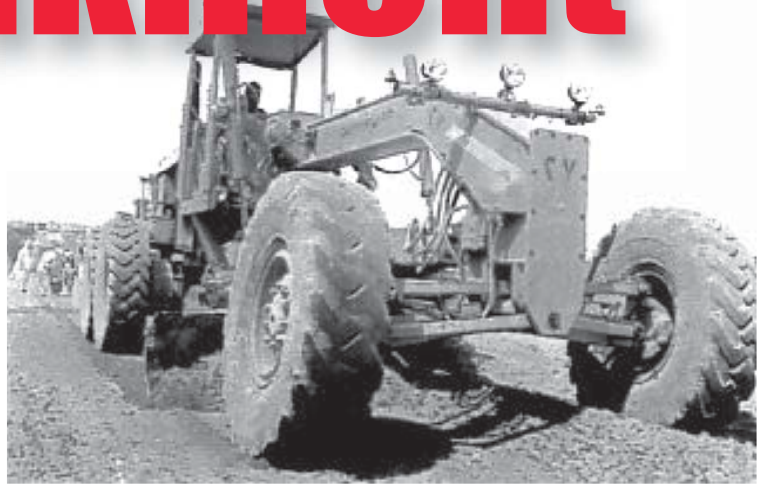


Excavation and Embankment



EXCAVATION & EMBANKMENT INSPECTION

The area of excavation and embankment inspection has become a complex task. An inspector should be familiar with all equipment, testing, and work procedures utilized during this phase of construction. If the embankment and foundation of a roadway are not properly constructed, only poor performance can be expected from any surface pavement. Therefore, an inspector must be able to make accurate decisions in the field while construction is in progress. This study course is designed to provide the background knowledge which, coupled with experience, will prepare the inspector of excavation and embankment to perform his/her duties.

By providing you with the excavation and embankment information, this course will periodically test your recall on that information. This method reinforces what you have just read -enabling you to retain the information longer than by traditional methods of instruction such as lecture and textbook.

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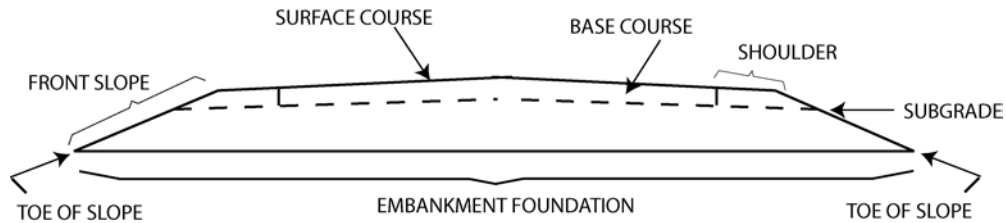
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CHAPTER 1

INTRODUCTION TO THE ROADWAY



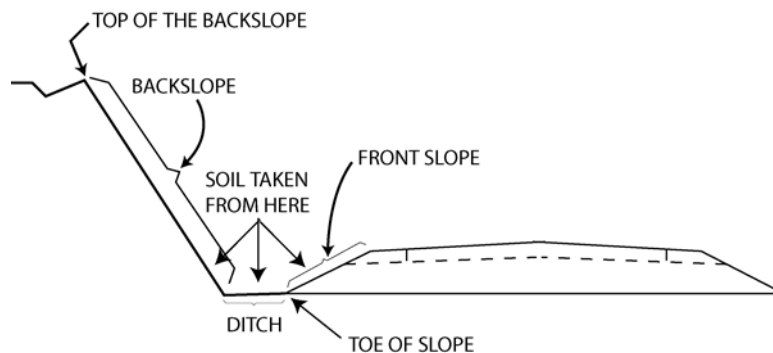
The above diagram is a cross section of a roadway. After the natural ground has been properly prepared, it becomes the embankment foundation. The embankment foundation is the support surface on which the embankment is constructed. Also an inspector must recognize drainage patterns that require special types of construction control measures.

An inspector should study and know the topography (land configuration) of the project. The embankment consists of soil that is placed on the embankment foundation in order to raise the level of the roadway to the correct grade and to provide adequate support for the layers of base and surface courses that make up the roadway.

Since the embankment foundation and embankment provide the basic support of the entire roadway, it is very important that they be properly constructed in accordance with all plans and specifications. Grades, slopes, density, and all other controls must be accurately monitored.

The front slopes are the side slopes of the roadway between the edges of the shoulder and the existing ground. The point where the front slope meets the existing ground is called the toe of the slope.

The soils used for constructing the embankment are taken from the surrounding area whenever possible. The excavation of these soils from the sides of the construction area creates side ditches for roadway drainage.



Such excavation normally begins where the back slope meets the existing ground line. This point is known as the top of the back slope.

Besides understanding the structure of the roadway, familiarity with soil types and the characteristics of each is important during this phase of construction, because soil type often determines the type of treatment that may be necessary to properly build the embankment.

Review Questions

Fill in the blanks for each of the following statements.

1. The soils placed between the embankment foundation and sub grade surface form the _____.
2. The support surface on which the embankment is constructed is the _____.
3. An inspector must be able to recognize different types of _____ that are encountered in embankment construction.

CHAPTER 2

EXCAVATION AND EMBANKMENT MATERIALS

Excavation consists of removal, hauling, disposal, placement, and compaction of all materials encountered within the limits of the work necessary for the construction of the roadway. All excavation is generally classified using the following terms; “unclassified excavation”, “stripping”, “muck excavation”, “rock excavation”, “borrow”, or “potholing” and are defined below.

