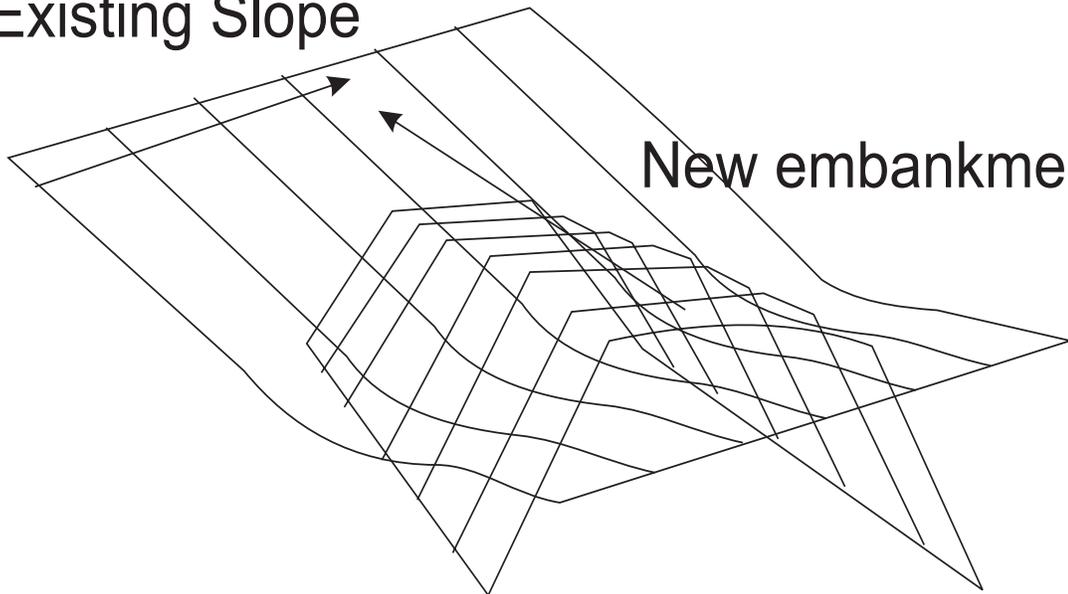


> 4.1

New embankment



Existing Slope



New embankment

Bench Existing Slope

Figure 2.24

When benching slopes steeper than...
4:1

But not steeper than...

1 1/2:1

Minimum bench width = ?

When benching slopes steeper than...

1 1/2:1

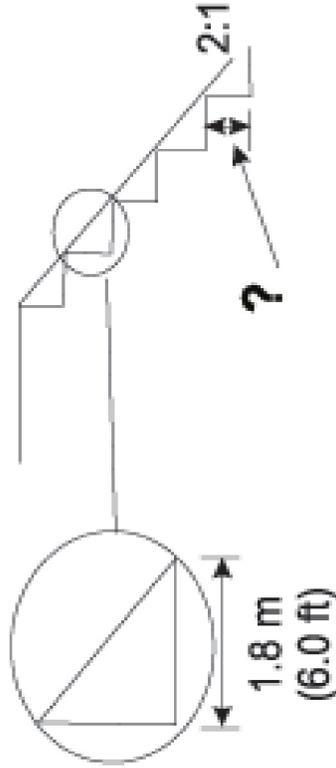
But not steeper than...

1/2:1

Minimum bench width = ?

When benching slopes steeper than...
4:1 but not steeper than 1 1/2:1

Minimum bench width - 1.8 m (6.0 ft)



When benching slopes steeper than...
1 1/2:1 but not steeper than 1/2:1

Minimum bench width - 1.2 m (4.0 ft)

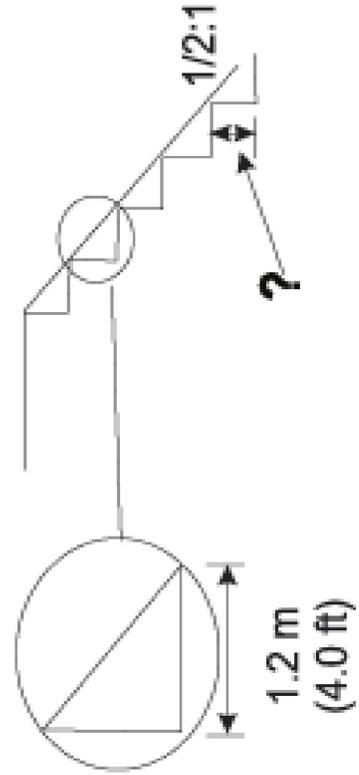
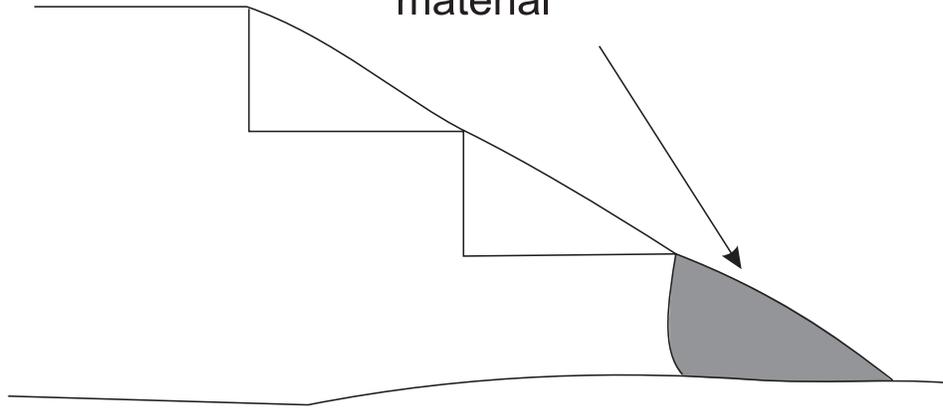


