GEM-12

GUIDELINES FOR EMBANKMENT CONSTRUCTION

GEOTECHNICAL ENGINEERING MANUAL
GEM-12
Revision #4

AUGUST 2015

NEW YORK STATE OF OPPORTUNITY. | Department of Transportation | Office of Technical Services | Geotechnical Engineering Bureau

GEOTECHNICAL ENGINEERING MANUAL:
GUIDELINES FOR EMBANKMENT CONSTRUCTION

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STATE OF NEW YORK
DEPARTMENT OF TRANSPORTATION

GEOTECHNICAL ENGINEERING BUREAU

AUGUST 2015

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1. INTRODUCTION

The specifications, plans, and Standard Sheets state the requirements of embankment construction in precise terms. This guide is intended to describe less technically and hopefully, more understandably; how to construct an embankment. The guide discusses,

Embankment Foundation
Embankment
Compaction Control
Moisture – Density – Strength Relationship
Proof Rolling
Embankment Failure
Winter Earthwork

Reference is made throughout the guide to the Standard Specifications, Standard Sheets, plans, proposals and various procedure manuals. It is intended that the guide will stimulate the reader to study these sources.

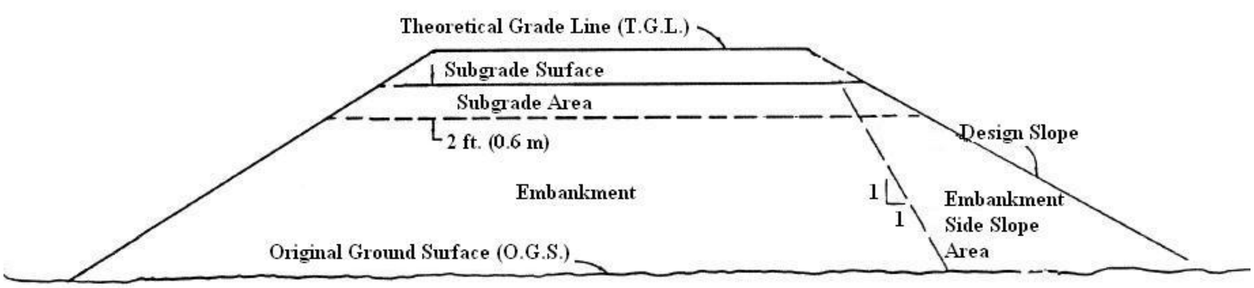

Figure 1 Definition of Embankment Construction Terms

2. EMBANKMENT FOUNDATION

The embankment foundation is the ground surface upon which the embankment is placed. It may be:

Stable
Transitional (part cut, part fill)
Unstable
Unsuitable

2.1 Stable Foundation

Fortunately, most embankment foundations are stable. If the embankment is to be less than 6 ft. (1.8 m), including the thickness of the subgrade and pavement, the specifications require that the topsoil be removed. There are situations where, although the embankment is less than 6 ft. (1.8 m) high, it would be advantageous to leave the topsoil in place such as where the topsoil is thing or removal would disturb and weaken the underlying soils. The plans or proposal will indicate if the topsoil is to be left in place.

2.2 Transitional Foundation

The longitudinal transition embankment foundation condition is encountered where the alignment places the embankment alongside a hillside or where an existing embankment is to be widened. The newly placed fill tends to slide down the slope of the hillside or the existing embankment. The standard sheet entitled "Earthwork Transitions and Benching Details" (available at the following website: https://www.dot.ny.gov/main/business-center/engineering/cadd-info/drawings/standard-sheets-us-repository/203-02.pdf) describes the preferred treatment for this condition. In effect, steps or benches are built into the existing slope to reduce the tendency of the new embankment to slide down the existing hillside or slope (Figures 2, 18 & 19).

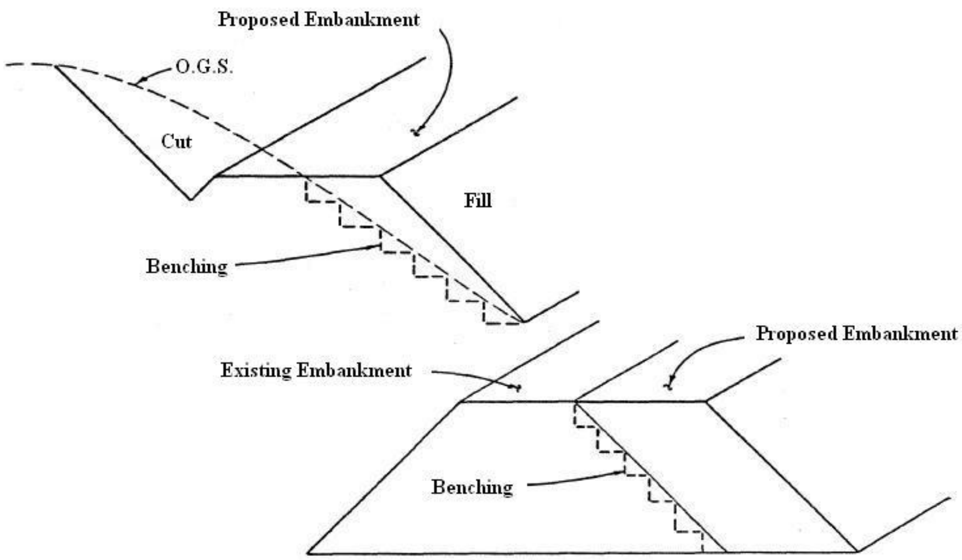

Figure 2 Benching

The same Standard Sheet ("Earthwork Transitions and Benching Details") describes the proper treatment of the transverse transitional embankment foundation at the interface where the roadway changes from embankment to cut. When an embankment is placed against existing ground, such as occurs in a fill-cut situation, a bump may occur in the pavement at the interface. This occurs because the existing hillside is inherently different than the constructed embankment. The standard treatment provides a more gradual transition between the fill and the cut.