Unclassified Excavation is the excavation of all materials within the right of way and includes surface boulders and the excavation of ditch and channels materials that may not be covered under other items. Overhanging rock or other rock considered dangerous is removed and classified “unclassified excavation”.

Stripping is the removal of *overburden* or other specified material from material pits, and the replacement of overburden or other specified material over the disturbed area of the site or pit after the underlying material has been removed.

Muck excavation is the removal and disposal of mixtures of soils and organic matter not suitable for foundation or embankment material. The material is removed to a depth as determined by the engineer and then backfilled and compacted to finished grade with approved material.

Overburden is material of any nature, consolidated or unconsolidated, that overlies a deposit of useful material.

Rock excavation is igneous, metamorphic, and sedimentary rock which cannot be excavated without blasting or the use of rippers, including all boulders or other detached stones having a volume of ½ cubic yard or more, as determined by physical or visual measurement.

Borrow is approved material obtained from outside the right of way, required for the construction of the project.

Potholing consists of exposing and verifying the location of existing utilities at locations as directed.

EMBANKMENT

Embankment material is approved material acquired from excavations, hauled and placed in embankments. Use of this material in an embankment is contingent upon it meeting resistance values specified in the contract and a minimum maximum dry density of 90 pounds per cubic foot. There are three types of embankment materials, soil, rock, and rock fill. These are defined below.

Soil embankment is material that is predominantly smaller than the no. 4 sieve in diameter. Soil embankments are constructed with moisture/density control.

Rock embankment is material that has 50% or more by weight, at field moisture content, of particle greater than the no. 4 sieve but smaller than 6 inches in diameter. Rock embankments are constructed with moisture/density control.

Rock fills consist of sound, durable stones, boulders, or broken rock having diameters of not less than 6 inches. At least 50% of the rock has a volume of 2 cubic feet or more as visually or physically measured.

NOTE: Claystone or soil-like non-durable shale is not treated as sound rock and needs to be pulverized, placed, and compacted similar to a soil embankment. Non-durable stone greater than 12 inches in diameter is not placed in an embankment.

CONSTRUCTION REQUIREMENTS

The excavations and embankments shall be finished to smooth and uniform surfaces conforming to the typical sections specified. Variations from the sub grade plan elevations specified shall not be more than 0.08 foot. Where bituminous or concrete surfacing materials are to be placed directly on the sub grade, the sub grade plane shall not vary more than 0.04 foot. Materials shall not be wasted without written permission of the Engineer. Excavation operations shall be conducted so material outside of the slope limits

will not be disturbed. Prior to beginning grading operations, all necessary clearing and grubbing in the area shall have been performed in accordance with Section 201 of the Standard Specifications.

The Contractor shall notify the Engineer not less than five working days prior to beginning excavation so the necessary cross sections may be taken. The Contractor shall not excavate beyond the dimensions and elevations established.

Archaeological and paleontological materials encountered during the work shall be dealt with in accordance with subsection 107.23 of the Standard Specifications.

Rock Excavation - Unless otherwise specified, rock shall be excavated to a minimum depth of 0.5 feet and a maximum depth of 1 foot below the sub grade, within the limits of the roadbed. Rock removed in the excess of 1 foot below the sub grade will not be paid for. Backfilling of the depth in excess of 1 foot below the sub grade will be at the contractor's expense. Approved embankment material shall be used to bring the rock-excavated areas to sub grade elevations within the tolerances specified in subsection 203.03

Un-drained pockets shall not be left in the rock surface and depressions shall be drained at the Contractor's expense.

Any change to cut slopes by the Department will be made prior to the next drilling operations.

Unclassified Excavation - Excess or unsuitable excavated material, including rock and boulders, that cannot be used in embankments may be placed on the side slopes of the nearest fill as approved.

Wherever specified by the Engineer, intercepting ditches shall be made above the top of cut slopes and carried to outlets near the ends of the cuts. In order to blend the intersection of cut slopes with the slope of the adjacent natural ground surfaces in a uniform manner, the tops of all cut slopes, except in solid rock, will be flattened and rounded in accordance the typical sections and details specified. Earth overburden lying above solid rock cuts shall be treated in the same manner as earth cuts.

Muck - Unsuitable materials encountered in the sub grade shall be removed to the depth directed by the Engineer. The excavated area shall be backfilled to the finished graded section with approved material.

Borrow - The finished borrow area shall be graded to a smooth and uniform surface and shall be finished so water will not collect or stand unless otherwise specified.