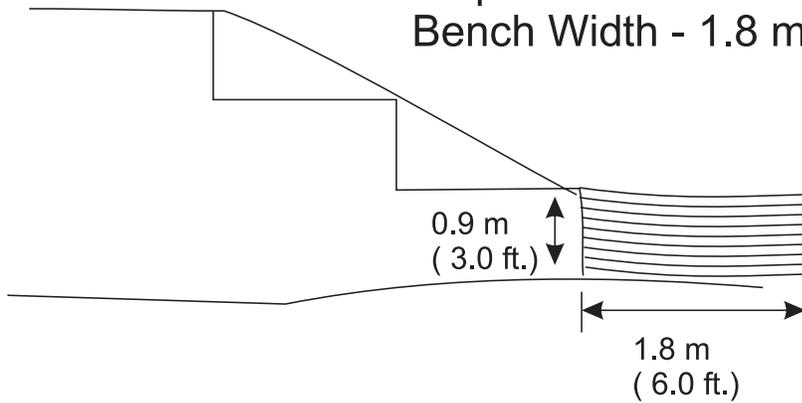
Figure 2.25

Re-compacted along
with new embankment
material



First Bench

Slope = 2:1
Bench Width - 1.8 m (6.0 ft.)



2nd Bench

Slope = 2:1
Bench Width - 1.8 m (6.0 ft.)

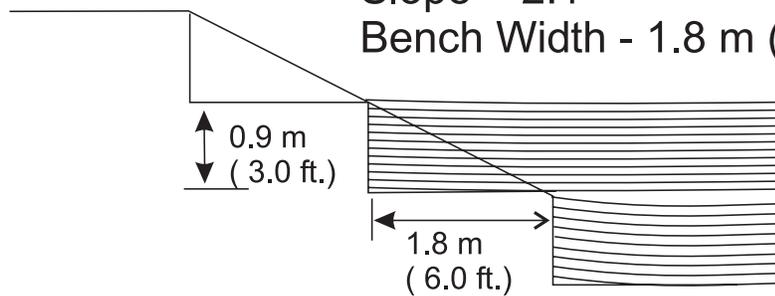


Figure 2.26

INTRODUCTION TO TESTING

DENSITY TESTING

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. It may also be necessary to take more proctor tests when the weather changes. Temperature, for example, can have a definite affect on the maximum density that can be achieved with some soils.

There are a number of density test methods available for compaction control. These have previously been covered in detail and will be briefly discussed. The important point to keep in mind when taking density tests is that the test should make sense when compared to actual field observations.

Field Density Testing Methods

- **Virginia Test Method (VTM) 10 (Nuclear Gauge)**
- **AASHTO T310 (Nuclear Gauge)**
- **AASHTO T191 (Sand cone)**

Field density determinations will be performed in accordance with the requirements of AASHTO T191 (Density of Soil In-Place by Sand Cone Method) modified to include material sizes used in the laboratory determination of density, with a portable nuclear field density testing device in accordance with VTM-10 or AASHTO T310, or by other approved methods. 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.

NUCLEAR TESTING

This 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 lb/ft^3 and moisture in lb/ft^3 . The moisture is subtracted from the total density and this value is compared to the maximum dry density obtained from the Proctor test.

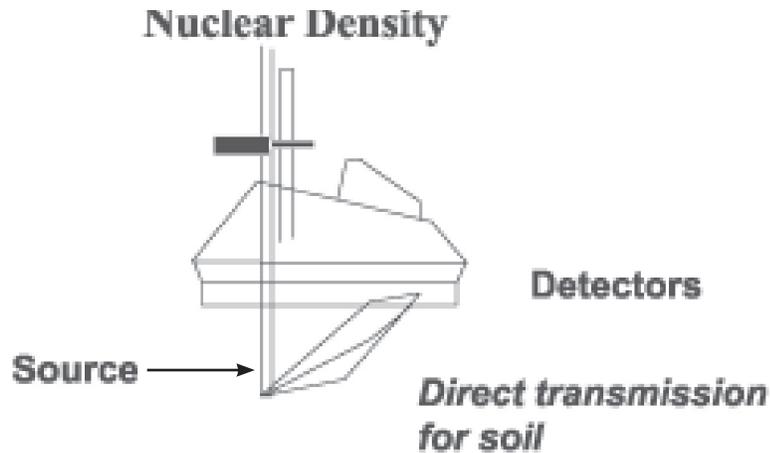


Figure 2.27

SAND CONE TEST

The Sand Cone Test (AASHTO Test Method T191) is usually referred to as "Conventional" density testing. It involves digging a test hole and finding the weight of the resulting sample. The volume of the hole is then measured by filling it with sand of known weight per unit volume. The actual density is calculated and this value is compared to the maximum dry density obtained from the Proctor test.