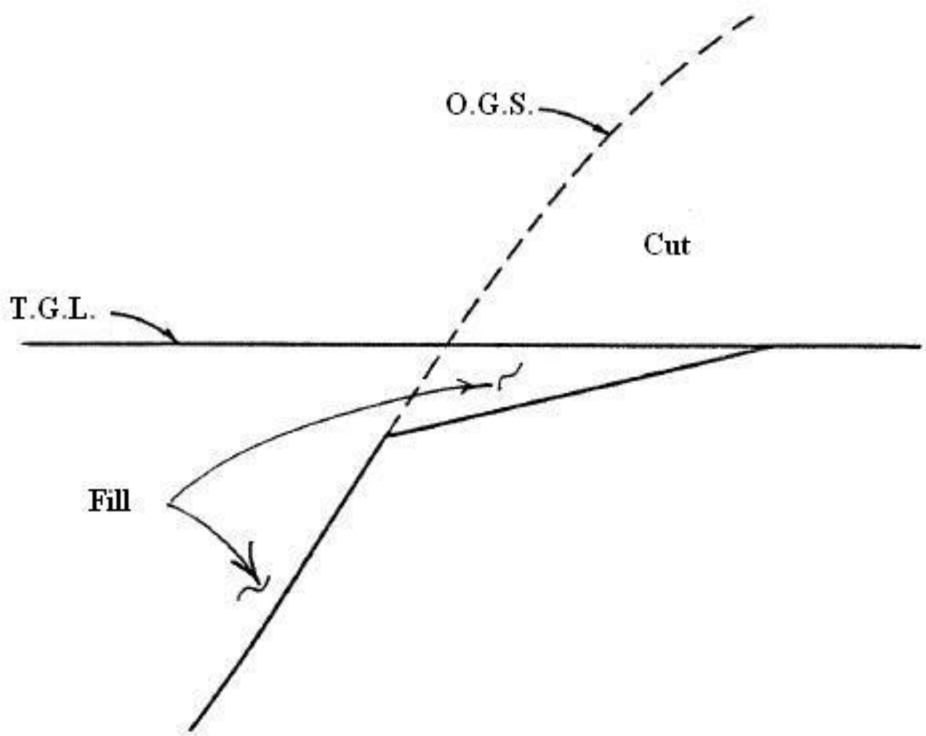

Figure 3 Gradual Transition Between Cut and Fill

2.3 <u>Unstable Foundation</u>

Unstable embankment foundation soils are usually silts and/or clays that are influenced by water. The saturated soils are too weak to withstand the high contact pressures of earthwork construction equipment.

The strength or stability of the soil may be increased by lowering the water table and the degree of saturation of the soil. In some cases this may be accomplished by installing ditches, either permanent or temporary, prior to construction.

The high contact pressures caused by construction operations on an unstable soil may be reduced by limiting the size of the construction equipment being used until the embankment is high enough to distribute the load of heavier equipment. This pressure may also be reduced by the construction of a "working platform" as described in the Standard Specification §203-3.03A. Embankment Foundation. This working platform is usually constructed by end dumping and bulldozing embankment or granular material to a maximum thickness of 3 ft. (1.0 m) (Figures 20 & 21). The working platform distributes the load of the equipment, thereby reducing the contact pressure on the unstable material. The construction of such a working platform requires the permission of the Engineer.

Geotextile (filter fabric) placed on the unstable foundation and under the working platform may also be effective as a separating membrane to help support the high construction loads.

The Regional Geotechnical Engineer should be consulted for recommendations of the most appropriate method of treating an unstable embankment foundation.

2.4 Unsuitable Foundation

The typical unsuitable embankment foundation is a wetland. Unsuitable material is organic, usually wet, black, and extremely weak (Figures 21 & 22). It is incapable of supporting any significant load. Improperly treated unsuitable materials will settle for many, many years. The unsuitable material is usually removed and replaced with suitable material before the embankment is constructed. The Standard Sheet entitled "Construction Details – Unsuitable Material Excavation and Backfill" (available at the following website: https://www.dot.ny.gov/main/business-center/engineering/cadd-info/drawings/standard-sheets-us-repository/203-01.pdf) shows the details of the embankment foundation treatment for most unsuitable material deposits. The plans should indicate the areas of unsuitable material, the depth of the material that must be removed and any required special treatments. If, during construction, unsuitable material is encountered unexpectedly, work in the area must be suspended until the Regional Geotechnical Engineer has determined the extent of the deposit and how it should be treated. An additional useful source of information on the treatment of unsuitable embankment foundation areas can be found in the treatise entitled "Unsuitable Material Treatment – Design and Construction" dated October, 1986. A reprint of this treatise is provided in Appendix B.

3. EMBANKMENT

The embankment consists of a series of compacted layers or lifts of suitable material placed on top of each other until the level of the subgrade surface is reached. The subgrade surface is the top of the embankment and the surface upon which the subbase is placed. Any suitable material (see §203-1.01.H) may be used to construct an embankment, although the Contractor may have to manipulate this material to make it stable. The maximum dimension of any particle of the material may not be greater than ⅔ the loose lift thickness. Any particles that are larger than ⅔ the loose lift thickness must be removed and disposed of, or may be put in the embankment side slope (see §203-1.01.F).

The components of embankment construction are:

Lift Thickness
Material
Degree of Compaction

The thickness of the lift is limited by the type and size of compaction equipment the contractor chooses to use. The Standard Specifications indicate the maximum loose lift thickness and mechanical requirement for various types of compaction equipment such as pneumatic-tired rollers, vibratory drum compactors, segmented pad rollers, and smooth steel wheel rollers (see §203-3.03.C). The compactors must have attached to them an identification plate which includes the manufacturer's name and the model number of the equipment. Manufacturer's brochures should provide the necessary data to determine the qualifications of the compactor.

3.1 <u>Pneumatic Tired Roller</u>

The pneumatic tired roller is classified according to tire size, tire pressure and wheel loads. Charts (Figures 203-1 & 203-2) in the Standard Specifications relate these classes to maximum loose lift thickness. The roller must make at least 6 passes at defined speeds.

Figure 4 Pneumatic Tired Roller

3.2 Vibratory Drum Compactor

The classification of a vibratory drum compactor is more complex, requiring computations based upon unsprung drum weight, drum width, dynamic force, operating frequency and rating frequency. This data must be supplied by the manufacturer. Fortunately, most of the vibratory rollers have been pre-qualified. The Geotechnical Engineering Bureau's website includes listing of rollers, by manufacturer and model, and the information needed to determine the maximum loose lift thickness, speed, number of passes and vibration frequency (http://axim22.nysdot.private:7779/pls/portal/docs/PAGE/WCC_PG/TSD/TSD_BUREAUS_TAB/TSD_GEOTECHNICAL_ENGINEERING_BUREAU_STAB/COMPACTDATA.PDF)

This listing is updated periodically. However, if an unlisted model is to be used, it may be evaluated by the Engineer based on the Manufacture's equipment specifications. The simplest way to make the evaluation is to supply the Regional Geotechnical Engineer with the data from the identification plate. The Geotechnical Engineering Bureau will acquire the equipment specifications and respond with the necessary information.

Figure 5 Vibratory Drum Compactor

3.3 Sheepsfoot Rollers

Sheepsfoot rollers have largely been replaced by its more efficient variant, the segmented pad roller, and will only rarely be encountered. The sheepsfoot roller compacts from the bottom of the lift upwards to the top of the lift. Therefore, the loose lift thickness is limited to 15% longer than the length of the feet. The maximum speed should be 6 ft./sec (1.8 m/sec), or less, if towed or 15 ft./sec (4.6 m/sec) if self propelled. Rolling continues until the roller "walks out" or the feet make little impression on the surface of the lift.

Figure 6 Sheepsfoot Roller

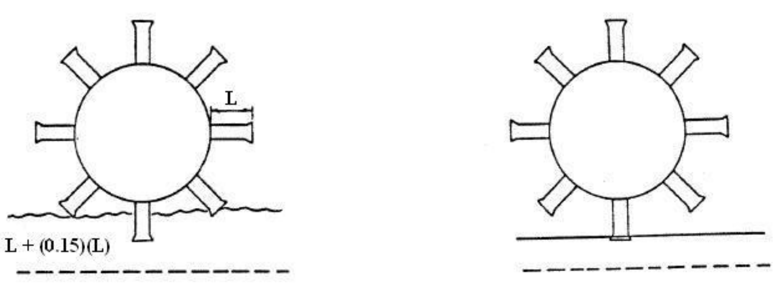

Figure 7 Sheepsfoot Roller – Loose Lift Thickness Limitation

3.4 Smooth Steel-Wheel Rollers

The smooth steel-wheel roller must weigh at least 10 tons (0.91 metric ton) and exert a load of 300 psi (2.1 MPa) of roller width. The maximum compacted lift thickness is 8 in. (200 mm) over the lift.