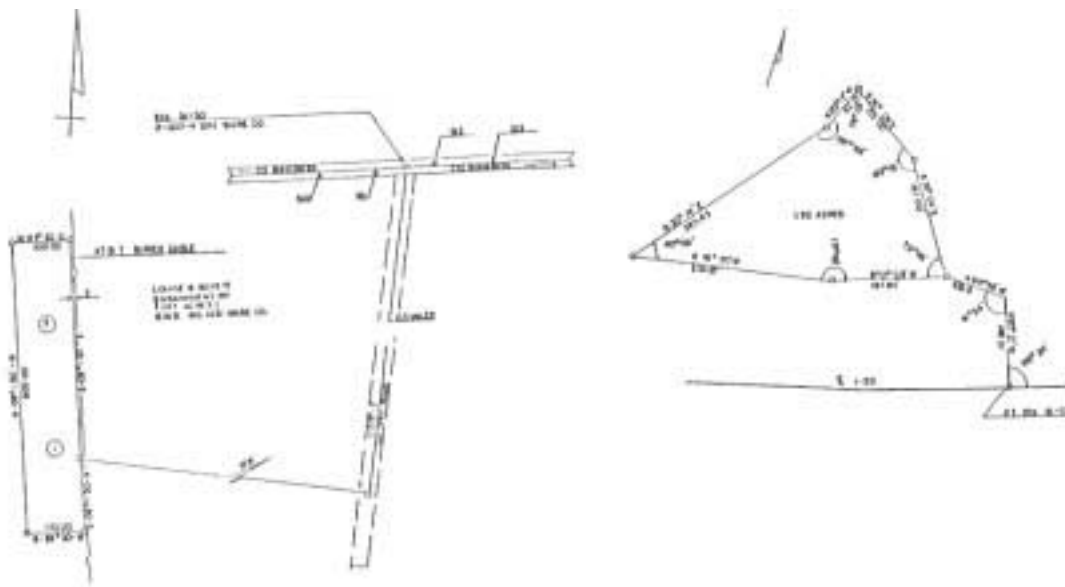
Stripping - Overburden shall be removed to the depth required for the production of acceptable material, and at least 5 feet beyond the working limits of the area being excavated.

Potholing - All necessary potholing as directed by the Contractor and agreed to by the Engineer shall be completed under this item with appropriate equipment as approved.

BORROW PITS

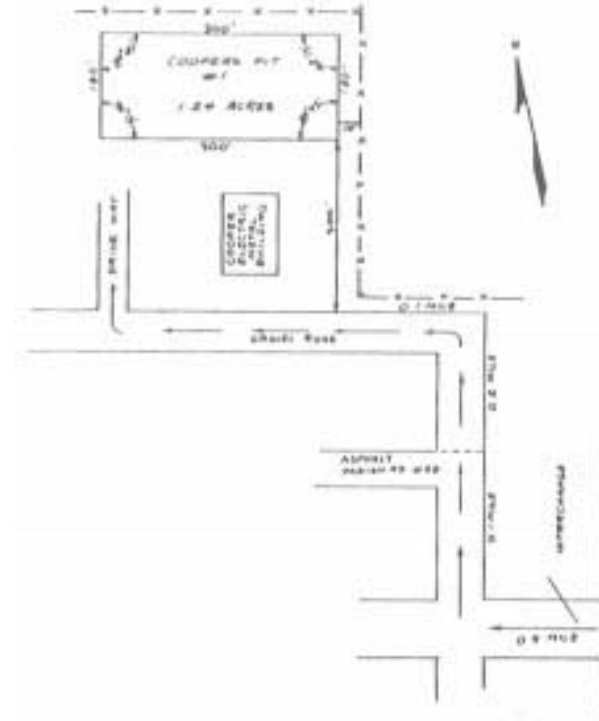
Soils excavated from within the right-of-way are referred to as unclassified excavation; soils brought in from other sources are called borrow material. Borrow material is excavated from areas known as borrow pits.

If the Department has the permits to a borrow pit and offers the pit to the contractor it is designated an *available* source. It is the contractor's responsibility to obtain any necessary permits if the Department hasn't. Any source, other than an available source, is considered a *contractor* source. The Region Materials Engineer must approve all pit and environmental clearances prior to any material being used from it. Region/ Central Laboratory may sample the pit and test the materials, as well. All results will then be transmitted to the Project Engineer for his project files. The borrow material will be tested and classified before being placed in the embankment, a pit sketch and sampling request must be submitted to the Region Materials Engineer. After the laboratory crew samples the pit and tests the material, the results are transmitted to the Project Engineer for his project files. The following drawing is an example of a properly completed pit sketch for a pit referenced to the centerline of the project. Note the inclusion of the North Arrow for direction, Station numbers, distances, measurements, and angles.



The above sketches are examples of boring diagrams that would be returned to the Project Engineer from the Region or Contractor's Laboratory.

Careful directions must be given to enable the boring crew and contractor to easily locate the pit. Again, note distances, measurements, angles, and North Arrow.



Project personnel should visually observe fill material periodically being placed in the embankment for any archeological, historical, and paleontological artifacts. Should the contractor or the project engineer notice any artifacts during construction, Project personnel should call a halt to operations in the immediate area of the findings. The project engineer and the Department's Environmental Section should be notified immediately upon any of these findings.

SOIL CHARACTERIZATIONS

An inspector needs to understand some basic information about soils. He needs to know the basic characteristics of the soil with which he is working. The laboratory will identify the soil types from their tests. Other information about soils in the construction zone may be found in the soil survey. The following information will be given when soil surveys are performed.

Gradation

As per Colorado Procedure 21, *Mechanical Analysis of Soils*. This method describes the procedure for the quantitative determination of the distribution of particle size in soils and soil aggregate mixtures.

Maximum Dry Density

As per AASHTO test methods T 99 & T 180, *Moisture-Density Relations of Soils*. This is the oven-dry density in pounds per cubic foot of the soil at optimum moisture content or the densest this particular soil can be compacted to.

Optimum Moisture

As per AASHTO test methods T 99 & T 180, *Moisture-Density Relations of Soils*. The peak of the curve at the maximum dry density point determines the optimum moisture. The corresponding moisture content at the maximum dry density is called the optimum moisture.