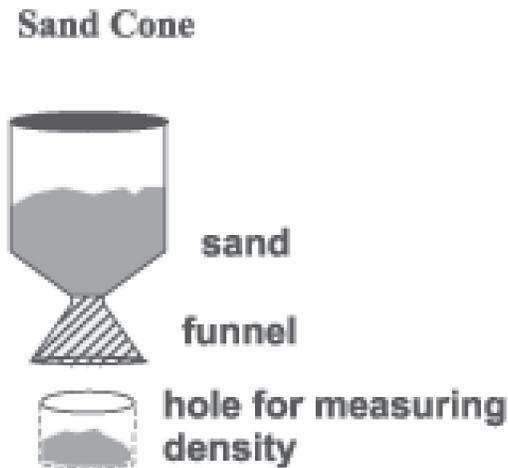


Figure 2.28

DENSITY SPECIFICATIONS FOR EMBANKMENT

- **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:

$$\frac{\text{Weight of wet soil} - \text{Weight of dry soil}}{\text{Weight of dry soil}} \times 100 =$$

$$\frac{\text{Weight of water}}{\text{Weight of dry soil}} \times 100 = \text{Moisture Content}$$

SPEEDY MOISTURE TESTER

This is the most widely used method for checking moisture, besides perhaps the nuclear gauge. It’s 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 it’s 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.

MOISTURE DENSITY RELATIONSHIPS

Every soil has one particular moisture content, known as optimum moisture, at which that soil can be compacted to it’s 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.

Take the results from the VTM-10 or AASHTO T191 and compare to the results of the proctor (VTM-1 or VTM-12) to determine the percentage density obtained.

Fig. 2.29 shows the relationship between moisture content and dry density for a soil compacted with the same compactive effort at varying moisture contents.

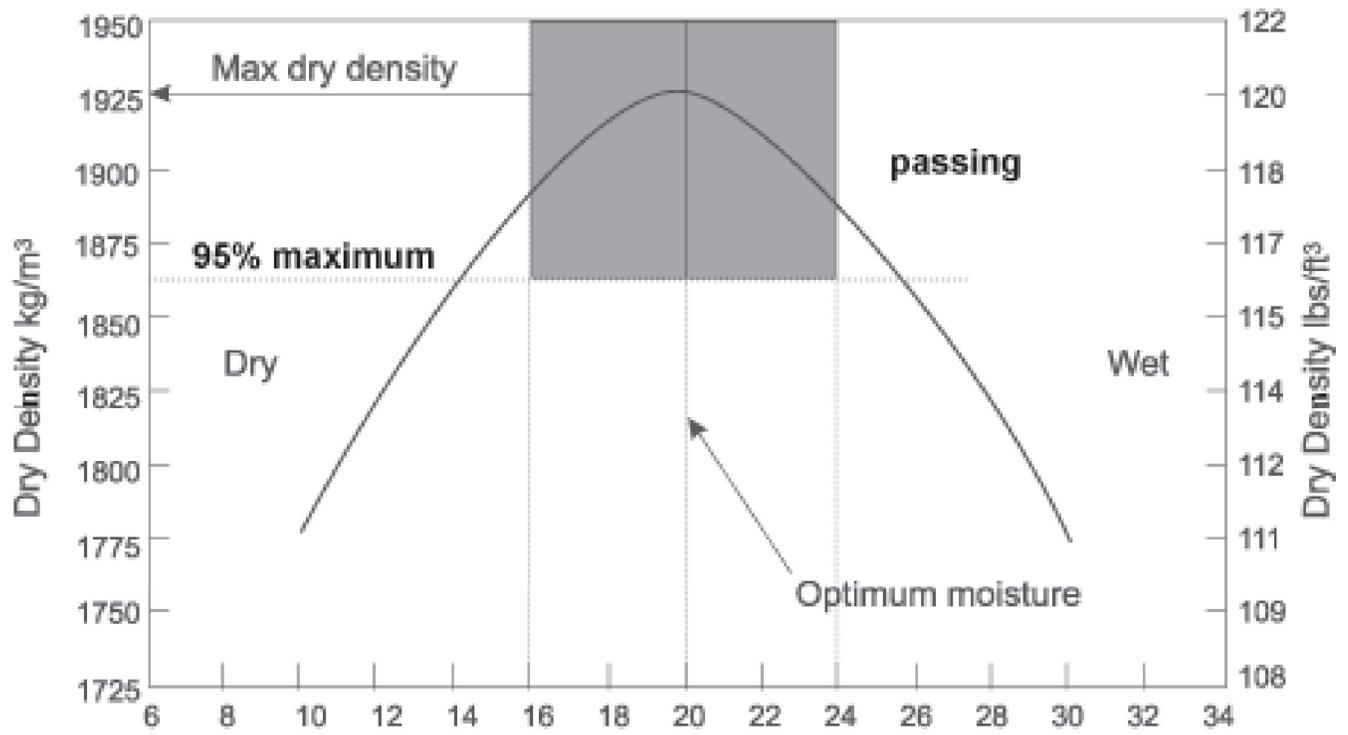


Figure 2.29

MOISTURE SPECIFICATIONS

Moisture Specifications

- Optimum moisture $\pm 20\%$ of optimum moisture for soils
- Optimum moisture ± 2 percentage points of optimum moisture for aggregates

For both the subgrade and embankment, the specifications require that each lift be compacted at optimum moisture content, with a tolerance of $\pm 20\%$ of that moisture content. This Specification and the range for a passing test is illustrated in Fig. 2.30. 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 optimum. The following examples illustrate how these specifications are applied.