Figure 8 Smooth Steel-Wheel Roller

3.5 Other Rollers

The contractor may choose to use a roller such as a segmented pad or a vibrating pad foot roller that cannot be classified or qualified as pneumatic, vibrating drum, sheepsfoot or smooth steel-wheeled. In this event, a test section must be construed to determine the appropriate method of using the equipment on a particular soil. The Regional Geotechnical Engineer should be consulted for advice.

Figure 9a Other Rollers – Pad Foot Roller

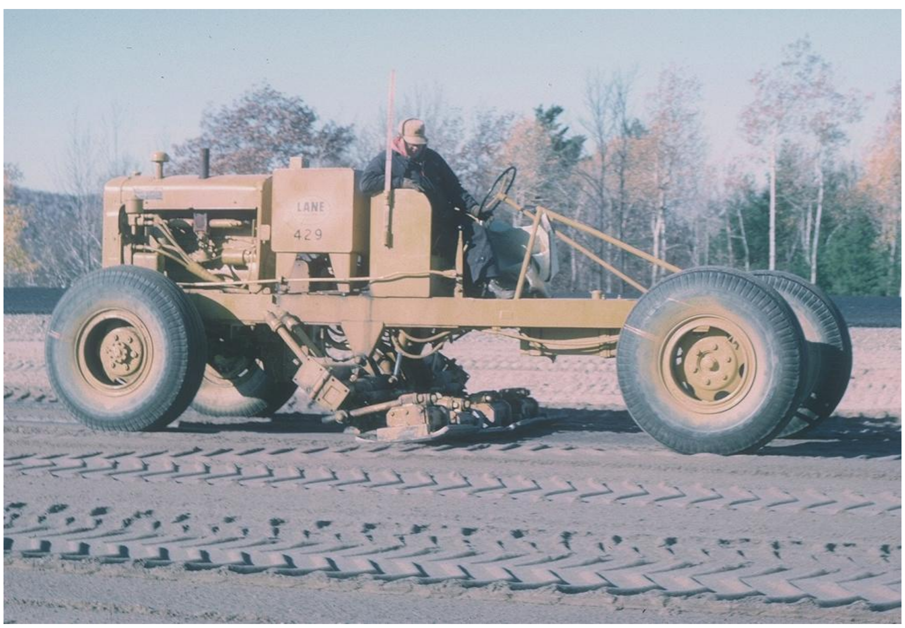

Figure 9b Other Rollers – Vibratory Compactor "Pitty-Pat"

The types of compaction equipment used are the prerogative of the contractor. In general, however, the smooth steel-wheeled, vibrating drum and pneumatic tired rollers work well on coarse grained cohesionless material. The pneumatic tired rollers usually work well on cohesive or sticky material.

It should be remembered that the loose lift thickness requirements for each type of roller as indicated in these specifications are maximum. Remember that the Contractor controls the material, lift thickness and the roller type and number of passes. As such, the Contractor is responsible for achieving acceptable results. If adequate compaction is not being attained, the thickness of the lift may have to be reduced or the size of the roller or number of passes may have to be increased.

4. COMPACTION CONTROL

The specifications require that each lift of the embankment be compacted to the satisfaction of the Engineer. If the Engineer elects to test, satisfactory compaction is defined as 90% (95% in the subgrade area) of Standard Proctor Maximum Density. Performing testing without inspecting construction operations should be avoided. However, testing is certainly desirable and recommended, particularly early in the operation or when work with different types of soils or compaction equipment is initiated (Figure 25) to help the inspector "calibrate their eyes". The correct procedure for compaction control testing is found in the Geotechnical Test Method (GTM-9) entitled "Test Method for Earthwork Compaction Control by Sand Cone or Volumetric Apparatus" and is available from the Regional Geotechnical Engineer. The "Construction Inspection Manual" includes a table of suggested testing frequencies depending on the operation (Exhibit 203-A) available at the following website:
https://www.dot.ny.gov/main/business-center/contractors/construction-division/construction-repository/murk1b_cim_2009.pdf

4.1 Moisture – Density – Strength Relationship

Each lift of an embankment must be strong enough to support the succeeding lift. The soil attains its greatest strength at close to (but slightly less than) its maximum density.

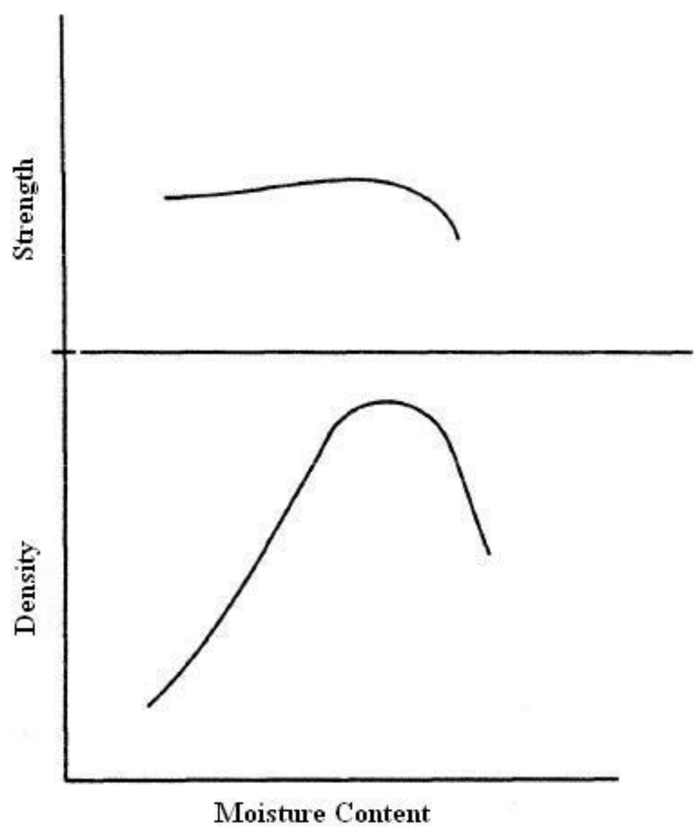

Figure 10 Moisture – Density – Strength Relationship

Since density is much easier to measure in the field than strength, the goal of compaction, therefore, is to attain the greatest practical density and ignore the slight reduction in strength.

The moisture content has very important impact on compaction operations. At any given compactive effort, the maximum density will be obtained at a particular degree of moisture called the Optimum Moisture Content. When the actual moisture content exceeds the optimum moisture content, the strength of the soil decreases rapidly. With increased moisture content the material becomes slop. This phenomenon may be observed on the grade. At moisture contents slightly over optimum, weaving of the embankment surface may occur.