Atterberg Limits

The Atterberg Limits are determined using two test procedures, AASHTO T 89, *Determining the Liquid Limit of Soils*, and by AASHTO T 90, *Determining the Plastic Limit and Plasticity Index of Soils*. The Liquid Limit (LL) is that water content at which the soil passes from a plastic to a liquid state. It is the greatest amount of moisture a soil can hold and still be stable under its own weight. The Plastic Limit (PL) of a soil is the lowest water content at which the soil remains plastic. It is the least amount of moisture a soil can hold and still be stable under its own weight. The Plastic Index (PI) is the difference (or range) between these two values with soils typically having larger PI's being more plastic or poorer quality soils.

AASHTO Soil Classification

The AASHTO Soils Classification is designated as M 145 and is found in the Colorado Field Materials Manual in Chapter 200. It "classifies" a soil into a group by use of the gradation, liquid limit, and plastic index.

R-Value

This test method is Colorado Procedure Lab 3101, *Resistance R-Value and Expansion Pressure of Compacted Soils or Aggregates by means of Hveem Stabilometer*. This procedure can be found in the Colorado Laboratory Manual of Test Procedures in the Soils Unit section. The method covers the procedure for testing both treated and untreated laboratory compacted soils or aggregates with the stabilometer and expansion pressure devices to obtain results indicative of performance when placed in the base, sub base, or sub grade of a road subjected to traffic.

LOCATION AND DEPTH OF BORINGS

These test procedures can be found in the Colorado Field Materials Manual in the chapter labeled *Soil Survey* and describes the procedures to locate and determine depth of borings for preliminary soil profiles and surveys. Boring logs are located in the plans or upon request from the Geotechnical Unit.

SOILS CLASSIFICATION

In the field, in order to tell if a soil is plastic or not, roll it into threads to see if it will crumble. If it doesn't crumble easily, it is plastic. This easy field test will let you know that working at or near the soils optimum moisture content will give the best results for embankment construction.

The gradation analysis is part of the information given on the soil survey sheets in the plans. Gradation analysis is a classification of soils based on particle sizes. The soils are divided into four groups:

1. Gravel
2. Sand (coarse and fine)
3. Silt
4. Clay

Sand and gravel are coarse-grained particles that do not stick together.

Silt particles do not stick together well and have a low to medium plasticity.

Clay particles are highly plastic and tend to stick together.

While it is easy to identify sand or gravel under field conditions, it is more difficult to distinguish between silt and clay. Soil test results should always be consulted for certain identification.

Each soil type has individual characteristics. For example, sand and gravel are both highly stable in roads, are easily penetrated by water, but drain easily.

Sand is a highly erodible material. The slopes of a sand embankment will tend to shift and wash. In order to prevent such erosion, the sand must be confined or held in place by a plastic soil such as clay. This procedure is sometimes referred to as "wrapping" or using a "clay blanket."

Silt also erodes easily and is highly unstable. In order to work with silt, it is critical that the material be maintained at optimum moisture content. Because silt is so unstable, silty soils are not normally used in embankments; however, should they be used, the silty material must be confined with a plastic material.

Clay soils tend to have a high Liquid Limit, because clay has a strong attraction for water. When clay soils are wet, they expand or swell. Care must be exercised in compacting these soils. If they are over-compacted, they will shrink; hence, when water enters the material the swell potential is increased. When clay soils swell after a roadway has been completed, the increased volume of the embankment can be reflected in surface failures.

The following shows some examples of soil types and name groups:

SANDS (50% or over of the particles are sand) Sand Sandy loam Sandy clay
SILTS (50% or over of the particles are silt) Silt Silty loam Silty clay loam Silty clay
CLAYS (50% or over of the particles are clay) Medium silty clay Heavy clay
LOAM (over 80% sand and silt) Study the above lists and then answer the questions that follow.

The soil survey sheets and lab reports also describe soils in terms of consistency and color. *Consistency* describes soil in terms of its cohesion (ability to stick together) and in-place moisture content.

For dry materials, the following terms often occur:

Loose
Crumbly
Hard
Very hard

The method by which soils will be classified is AASHTO M-145 or A-groups . Soils are arranged into eight major groups, A-1 through A-8.

A-1, A-2, and A-3 are granular soils (sand, gravel).

A-4, A-5, and A-6 are soils containing both clay and silt, and sometimes sand.

A-7 is usually a clay soil, although some silts may fall into this classification.

A-8 is the classification for soils that contain 15% or more organic matter. Muck falls into this classification.

Sand soils are classified by smaller numbers; clay soils by the large numbers.

Soils in the following categories are called select material.

A-1
A-2-4
A-3
A-4

Some projects require that Select Material be used in the top of the embankment. A cross-section of such an embankment would look like this.



When materials, such as sands or silt that tend to flow or shift, are used in embankments, they are wrapped with soils having much higher clay content (A-4, A-6, A-7) to hold the embankment in place.

Review Questions

1. Material excavated from within the right of way is called (unclassified excavation/borrow).

2. What is the formula for determining the Plastic Index? _____
3. Soils containing organic matter are usually (white/dark).

CHAPTER 3

SEQUENCE OF OPERATIONS/EQUIPMENT

All equipment should be performing properly. If the equipment is not providing satisfactory results, it should be repaired or replaced. The inspector should advise the contractor if he sees visible fluid leaks or is concerned about the safety of a piece of equipment.

Machinery used for earthwork procedures falls into two general categories of use - excavation and compaction. Excavation equipment includes scrapers and bulldozers, backhoes, trenchers, and motor graders.