MOISTURE LIMITS EXAMPLE - SOILS

Given: OMC = 20%

Find Range ($\pm 20\%$): $20\% \times 0.20 = 4\%$

Upper Limit: $20\% + 4\% = 24\%$

Lower Limit: $20\% - 4\% = 16\%$

Acceptable Moisture Range: 16% to 24%

MOISTURE LIMITS EXAMPLE - SOILS

Given: OMC = 15%

Find Range ($\pm 20\%$): $15\% \times 0.20 = 3\%$

Upper Limit: $15\% + 3\% = 18\%$

Lower Limit: $15\% - 3\% = 12\%$

Acceptable Moisture Range: 12% to 18%

MOISTURE LIMITS EXAMPLE - AGGREGATES

Given: OMC = 8%

Find Range (± 2 percentage points)

Upper Limit: $8\% + 2.0\% = 10.0\%$

Lower Limit: $8\% - 2.0\% = 6.0\%$

Acceptable Moisture Range: 6.0% to 10.0%

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.

INSURING 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.

MOISTURE TOO HIGH...

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

MOISTURE TOO LOW...

- **Add water**
- **Thoroughly mix**

MOISTURE THAT IS 30% ABOVE OPTIMUM

- **Can be placed on grade for the purpose of drying**
- **Must demonstrate no detrimental affect to previously placed layer**

TESTING RATES

DENSITY TESTING RATES FOR ACCEPTANCE

- Embankment
- Bridge abutment/retaining walls
- MSE Walls

The minimum rates of acceptance testing for all the materials in this course are presented in Appendix B. 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. These rates of acceptance testing were written before the nuclear density gauge was in widespread use (when compaction testing was done by the sand-cone or balloon method). Today, using the nuclear gauge and "Speedy", testing can be done in a mere fraction of the time it used to take. The testing rates are in the process of being revised to reflect this new technology.

Figures 2.30 & 2.31 illustrate the minimum rate of density testing required for acceptance.

EMBANKMENT SOILS

TESTING RATE DEPENDS ON LENGTH OF FILL

LESS THAN 500 ft.

FROM 500 TO 2000 ft.

GREATER THAN 2000 ft.

**FILLS LESS THAN 500 FEET
ONE FIELD DENSITY TEST FOR
EACH 2,500 YD³ FROM BOTTOM TO TOP OF FILL
PLUS ONE FIELD DENSITY TEST FOR
EVERY OTHER 6" LIFT STARTING WITH THE SECOND LIFT**

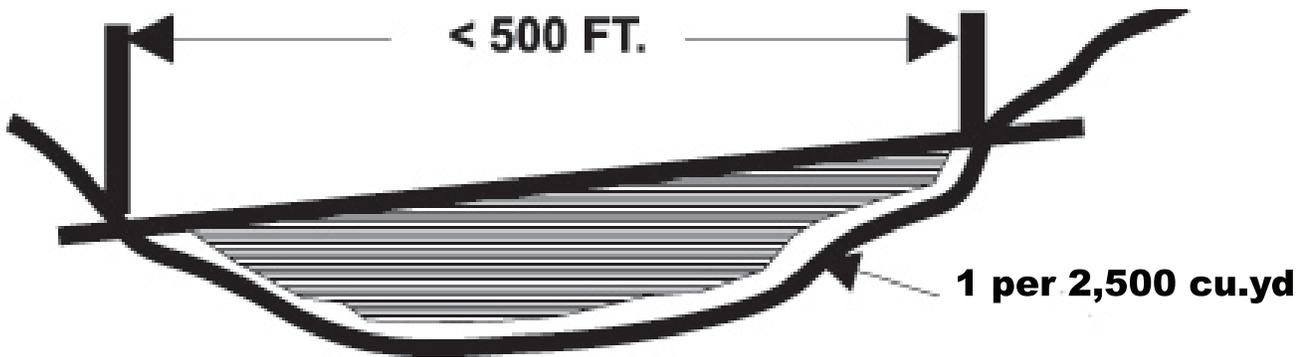


Figure 2.30

**FILLS FROM 500 - 2000 FEET
ONE FIELD DENSITY TEST FOR
EACH 2,500 YD³ FROM BOTTOM TO TOP OF FILL
PLUS TWO FIELD DENSITY TESTS FOR
EVERY 6" LIFT WITHIN TOP 5' OF FILL**