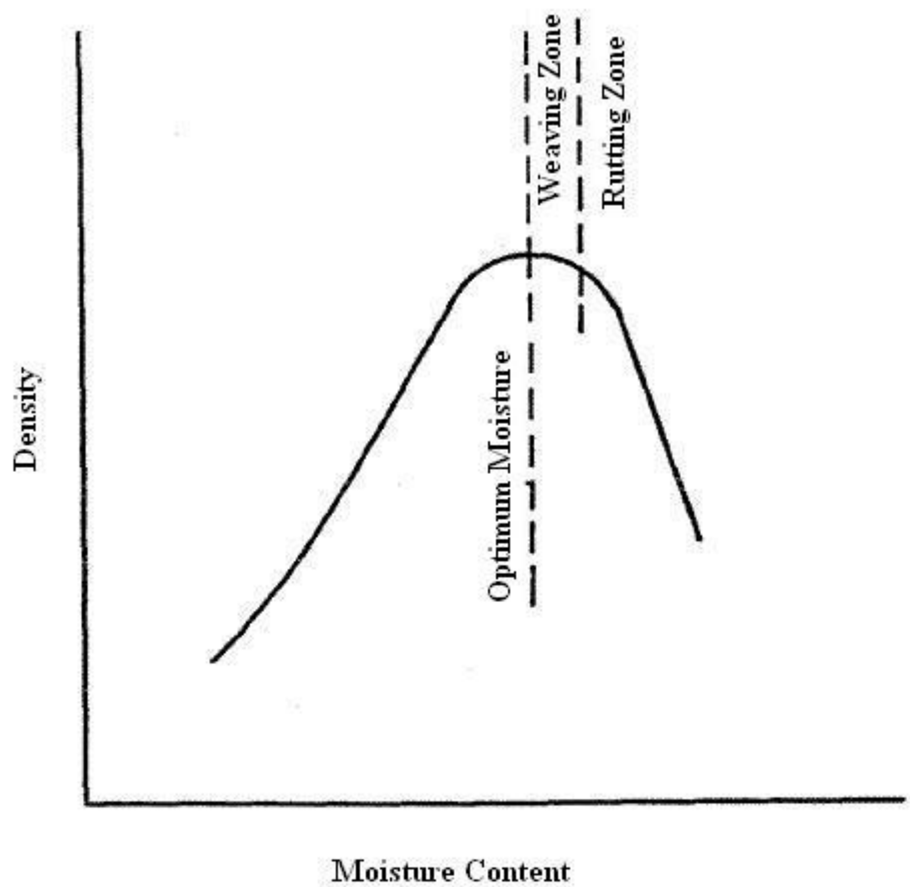

Figure 11 Moisture Content Impact on Compaction Operations

That is, when a load such as a roller or heavy earthmoving equipment goes by, the embankment surface may depress. When the load has passed, the surface will spring back.

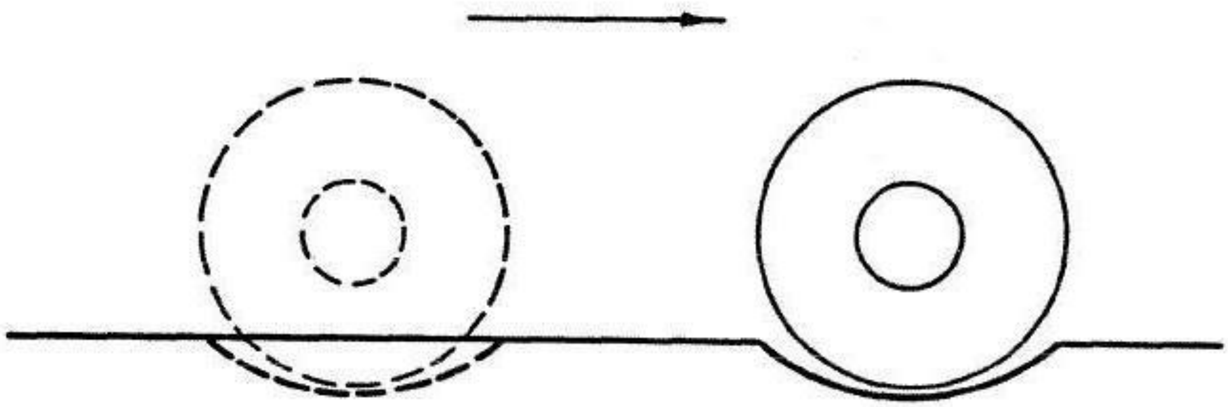

Figure 12 Weaving

At a greater moisture content, the embankment surface will not return to its original level and will leave ruts. These ruts are caused when the soil is too weak to support the roller and the soil shears or the surface is punctured. Significant rutting under the action of the compactor on the final passes on a lift is not acceptable by the specification. The degree of rutting that is significant rutting is up to the discretion of the Engineer. The Regional Geotechnical Engineer is available to advise the Engineer on the significance of the rutting.

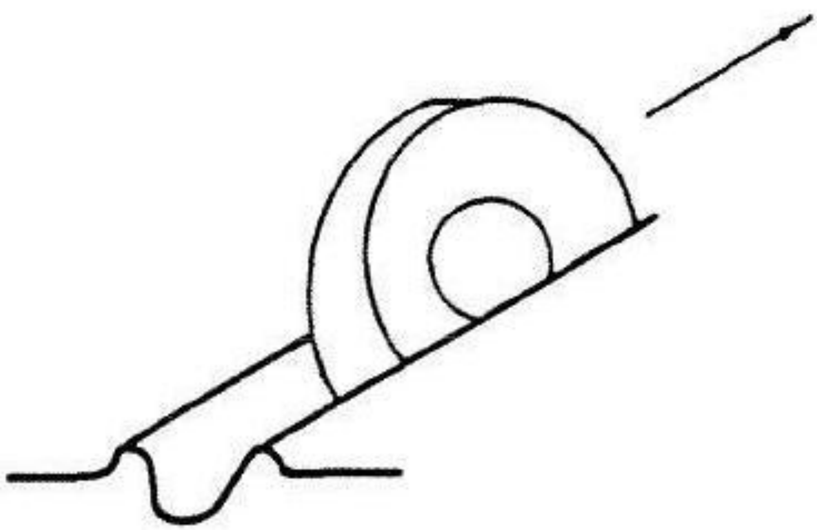

Figure 13 Rutting

The Contractor has the responsibility of controlling moisture content. Excessive moisture content may result form poor drainage practices or failure to seal the surface prior to a rain, the borrow material used for embankment may also be excessively moist. The moisture content may be reduced by loosening the material with a disc harrow or cultivator and exposing the soil to the wind or sun (Figures 26 & 27). If the moisture content is lower than optimum, it will be difficult to attain the required degree of density. Water is usually added by a spray bar attached to a tanker (Figure 28).

Equally important are the loads imposed on the soil, or the compactive effort. If the compactive effort is varied, the maximum density and the optimum moisture content (moisture content at maximum density) will vary. The compactive effort is related to both the roller weight and the number of passes. If the compactive effort is increased, the maximum density will increase and occur at a lower optimum moisture content. If the compactive effort is decreased, the maximum density will decrease and the optimum moisture content will increase.