Before embankments can be compacted, the soil must be at the proper moisture level. If the material is too dry, water trucks are necessary to dampen it; if it is too wet, the embankment should be opened up and allowed to dry.

If water trucks are utilized, the spray bar at the back must operate properly. It should distribute water evenly over the surface. Any type of compaction equipment that will achieve the required density can be used on embankments, as long as no detrimental side effects, such as differential settlement, occur. Generally pneumatic, sheepsfoot, or vibratory rollers are employed. Differential settlement is uneven settlement. It can cause damage to cross drains and underlying utilities.

Pneumatic rollers have rubber, air-filled tires. The tires should be smooth (without tread) and should all be equally inflated. They are typically used on sandy soils.

The weight of some pneumatics can be adjusted by adding sand or water or both to the ballast box. Increasing weight will increase the compactive ability of the roller. The inflation pressure of the tires also affects the compactive ability of the roller. Some pneumatics can adjust tire inflation during operation.

Sheepsfoot rollers have metal drums with prong-like projections. They are typically used for clayey soils. These projections traditionally are shaped like sheep's feet, hence the name. However, other configurations can be used. These projections should all be uniform and in good condition. The weight of sheepsfoot rollers can also be adjusted by adding sand or water to the ballast box.

CLEARING AND GRUBBING

Clearing and grubbing operations remove trees, shrubs, sod, and other natural materials found in the construction area. Specifically, clearing refers to the removal of trees, brush, and boulders and grubbing to the removal of roots and stumps.

GROUND PREPARATIONS

The process of embankment construction is basically a combination of cut and fill. Cuts are made when the required grade is below the level of the natural ground. Fills are used when the required grade is above the level of the natural ground. Before fill material can be placed, the embankment foundation must be properly prepared. The following provides guidelines for this work.

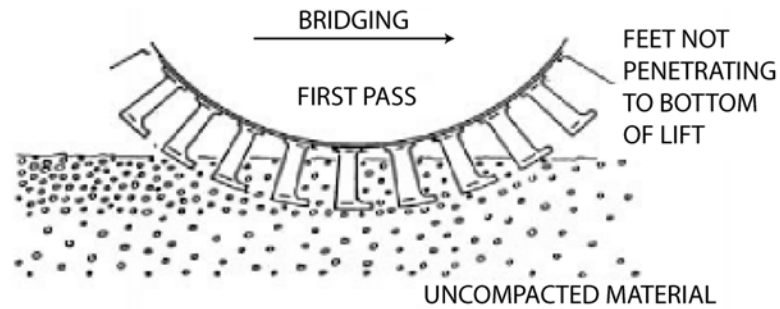
Preparation for Embankments

The contractor can re-compact the scarified ground by any acceptable means. All sod, vegetable, and organic matter within 4 feet of the base of where the sub grade will be placed shall be removed from the surface, scarified to a minimum depth of 6 inches, and re-compacted. Generally either a sheepsfoot or steel vibratory roller is used. Proper moisture control is necessary for adequate compaction to be achieved. If a sheepsfoot roller is used on material too wet, mud will collect between the roller feet and very little compaction will be achieved. If the material being compacted is too dry, then the feet of the roller will not penetrate to the bottom of the lift. This problem is known as bridging and will prevent the bottom of the lift from being properly compacted. The sheepsfoot roller will have tamping feet protrusion of a minimum of 4 inches.

Accelerated Embankment Consolidation

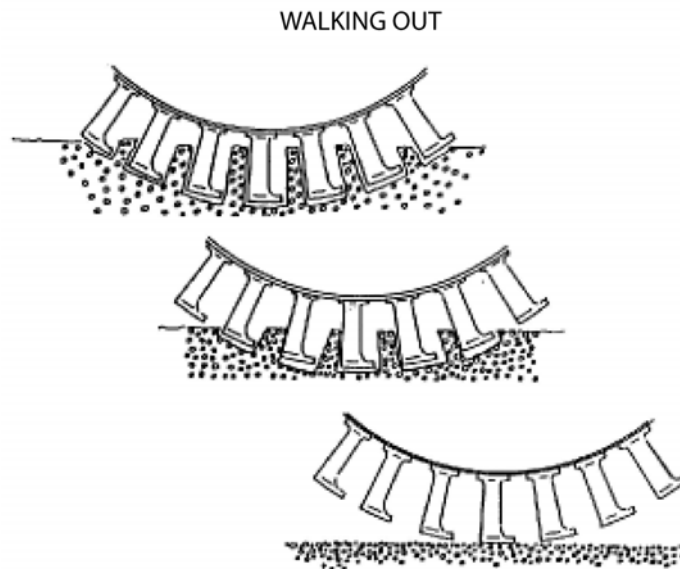
Check your project plans and special provisions to see if your project requires accelerated embankment consolidation. If it should, then be aware that the guidelines specified in your project plans need to be followed.

Some general practices for accelerating the consolidation of an embankment are to surcharge the embankment, installation of wick drains, and time. When surcharging an embankment, make sure the correct amount and type of material is used. Verify this in your project plans. When wick drains are used, be sure that the correct type, number, and placement of the wick drains are as per the project plans. The time frame to consolidate an embankment will vary from project to project. Reference your project plans to ensure the required amount of time has passed and or the measured amount of movement has been obtained. Consolidation is usually measured from fixed survey points on the embankment. Make sure the points are protected and haven't been disturbed. If you have any questions contact the Geotechnical Program.