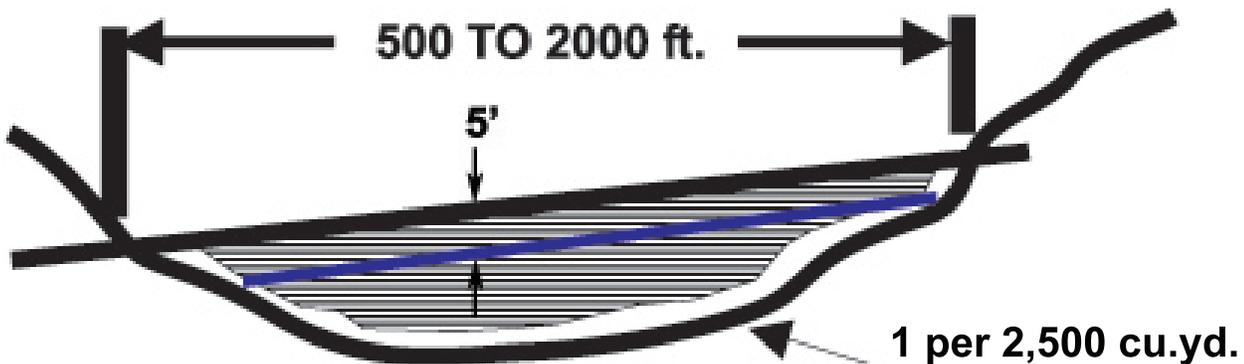
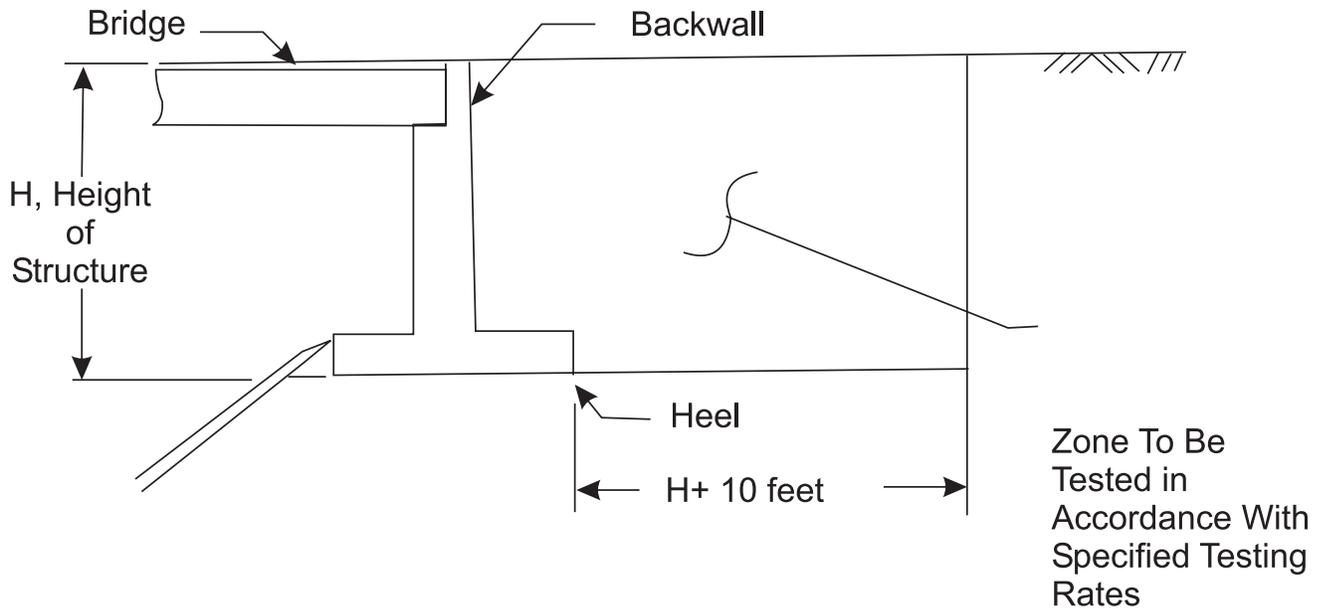


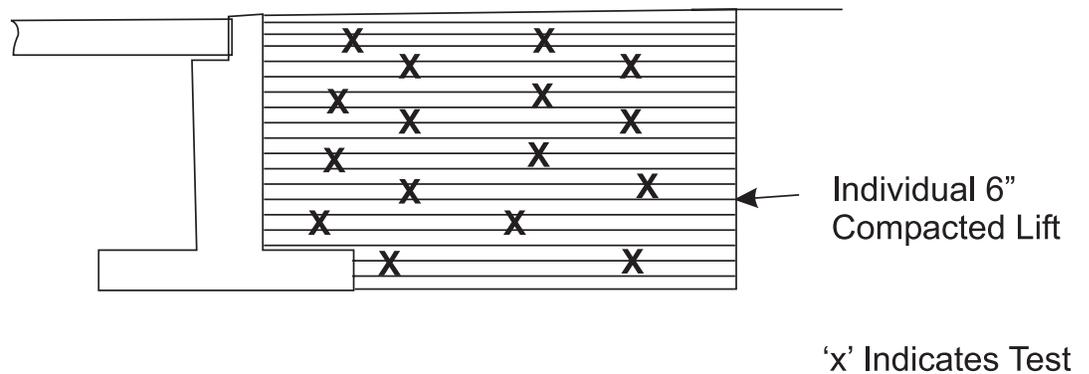
Figure 2.31

Frequency of Testing For Backfill Behind Abutments, Gravity and Cantilever Retaining Walls