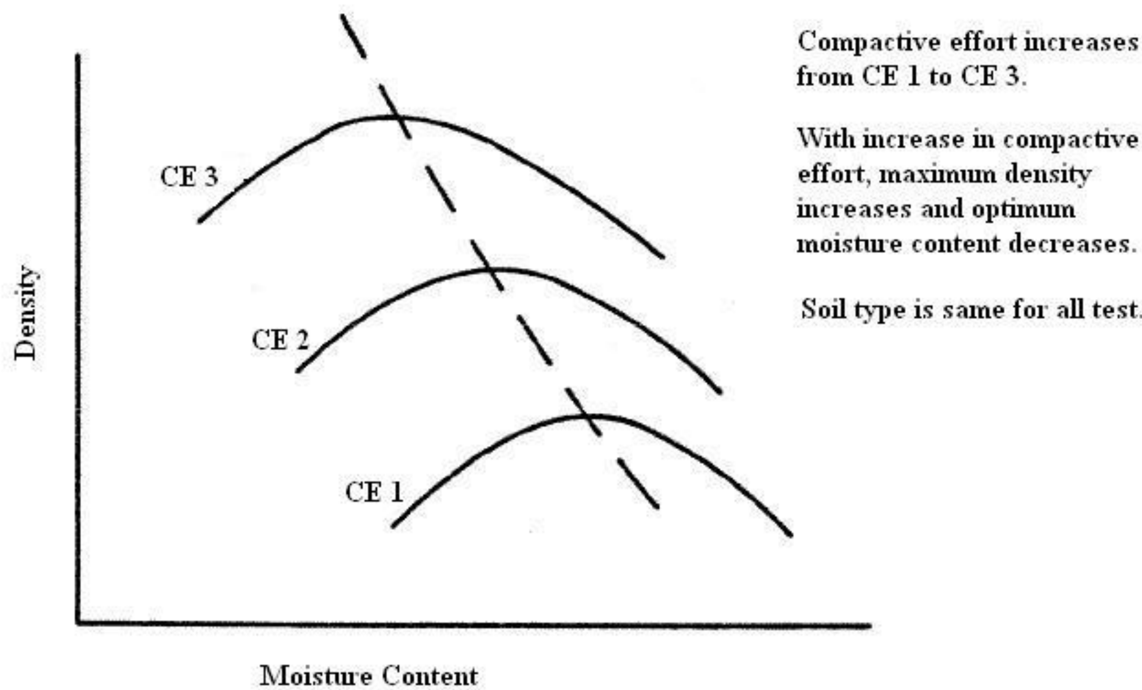

Figure 14 Compactive Effort Effect on Density and Optimum Moisture Content

The test methods in Geotechnical Test Method (GTM-9) entitled “Test Method for Earthwork Compaction Control by Sand Cone or Volumeter Apparatus” mentioned previously are pertinent to normal compaction efforts. However, hauling equipment may impose loads or “efforts” that are greater than the compactive efforts. As previously stated, the greater the compactive effort the lower the optimum moisture content. The optimum moisture content under the loads imposed by the hauling equipment may be such that the existing moisture content is excessive. This condition often occurs when an embankment is indiscriminately used as a haul road, resulting in rutting of a previously accepted lift (Figures 30 & 31). The rutted lift is damaged and must be repaired or replaced at no expense to the State. To avoid this problem the Contractor would be well advised to avoid using the finished embankment for a haul road. If the embankment must be used the equipment should avoid forming paths. In fact, the specification states under §203-3.03.B "…*earth moving equipment shall be routed so as to prevent damage to any compacted lift. Damage to any compacted lift at any time during the course of construction, such as rutting under the loads imposed by earth moving equipment, shall be fully repaired by the contractor at his/her own expense prior to placement of any overlying materials*".

Another moisture content phenomenon concerns the vibratory roller. The vibrating actions of the roller can act as a pump. Vibrations of the roller on embankments made of fine grained soils, such as silt and fine sand, have been known to cause liquefaction and have turned previously approved embankments into mud.

5. PROOF ROLLING

Once the embankment is completed, and immediately prior to subbase placement, the subgrade surface must be proof rolled (see §203-3.03.D). The proof roller is a large box supported by 4 pneumatic tires on one axle.

Figure 15 Compactive Effort Effect on Density and Optimum Moisture Content

The weight of the roller is controlled by the load placed in the box and ranges from 30 to 50 tons (27 to 45 metric ton). At 30 tons (27 metric ton) the box is empty, at 50 tons (45 metric ton) the box is filled to heaping. It is not the purpose of this proof rolling operation to cause rutting or failure of the embankment. It is intended to indicate the uniformity of the supporting ability of the embankment. If the roller is causing uniform excessive rutting, the stress level should be reduced as shown on Figure 203-3 of the Standard Specifications. If individual areas of distress are exposed by the proof rolling operation, the distressed area must be repaired or removed and replaced to the satisfaction of the Engineer at no additional cost to the State.

6. EMBANKMENT FAILURE

Embankment shear failures are rare, but when they do occur, are very eventful. An embankment shear failure occurs when the embankment or the underlying foundation soil can not support the weight of the embankment. The first indication of an embankment failure is usually a crescent shaped or linear crack along the top surface of the embankment.

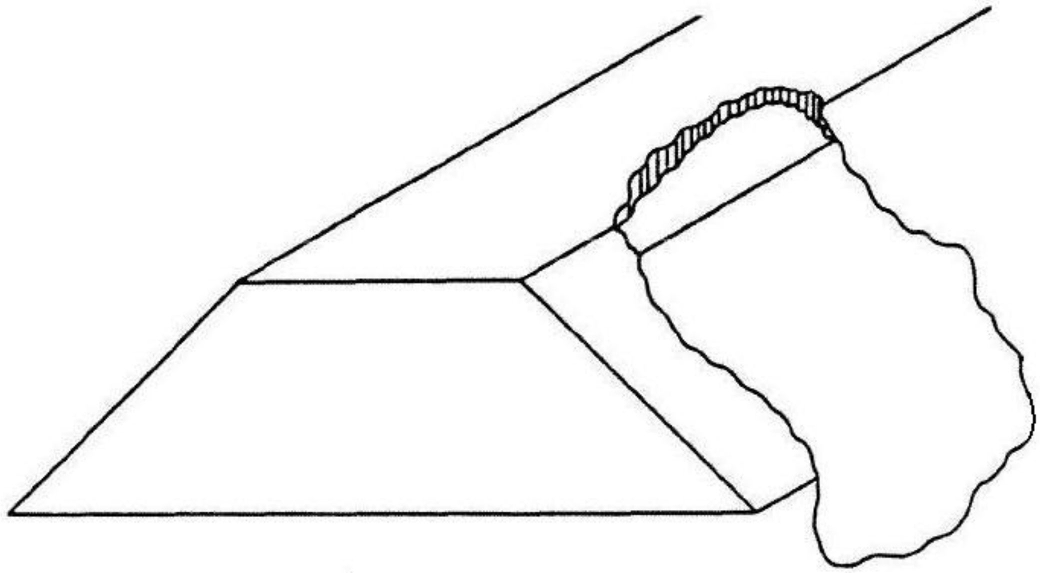

Figure 16 Embankment Failure

The long side of the crescent will be parallel to the centerline of the embankment. The embankment surface on the outside of the crescent will drop. If the embankment itself is failing, a bulge will usually occur on the sideslope. If the subsurface soil is failing, the ground surface beyond the toe of the slope will heave up.

In either case, at the first indication of an embankment failure, operations in the area should cease and the Regional Geotechnical Engineer should be notified.