In order to compact properly, the feet of the sheep's foot roller must penetrate to the bottom of the scarified material on the first pass. Each time the roller passes over the material, it should penetrate less. This action of penetrating less and less with each pass is called walking-out. The roller should "walk-out" properly.

Refer to the following sketches.



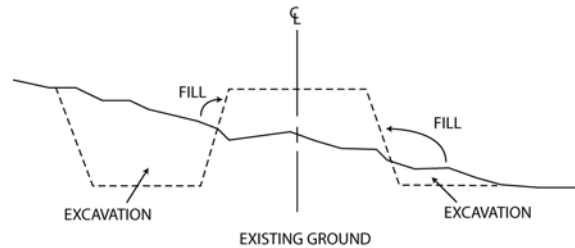
To check the walk-out of a roller, observe the holes made by the feet in the soil, as well as the distance between the drum and the soil. The roller should operate at a speed not exceeding 3 miles per hour (a quick walk).

The sheep's foot roller will walk out too soon if the soil is too dry. The roller will also walk out too soon if the drum is not heavy enough. If the drum is the correct weight, the feet will penetrate to the bottom of the scarified material, but the drum will not ride on the material.

FILLS

Embankment fills can be built from unclassified excavation material, borrow material, or rock. Only approved materials shall be used in the construction of embankments and fills.

Frozen material shall not be used in the construction of embankments. Free running water shall be drained from the material before the material is placed on the roadway foundation. For some embankment jobs, if specified in the project plans, the contractor may excavate the side ditches and use this material (unclassified excavation) to construct the fill.



If borrow is to be used for fill material, it will be excavated at the pit, hauled to the job site in trucks or other hauling equipment, and placed on the prepared foundation. No excavated material greater than 6 inches in the greatest dimension shall be used as embankment material unless designated in the Contract or approved by the Engineer. When borrow is to be used, project personnel should check the pit to be sure that all clearing and grubbing has been done at the pit site, that all sod and other objectionable material has been removed, and that any required erosion control devices are in place. Project personnel should also be aware of the method of excavation the contractor is using. Soils in their natural state tend to be in layers. Additionally, drastic or unexpected changes in borrow material brought to the job site should be noted and monitored. This is necessary if problems occur during embankment construction. It will help isolate the areas that may need reworking. Embankment materials consisting of non-durable stone, (claystone, shale, etc.) shall be pulverized to a maximum of 12 inches in diameter and placed in a maximum layer thickness of 12 inches and watered to promote slaking and breakdown of the non-durable material.

Broken concrete, asphalt, or other solid materials more than 6 inches in the greatest dimension shall not be placed within embankment areas supporting the roadway shoulders or pavement structure. Broken concrete, asphalt, or other solid materials greater than 6 inches in the greatest dimension may be placed in the side slope outside of the supported roadway. The material shall be placed in layers with each layer thickness no greater than 1 ½ times the following requirements.

Rocks and concrete having one single dimension greater than 2 feet and asphalt greater than 12 inches, shall be separated by a minimum of 6 inches of compacted and approved embankment material.

No layer shall be within 2 feet of the sub grade or the final finished side slope surface.

When rock fills are to be used, rock not exceeding 3 feet in the largest diameter can be placed in thickness up to the average rock dimension, but not to exceed 3 feet. Occasional larger boulders can be placed with the Engineer's approval. Each layer shall be leveled, smoothed, and compacted under the direction of the Engineer.



Each layer, as shown in the previous cross section, may have different qualities. If the borrow pit is excavated horizontally, as with a scraper, the material can change as different layers are reached. Since a change in material can alter moisture and needed compactive effort, horizontal excavation requires close observation. It is better to excavate the material vertically through all layers with a dragline or a backhoe.

The embankment material is spread across the roadway in layers (called lifts). Although exact grade is not required in early lifts, they should conform somewhat to the planned elevations and cross sections.

Each lift should be placed across the full width of the embankment and shall consist of uniform layers of loose material no greater than 8 inches thick or as otherwise specified by the plans or Specifications.

Because proper moisture content is important in achieving required density, the contractor will adjust the moisture content of the soil. If it appears too wet, it should be disked. By breaking up the soil, more surface area of the soil particles is exposed to the air, speeding up drying. This procedure is known as aeration.

If the material is too dry for proper compaction, a water truck can be used to increase moisture content. The spray bar on the truck should spray water evenly. The truck should not stop on the roadway with the water running, as this will cause a wet spot in the embankment. If necessary, the material will then be disked, so that it is thoroughly blended.

The lift will be compacted with a sheepsfoot ,vibratory roller, or any other means that will ensure proper compaction has been achieved. Before the density test, project personnel should visually observe the lift. Any areas that do not appear satisfactory compacted must be corrected.

Each succeeding lift is constructed in the same manner as the first. It is good construction practice to have the sheepsfoot roller leave the top surface of the lift roughened; therefore, the top 2 inches of lower lift may be compacted with the lift placed above it. Compacting the top 2 inches of a lower lift with the succeeding lift also helps bind the two lifts together.

Proof Rolling specification - Follow the Revision of Section 203, Proof Rolling, dated March 2002 in your project plans or special provisions. When checking the lift for uniformity, soft spots should be looked for. Soft spots can be identified by non-uniform movement, in a localized area, of the compacted lift when driving over the compacted lift with a heavy piece of equipment. As the wheels of the equipment enter a soft spot the area will depress

and spring back. Such soft spots are caused by material that is unstable or too wet. If the material is unstable (e.g. an area of excessive clay content), it may be unusable in the embankment. In this case, chemical stabilization or a geotextile may be required, or the unstable material may have to be removed by undercutting.