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



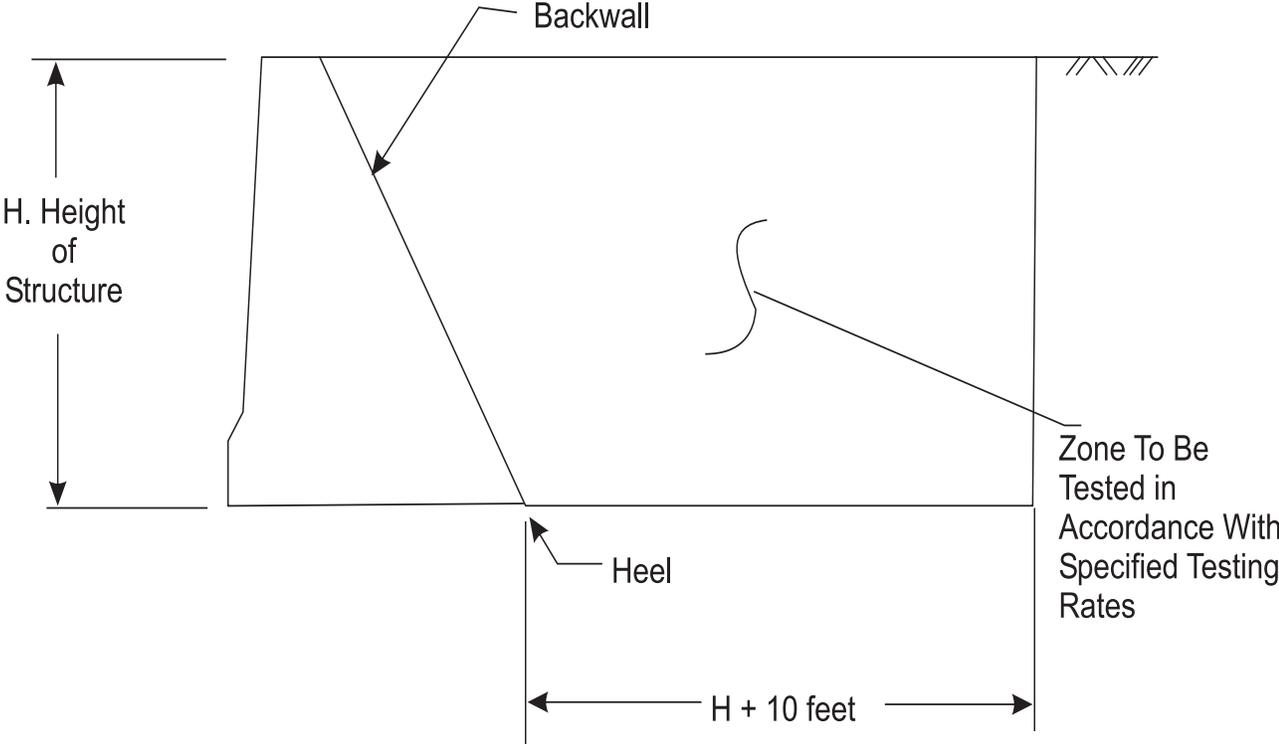
Rate of Testing



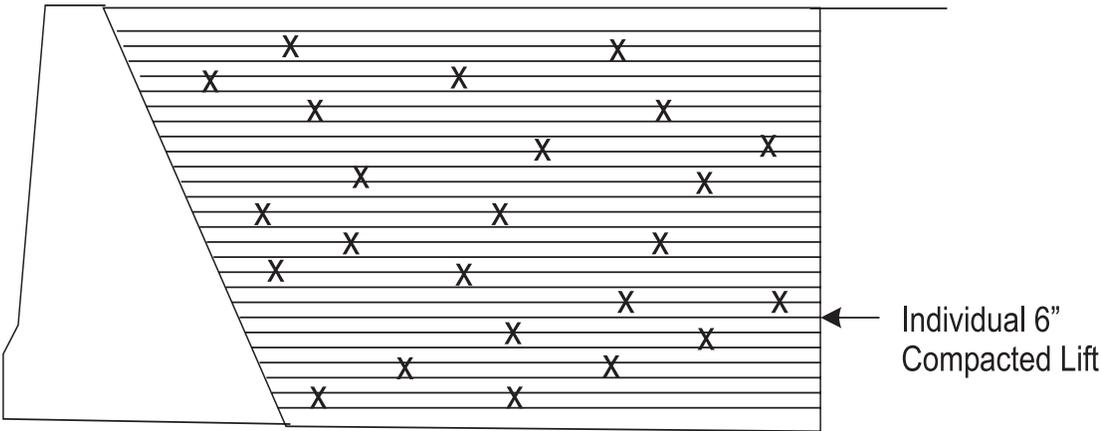
* Two Tests Every Other Lift

Figure 2.32

Gravity Retaining Wall Zone To Be Tested



Rate of Testing



* Two Tests Every Other Lift

'x' Indicates Test

Figure 2.33

Frequency of Testing 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 8 feet away from the back-face 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.

Walls more than 100 linear feet, a minimum of two tests every other lift not to exceed 200 linear feet.