7. WINTER EARTHWORK

Earthwork operations which require compaction of soil should not be attempted in cold weather. Compaction of soil during cold weather is not only uncomfortable but very difficult. Water acts as a lubricant aiding in the process of compaction. As the temperature decreases, the water becomes more viscous (less slippery) and inhibits efforts to pack the soil particles together. Eventually, the water becomes ice, at which point compaction is impossible, as can be seen below.

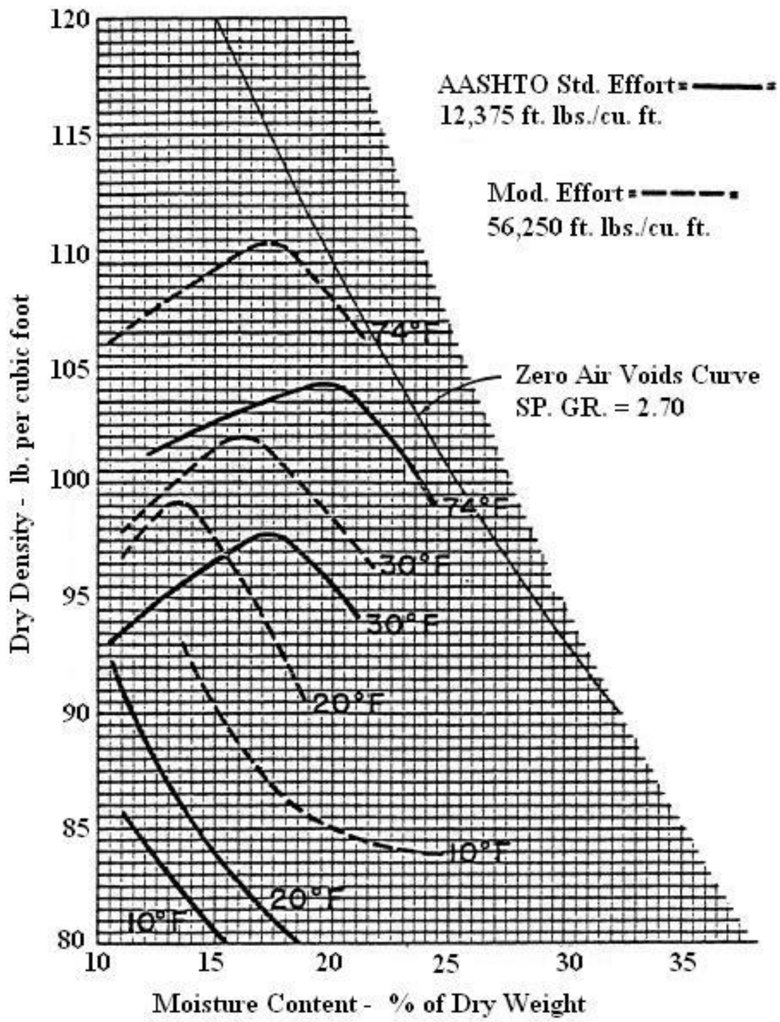

Figure 17 The Effects of Temperature on Compaction

All earthwork stops on November 1 *unless* the Contractor has submitted, and the Region has approved, a Winter Earthwork plan. The specification provides the requirements of a Winter Earthwork Submittal under §203-3.01.A. A Winter Earthwork Submittal form is provided in Appendix A.

Assuming the Contractor's Winter Earthwork Submittal is approved, then:

- The Contractor may continue to use traditional materials only as long as the temperature of the fill, the ground and the air is above freezing **at the time of placement**. That means that even if it freezes at night, if **everything** warms up to above freezing at some time during the day, the Contractor may proceed using traditional materials.

- If the temperature is at or below freezing for the fill, the grade or the air at the time of placement, traditional earthwork materials may only be placed by utilizing modified methods and procedures to adjust for the weather influence on the compaction operations (e.g. enclosure and heating scheme such as used for winter concrete) as outlined in the approved Winter Earthwork Submittal. If this is not done, the material must meet §733-16 *Winter Earthwork* as defined in the Standard Specifications for each item.

- Subbase cannot be placed if the temperature is at or below freezing for the fill, the grade or the air at the time of placement. If the temperature is above freezing for all three, then traditional approved subbase materials may still be used. We do not at this time have an option for a material that can be used for subbase for placement when temperatures are at or below freezing.

7.1 Winter Earthwork Inspection

In all work incorporated into an earthwork operation, the Contractor shall not place material that is frozen, or place fill material on frozen ground regardless of the date.

Regardless of whether appropriate materials are being used, close monitoring of cool and cold weather earthwork operations is critical to the long term performance of an embankment or a structural backfill, which may involve many responsibilities for the inspector throughout the day, such as: (1) The temperature of the air, ground surface, and fill must be repeatedly checked throughout the day to identify if materials should be changed from standard to winter earthwork requirements, (2) a determination of when a thinner loose lift thickness may be required, (3) ensuring that a ground surface which has temporarily experienced freezing temperatures is compacted again prior to placement of additional fill (temporarily frozen soil surfaces may have "heaved" and remained loose), (4) compaction tests should be done more often at temperatures below 40° F, and with soil density results always evaluated against a Standard Proctor Control Density obtained from material warmed to at least 50° F, and (5) preventing rutting and weaving of placed materials which becomes more common at temperatures below 40° F, and (6) ensuring that excessive ground disturbance is corrected before placing additional fill.

Satisfactory compaction of most materials can only be achieved when the temperature is 32° F or higher. Compaction of both unclassified material and granular material becomes increasingly difficult as air and material temperatures approach freezing. This fact has been verified repeatedly through both laboratory and field testing. The increased difficulty is caused by the water in soil reacting less and less as a lubricant, typically below a temperature of 40° F, until it actually becomes ice, at which point compaction is totally inhibited.

8. SUMMARY

By way of summary, some aspects of embankment construction should be emphasized:

1. The embankment foundation is assumed to be stable. The plans and proposal should indicate any unstable or unsuitable conditions.
2. The embankment consists of a series of compacted layers of soil. The construction of each layer or lift must be approved by the Engineer. Compaction Control Tests should be performed frequently. Guidance for testing frequency is included in the Inspectors Guide for SiteManager, Exhibit 203-A.
3. A properly constructed embankment may easily be damaged by injudicious use as a haul road for earth moving equipment. Repair of such damage is the responsibility of the Contractor. See Figures 30 & 31).
4. The Regional Geotechnical Engineer is available to provide technical guidance for embankment construction.
5. Thorough familiarity with the Standard Specifications, particularly Section 203, is not only desirable but essential.

9. ADDITIONAL FIGURES

Figure 18 Benching

Figure 19 Benching

Figure 20 Unstable Embankment Foundation

Figure 21 Construction Lift Backfilling Undercut of Embankment Foundation Utilizing a Geotextile Separator

Figure 22 Typical Unsuitable Material Deposits (Wetland)

Figure 23 Unsuitable Removal

Figure 24 Normal Compaction Operation – Vibratory Drum Compactor

Figure 25 Compaction Control – Volumeter

Figure 26 Disc Harrow Attachment - a tillage implement typically for agriculture.

Figure 27 Cultivator (with accessories) Attachment - a tillage implement typically for agriculture.