If the area is wet, the situation may have been caused by inadequate drainage or by heavy equipment pumping moisture up from the sub base.

For wet areas, the material can be dried by disking, chemical stabilization, use of a geotextile, or by correcting improper drainage.

CUTS

Cuts refer to excavation made below the level of the natural ground.

Cuts are used for reaching grade when the elevation of the natural ground is above that of finished grade. They are also used for removing muck and for undercutting. The plans will indicate which areas of a project are to be cuts.

In planning a roadway, designers often attempt to use balanced cut and fill. This means that the material excavated for ditches and other cut sections will provide exactly enough suitable material for fill sections. All such unclassified excavation must be acceptable soils and must be free of objectionable material.

Any material which is not suitable for fills or which is not needed for fill construction must be wasted outside the right-of-way. Excavation areas where the material is known to be unsuitable for embankment construction will be indicated on the plans. Project personnel should observe the material being excavated. If it appears to be unsuitable for embankment construction, he should notify the Project Engineer and the Region Materials Engineer. Grade and slope for embankments apply to cuts as well as fills. The procedures for checking grade and slope will be the same.

TESTING AND GRADE CHECKING

The Colorado Department of Transportation has approved the following Colorado Procedures (CP's) for methods of density testing.

CP 80-03 Nuclear Gauge

CP 22-93 Sand Cone

These methods are explained in detail in the CDOT's Field Materials Manual. The nuclear gauge is the most common method used.

Density tests must be taken a minimum of once every 2,000 cubic yards. These sites should be selected randomly. The selected site should be representative of the entire area.

MOISTURE/DENSITY CONTROL

All embankment material shall be compacted to the specified relative compaction using ASSHTO T 99 and T 180 or a modification thereof.

The amount of water to be used in compacting A-2-6, A-2-7, A-4, and A-6 through A-7 soils shall not deviate from optimum on the dry side by more than 2 percent. All other soils shall use the required amount of water to obtain the percent relative compaction. The percent relative compaction specified shall be equal to or greater than minimum values as shown in the following table for the various classes of soil and type of compaction.

Soil Classification (AASHTO M145)	AASHTO T99 Minimum Relative Compaction (Percent)	AASHTO T180 Minimum Relative Compaction (Percent)
A-1	100	95
A-3	100	95
A-2-4	100	95
A-2-5	100	95
All Others	95	90

Proper compaction is best achieved at near optimum moisture content; hence, if density has not been attained, information about moisture content can be helpful. Project personnel should also check that the lifts are approximately the correct thickness. Embankment lifts should be uniform in thickness.

Grade Slopes

Grade, slope, and crown should be checked periodically, as the fill nears completion. Therefore, it is not necessary to check every lift.

The embankment slope shall be no greater than 4:1 in the steepest direction, or as shown on the plans, and shall be continuously benched as it is brought up. Benches, when practical, shall be keyed in a minimum of 8 feet.

In order to check grade, first decide at which station it is to be checked. Then refer to the typical sections and/or the cross sections for that station.

If the final lift of the embankment is to be select material, the contractor will roll the preceding lift with a sheepsfoot, and leave the top 2 inches rough. Usually this lift will be ½ to 1 inch lower than plan grade, so that the proper amount of select material can be added. If no select material is to be added, the contractor will bring the embankment to final grade.

When the embankment is at final grade, blue tops must be set to grade, at the edge of the embankment.

The inspector should randomly check elevations, to be certain that they are accurate. The contractor will fine-blade the material with a motor grader or fine grader to assure that grade and slope are uniform. The blade of the equipment will be set to cut material from high places and deposit it in low ones.

The last step in finishing an embankment is to roll it with a roller. It will seal the surface of the top lift and provide protection against weathering and traffic.

After the embankment is finished, final grade and crown must be checked using a string line and the blue tops, as explained earlier.

The side slopes of the embankment must also be ready for inspection. The Inspector must check their final slope ratio.

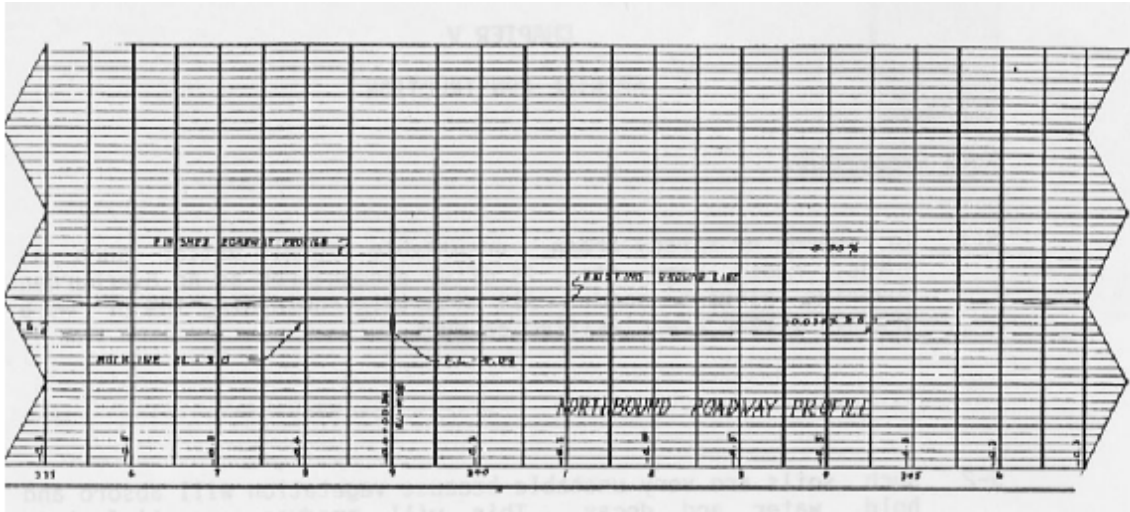
When all of the embankment has been completed, the entire surface of the roadbed and the slopes shall be shaped to reasonably true grade alignment and Cross Sections shown on the Plans or established by the Engineer.