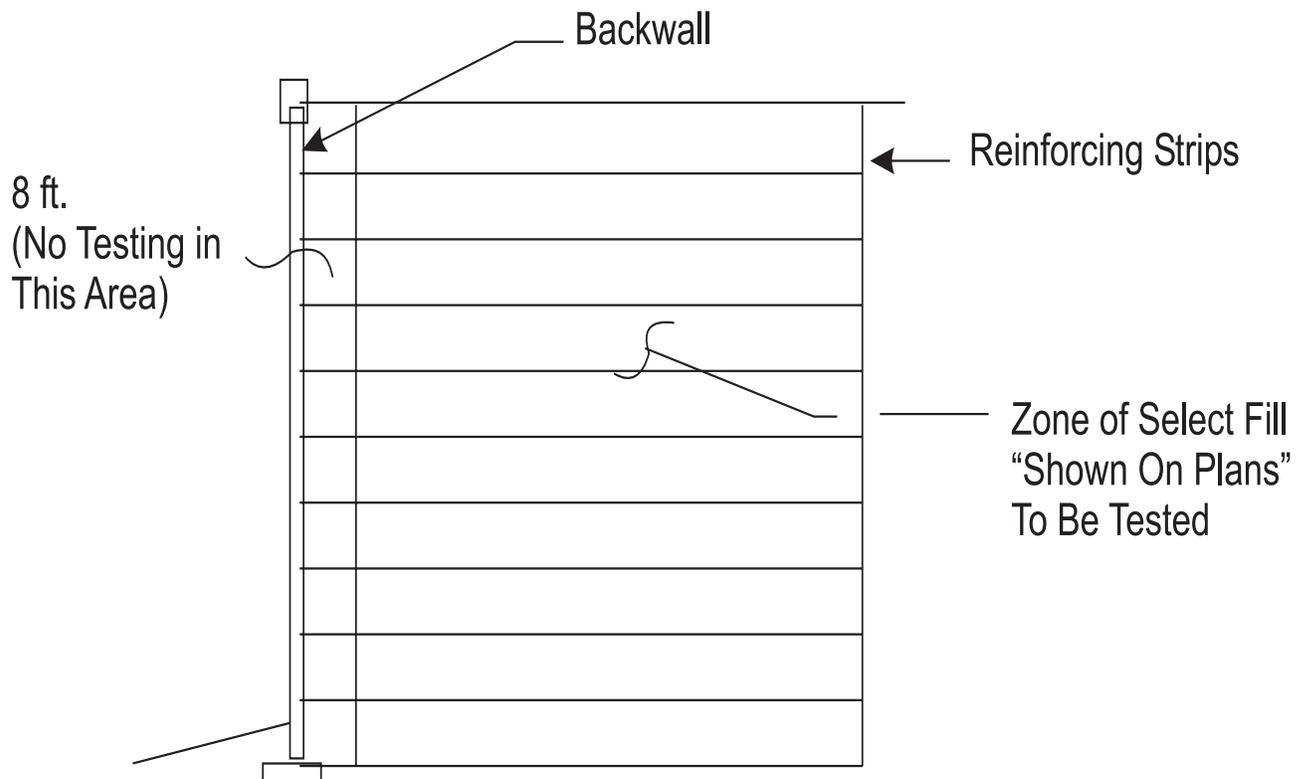


Figure 2.34

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

UNSUITABLE MATERIALS

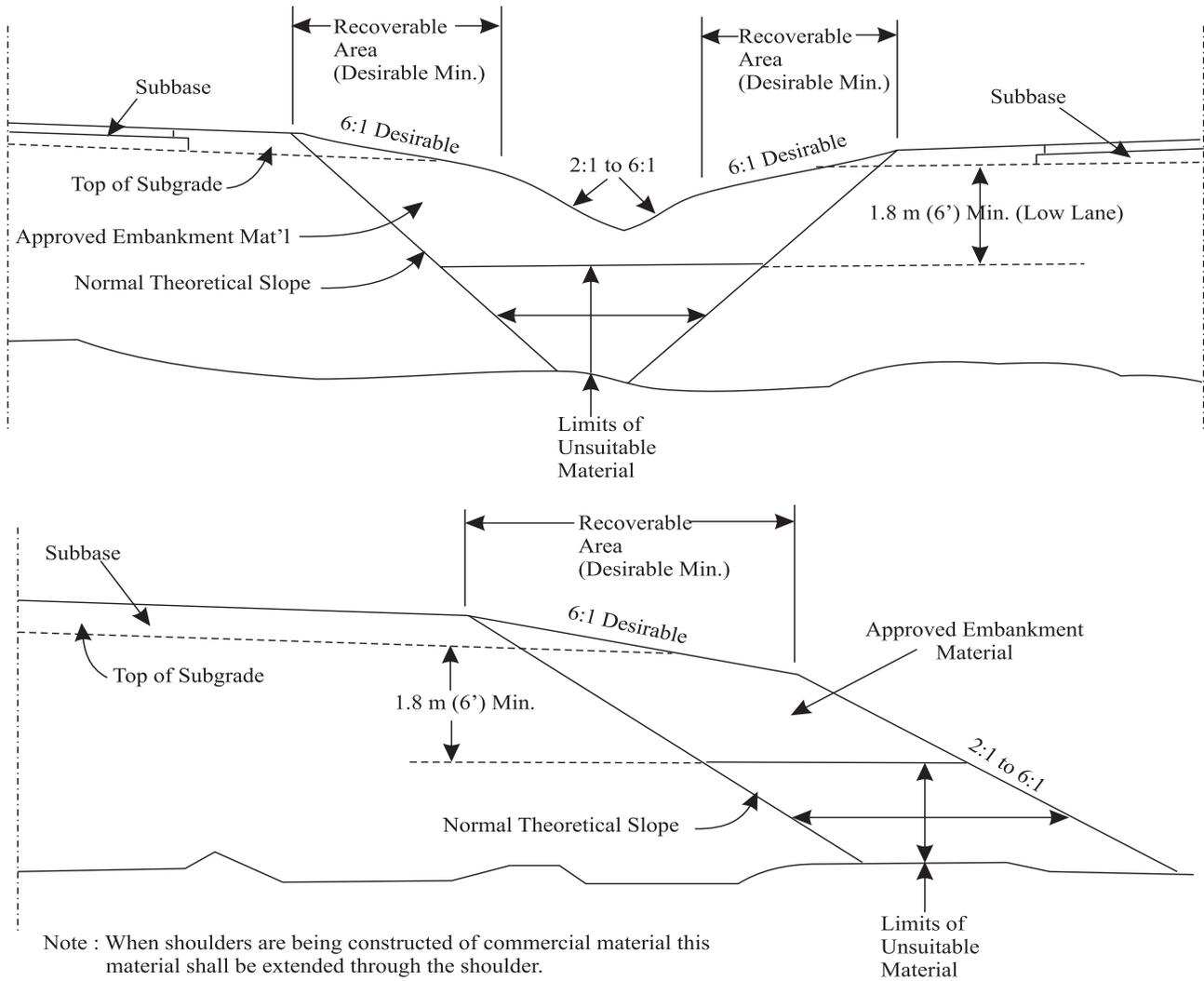
VDOT accepts a wide variety of materials for use in embankments. The only soils that will not be accepted are topsoil, rootmat, any soil containing organic matter, saturated or highly plastic soils. Saturated or highly plastic soils have little load bearing capacity and would pump and rut significantly 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.