Figure 28 Water Being Applied By Water Truck

Figure 29 Normal, Stable Embankment Construction

Figure 30 Haul Road Damage

Figure 31 Haul Road Damage

APPENDIX

NEW YORK STATE DEPARTMENT OF TRANSPORTATION
WINTER EARTHWORK SUBMITTAL

PURPOSE: Compaction of soil during cold weather is difficult and can be impractical. Water acts as a lubricant aiding in the process of compaction. As the temperature decreases, the water becomes more viscous (less slippery) and inhibits efforts to pack the soil particles together. Eventually, the water becomes ice, at which point compaction is impossible.

PROJECT LOCATION:

Project____

Contract No. _______________ P.I.N. _________________ Region No.____ County ___________

Earthwork construction operations requiring compaction are requested to be performed between November 1st thru April 1st on the above noted project. To ensure the satisfactory installation of a material that will perform properly throughout its design life, this Winter Earthwork submittal is provided for approval and is subject to the Standard Specification requirements, including the following:

- In all work incorporated into the final product, frozen material will not be placed nor will fill material be placed on ground frozen to any depth regardless of the date.

For each geotechnical element to be constructed, provide the modifications to the materials and/or methods of placement. Submit a separate form for each geotechnical element.

Winter Earthwork Submittal No. ________ of _________	
ELEMENT PROPOSED TO BE CONSTRUCTED	
Type and Location - e.g. Retaining Wall between Sta.__ & Sta. __, Embankment between Sta.__ & Sta. __, Begin & End Abutment Construction	

MATERIAL REQUIREMENTS (see §733-16):

Provide information on material composition and source substitute, if proposed.

Stockpile No. ________________

Stockpile Location ____

Source of Material ____

Address ___________________________Township_________________ County ______________

U.S.G.S. Quad Location _____________________________________

NOTE:

203 Items: • To continue without modifications to methods and procedures to control weather influences, the material must meet §733-16 *Winter Earthwork.*

304 Items: • Cannot continue without modifications to methods and procedures to control weather influences.

554 Items: • To continue without modifications to methods and procedures to control weather influences, the material must meet §733-16 *Winter Earthwork* and be compatible with the wall design.
• For MSES or MSWS construction, switching material in mid-construction shall only be allowed in accordance with §554-3.01C, §733-16 *Material Requirements* C.3, and as described in the Approved Winter Earthwork submittal.

NEW YORK STATE DEPARTMENT OF TRANSPORTATION
WINTER EARTHWORK SUBMITTAL

MATERIAL PLACEMENT:

Provide information on the proposed methods for controlling the weather effects on the material and existing ground conditions (i.e. insulation, enclosures, canvas and framework), if proposed. Include diagram of structural layout, cut sheets for all materials, location and type of heating source, and other pertinent information. In addition to the logistics within the project limits, provide information addressing the source locale or stockpile conditions. Provide attachments as needed.

____

____

____

PROCEDURES:

Provide verification procedures to ensure the existing ground is not frozen to any depth (e.g. test pit location(s) and frequency). Provide procedures to address freeze-thaw action in earthwork that has remained idle during temperature fluctuations (e.g. re-roll and seal the surface prior to placement of succeeding lift). Provide attachments as needed.

____

____

____

SEASONAL ADJUSTMENT ACCEPTANCE:

- Transitioning from the normal construction season to the exempt winter earthwork months between November 1st and April 1st, standard earthwork materials will be used only under the conditions where the air temperature, ground temperature and material temperature are all above 32° F at the time of placement. The following modifications to compaction procedures will be used when the temperatures are above 32° F but below 39° F at the time of placement (e.g. thinner lifts)

____

____

- Between November 1st and April 1st, if the air temperature, ground temperature, or material temperature is at or below 32° F, earthwork will only proceed using material that meets the requirements of §733-16 *Winter Earthwork* and/or standard earthwork material placement utilizing the modified methods and procedures contained in this Winter Earthwork Submittal.

NOTE: **203 & 554 Items –** When either the backfill material, the grade, or the air temperature drops below freezing, standard earthwork materials may only be placed by utilizing modified methods and procedures to adjust for the weather influence on the compaction operations. If this is not done, the material must meet §733-16 *Winter Earthwork* as defined in the Standard Specifications for each item.

304 Items – When either the backfill material, the grade, or the air temperature drops below freezing, standard earthwork materials may only be placed by utilizing modified methods and procedures to adjust for the weather influence on the compaction operations.

SUBMITTED BY:

Company Name ____

Representative (print) ____

Signature ____

UNSUITABLE MATERIAL TREATMENT

DESIGN AND CONSTRUCTION

UNSUITABLE MATERIAL TREATMENT

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APPENDICES

UNSUITABLE MATERIAL TREATMENT

I. Introduction

A. General

This is written as a guide for those involved in the design and construction of highways across unsuitable foundation deposits; from the person responsible for locating and exploring the deposit to the person who directs the construction of the highway. This treatise should aid in the decision process as well as guide the Geotechnical Designer and the Construction Engineer.

Unsuitable materials as used in this treatise are those organic soil deposits which do not make a proper foundation for highway construction. Unsuitable materials have the poorest of foundation characteristics. They have large settlement potential and very low strength. Any structure, whether a building or a highway embankment, constructed on these soils without proper treatment will settle and become distorted.

Treatments for these soils can include the following: removal and replacement with a better material, surcharging to reduce post construction settlement, or displacement with a heavier material and removal of the displaced unsuitable soil.

B. Organizational Responsibilities

The Geotechnical Design Manual (GDM) describes the responsibilities for obtaining the soils information and for obtaining proper designs. The Regional Geotechnical Group locates and explores the deposit; the Geotechnical Engineering Bureau analyzes and designs the proper treatment; and the Design Engineer is responsible for the overall design of the project.

Within the Geotechnical Engineering Bureau, the Area Engineer is responsible for deciding the extent of involvement the various sections of the Bureau will have on any particular unsuitable material problem. It is his responsibility for deciding whether the deposit can be left in place, removed, or whether the problem is more complex requiring detailed analysis.

II. Organic Deposit

A. The Deposit

Organic deposits can vary from the simple surface layer of organic over a dense foundation to a complex layered system of organic, marl, and clay with perhaps more than one layer of each. In several instances a coarse layer of sand and gravel has been found in these systems.

Frequently, an organic layer is underlain with marl or clay thereby making a complete settlement and stability analysis necessary to develop a proper treatment. In some instances a stream meander which filled with organic has subsequently been covered by alluvium. Those that are not located and treated can cause a bump (“Thank You Ma’am”) for the traveling public.

B. Recognizing the Deposit

Air photos, USGS topographic sheets, Soil Conservation Service Soil Survey publications, and Geotechnical Engineering Bureau records can be useful in locating unsuitable deposits. However, it is also important to occupy the site and look.

The deposits are generally found on flat, low topography with the water table at or near the ground surface. Most deposits are easily recognized because cattails or swamp grass cover the area. However, some deposits are tree covered or disturbed by man, making recognition difficult. Kettle holes filled with organic soil are very difficult t to recognize, at times having vegetation similar to that of the surrounding area. Buried stream channels in flood plains are also difficult to find. Old maps and air photos can be very helpful in locating deposits masked by changed conditions or those formed in kettle holes and old stream channels.