Review Questions

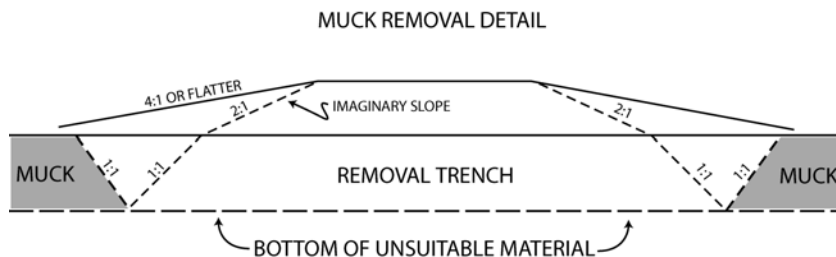
1. All sod, vegetative, organic matter within _____ of the base where the sub grade will be placed shall be removed from the surface.
2. Embankment slopes shall be no greater than _____ in the steepest direction or as shown on the plans.
3. The last step in finishing an embankment is to roll it with a roller to seal the surface.
True or False

Chapter 4

SPECIAL CONSTRUCTION - MUCK EXCAVATION



In other cases, only a typical muck excavation section will be shown.



Material should be removed to the depth indicated on the plans or deeper, if necessary. Regardless of the amount of detail regarding muck excavation incorporated in the plans, the Inspector must carefully observe the material being excavated, to be certain that all muck is removed.

Occasionally, muck will be encountered unexpectedly on a project. If it is a small area, the Engineer advises the contractor to remove it and the work is paid for as unclassified excavation. If it is a large area, the Geotechnical Program should be notified, so that borings can be made to determine the limits of the muck.

After the extent of the muck has been ascertained, a change order may be necessary in order to complete the work.

Expansive Soils

Expansive or Swelling soils are those which exhibit high volume change with an increase in moisture content. These soils usually occur in bedrock formations, are dense and fairly dry, and normally have a high liquid limit and plastic limit. Problems from expansive soils

usually occur in cut areas, in the transition from cut to fill areas, and in fill areas when cut material is utilized.

It is important for the inspector to have read the preliminary soils investigation report to see if expansive soils were identified. When expansive soils are present, it is important that the inspector make sure that the contractor follows the recommended form of mitigation. Chapter 200 and the Soils Survey chapter in the Field Materials Manual have additional information. Contact the Soils Program if you have any questions.

Collapsible Soils

Collapsible soils occur as naturally relatively dry alluvial fans, colluvium, and wind-blown deposits. These soils are typically silt and sand size with a small amount of clay. Collapsible soils show relatively high apparent strength (cohesion) in their dry state, but have a low density, porous structure and are susceptible to large settlements upon wetting.

Review Questions

1. To what depth should muck be removed? _____
2. Where would you expect to see expansive soils? _____

CHAPTER 5

CHEMICAL AND MECHANICAL SOIL TREATMENTS

Chemical soil treatments are sometimes applied to sub grade or embankment soils to improve them by lowering their Plasticity Index, improving their permeability, or to dry the soil more rapidly, so that construction operations can proceed.

These treatments include the addition of lime, lime/fly ash, fly ash, Portland cement, and other approved chemical agents. These treatments can be used individually or in combinations.

Additional information on chemical soils treatment can be found in the Colorado Department of Transportation's Design Manual in Chapter 2 under section 2.7, "Stabilizing Agents" and in the Colorado Department of Transportations Standard Specification for Road and Bridge Construction in Section 307, "Lime Treated Sub Grade."

Mechanical stabilization is the use of geotextiles to re-inforce sub grade and embankment soils. Geotextile applications have five different functions; separators, re-inforcement, filtration, drainage, and cushioning. There are also two different types of geotextiles, woven and non-woven. Woven geotextiles are used when high tensile strengths and low elongation are required and non-woven where high permeability and high elongation is required. There are a number of different types of geotextiles for specific applications. Contact the Soils Unit for the specific types and installation practice, dependent upon site conditions.

Review Questions

What types of chemical additives are used to improve pool soils? _____

Name 3 functions of a geotextile. _____, _____, _____

CHAPTER 6 DOCUMENTATION

Record keeping is an important and necessary part of project records. There are several departmental documents that you will have to maintain as part of the project record. Project records must contain actual facts of construction. The records must be kept current and complete. The records must be neat, legible, well organized, and concise. The project records must show the Project Number. The calculation methods used, the signature of the person(s) preparing for certifying the record, and the date and location.

Work or material that does not meet Specifications or contract requirements must be noted.

Additional information on documentation is available in the Colorado Department of Transportation's Field Materials Manual in the Documentation section and in Chapter 200.