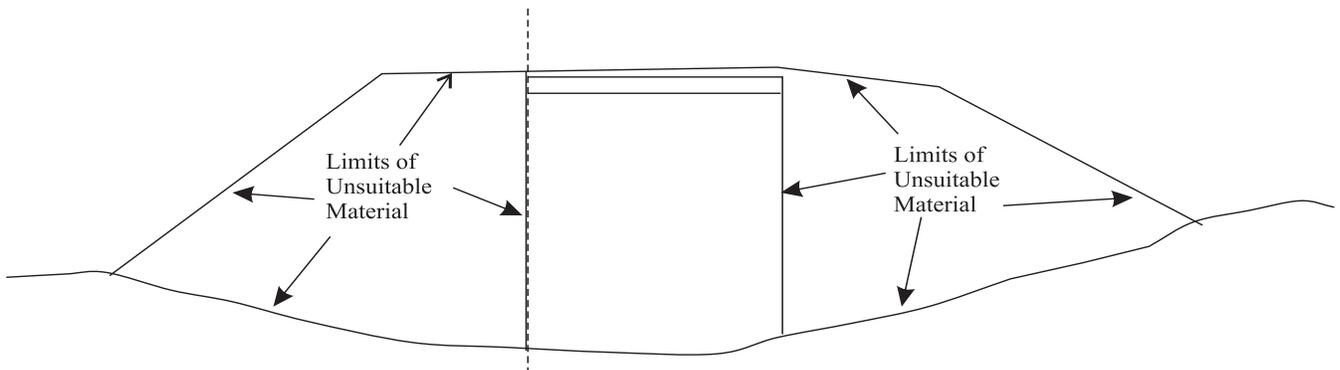
The unsuitable materials do have one useful purpose in that they can be placed on the outside slope of embankments to make the overall slope angle flatter, thereby improving the stability of the slope. In order to avoid adversely affecting the drainage of the pavement, unsuitable materials cannot be placed within 6 feet of the top of the embankment. (see Fig. 2.35)

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.

TYPICAL METHOD OF PLACING UNSUITABLE MATERIAL



INCORRECT METHOD OF PLACING UNSUITABLE MATERIAL



Note : Experience has shown that it is impossible to construct fill with a vertical line clearly separating the good material and the unsuitable material.

Figure 2.35

CHAPTER 2

Study Questions

1. True or False. Clearing and Grubbing is required in fill sections less than 5 ft. 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.
 - 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 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 fills less than 500 feet long?
15. What is the density testing rate for fills 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 more than 30% above optimum can be placed on a previously placed layer for drying, unless it is shown that _____ .
18. The typical lift thickness for soil is _____ loose, _____ compacted.

CHAPTER 2

Practice Problems

Practice Problem 1

Using the given information determine the surface elevation at Sta.25+35.

Finished Grade Elevation at Sta.25+00 = 260.6 ft.

Reference Elevation = F 4.9

Height of Instrument = 5.2 ft.

Finished Grade Elevation - Reference Elevation = Target Elevation

Target Elevation - Height of Instrument (HI) = Surface Elevation

Practice Problem 2

Using the given information determine the surface elevation at Sta.36+25.

Finished Grade Elevation at Sta.36+00 = 321.4 ft.

Reference Elevation = F 5.1

Height of Instrument = 4.8 ft.

Finished Grade Elevation - Reference Elevation = Target Elevation

Target Elevation - Height of Instrument (HI) = Surface Elevation

Practice Problem 3

The known elevation is greater than 50 feet away. Using the given information determine the Surface Elevation at Test 295, the thickness of the lift, and if it meets specifications.

Reading on Sta. 27+50 O/S Stake = F 15.8

Finished Grade at Sta.27+50 = 625.3 ft.

Previous Elevation at Test 295 = 600.9 ft.

Location	Surface Ele.	HI Reading	Target Height	Target Ele.
Test 295		5.1 ft.	 	
TBM1	 	4.0 ft.	2.7 ft.	
TBM2	 	4.8 ft.	3.0 ft.	
St. 27+50 O/S Stake	 	 	 	

Practice Problem 4

The known elevation is greater than 50 feet away. Using the given information determine the Surface Elevation at Test 212, the thickness of the lift, and if it meets specifications.

Reading on Sta. 32+00 O/S Stake = F 5.8

Finished Grade at Sta.32+00 = 595.5 ft.

Previous Elevation at Test 212 = 590.1 ft.

Location	Surface Ele.	HI Reading	Target Height	Target Ele.
Test 212		5.0 ft.	 	
TBM1	 	4.5 ft.	2.8 ft.	
TBM2	 	5.2 ft.	3.0 ft.	
St. 32+00 O/S Stake	 	 	 	