Some wetlands are formed in uplands and may pose a problem in a cut situation. An example of this is on I-87 just north of Route 9N at Elizabethtown where a dam had to be constructed at the top of a cut slope to keep the water and unsuitable material from flowing down the slope.

C. Exploring the Deposit

Subsurface explorations are necessary to determine the extent and depth for quantity purposes, to obtain samples for design analysis, and to evaluate the underlying soil for stability and settlement characteristics.

Cased drill holes are required to establish the soil profile sufficiently to rule out buried organics and any problem associated with the underlying deposits. Undisturbed samples may be required for detailed testing and analysis purposes.

Once the deposit is generally defined, less sophisticated exploration procedures can be used to fill in the limits and depths for quantity purposes. These can be hand augers, or in some instances, probes or resistivity methods. Special tools may be needed to obtain the top of the deposit when the deposit is soft and under water.

The important thing is to obtain adequate samples to define the material characteristics and to ensure that all engineering questions can be answered. The moisture content is the most important characteristic since it can readily be related to settlement parameters. Consequently, too many samples cannot be obtained for this purpose.

III. Design Considerations

The first design consideration should be to avoid the organic deposit if feasible. However, in many instances other circumstances make it impractical to change locations. It is then necessary to design a treatment to avoid or minimize differential settlement.

Organic soils are extremely compressible and settlement is great under even small loads. The settlement is comprised of two components: primary and secondary. The primary is of large magnitude and occurs rapidly while the secondary, although of smaller magnitude, continues practically forever. In addition, organic soils are very weak and moderate loads may cause embankment failures. For these reasons, the organic soils are usually excavated and replaced with a suitable granular material or broken rock.

Some organic deposits have variable amounts of inorganic material contained in them. As the amount of inorganic material increases, the deposit becomes capable of supporting greater loads and the settlement occurs more rapidly with little to no secondary settlement. These deposits may be suitable as a foundation or substantial loads with proper treatment.

To properly design a treatment for a highway over organic material, the geometry of the proposed highway must be known. The grade of the highway (fill height), the width of the embankment and the slope of the side slopes are needed.

It is also of value to realize that for some low volume roads some distortion may be tolerated, although for the normal project the design objective is to have no distortion.

If the project is the reconstruction of an existing roadway, the past performance and soil treatment must be known. The removal limits used today are different than those used in the past and they may have varied from job to job. (See Appendix, Figure A for typical removal section comparison). It is also possible that the excavated material was disposed of on the side slopes.

The basic question relating to an organic deposit is whether it can be used as a foundation or not. This determination is based on almost entirely on the moisture content and drawing SM 1612A (Appendix, Figure D). If the moisture content is border-line, the design might include stage construction with a surcharge and waiting period rather than removal.

The depth of the organic deposit usually determines the need for a displacement treatment, but a weak underlying layer might also cause the need for this type of treatment.

The overall soil profile must be evaluated in the selection of the foundation treatment. The stability of the roadway and post construction settlement due to the underlying soil must be analyzed and resolved. Environmental aspects must be considered in the details of design. These include changing water conditions which might kill plants, silting up of streams, spilling material on public highways and odor control.

IV. Design Treatments

A. Excavate and Backfill

The usual design used to treat a wetland crossing is to remove the organic material and replace it with granular soil or rock. The following factors must be considered during design:

1. The deposits must be shown on the plans. Various methods are acceptable for presenting this information, such as contours showing the bottom of removal, or a table indicating depth of removal at each section or at each exploration location.

2. For most organic deposits, Standard Sheet 203-1, Construction Details Unsuitable Material Excavation and Backfill, can be used as the Typical Section (Appendix, Figure E). This sheet may be used for all deposits less than 20 ft. deep. For wetlands greater than 20 ft. deep, special consideration is necessary and usually a displacement operation is used.

3. Environmental concerns must be considered such as water pollution and the need for silt curtains, straw bales, and settlement ponds. If it will be necessary to haul over public highways, some hauling restrictions may be necessary.

4. The backfill material should be a select granular material or broken rock from the project excavation. Broken rock from the project must be available in sufficient quantity to complete the backfill to be specified for that use. When specified, the payment method for placing it must be clearly stated.

5. The top of the backfill should be 2 ft. above the existing water surface. If for some reason the excavation is “dry”, a 2 ft. lift should be placed before normal embankment construction is started.

6. The organic material may be disposed of in the “side slope area” as defined in §203-1.01F of the Standard Specifications or other designated areas on the job. If no such provisions are made in the contract, the Contractor is responsible for disposing of the material. When the excavated material is designed to be wasted in the “side slope area”, a note should be used to indicate the side slope may require re-grading due to the organic’s shrinkage upon drying.

7. The plans should contain provisions for a boat to facilitate checking the excavation for completeness.

B. Displacement

A wetland greater than 20 ft. in depth cannot be cleanly excavated. A displacement operation can be used to squeeze the deeper unsuitable material forward and upward by carrying the backfill at a sufficient height to "fail" the underlying material.

The design in this case will be similar to the excavation and backfill procedure with these additional provisions:

1. The quantities of excavation and backfill will have to be predetermined based on an assumed displacement depth. The excavation can be paid as a "Lump Sum" or "Lump Quantity" (see specification in Appendix, Figure F) and the backfill can be paid as "Select Borrow" and measured in the borrow pit. The "Lump Quantity" payment which is paid on the cubic yard basis is preferred, as adjustments can be made in the quantity if necessary.

2. A Typical Section is required to show the following (See Appendix, Figure B):

    a. The elevation of top of backfill.

    b. A note to describe the backfill placement procedure necessary to obtain and maintain a steep backfill face, i.e. dump on the backfill and push forward and maintain dozer blade horizontal.

    c. The minimum opening between the toe of the advancing fill and the front of the excavation must be determined by design.

    d. A note to tell the contractor to remove the mud-waves caused by the displacement.

    e. The depth of initial excavation is to be designed (usually 20 ft.).

    f. A note to tell the Contractor to maintain the water elevation as high as possible.

C. Close Excavation and Backfill

Many times an existing facility is to be widened through an organic deposit and the removal of the organic under the widening may cause an unstable condition. In this case excavation and backfill is progressed by keeping the length of open excavation very short parallel to the roadway. Notes and drawings are required to show this procedure (See Appendix, Figure C). Rock backfill will be necessary to maintain a steep backfill face under water.

D. Surcharge and Waiting Period

A load on organic soils will cause a certain amount of settlement which takes place over a long time span. Placing a larger load for a shorter time can affect the same amount of settlement. Using the proper overload and the proper time span, post construction settlement can be avoided.

This procedure may be applicable to situations where embankments can be built on the organic deposit or where the organic was partially removed with some settlement still expected.

The fill height, including the surcharge, must be such that the shear strength of the foundation soil is not exceeded. It is most effective where low fills are designed over organics as the surcharge can be significant without overloading the soils. The use of geotextiles and flatter side slope can increase this height.

The technique has been used successfully to widen an existing roadway over an organic deposit by surcharging the widening.

E. Construction Lift

In the past, all organic deposits were excavated and replaced with granular material. Some of these deposits were shallow and covered large areas. There was a tendency to over-excavate these deposits and overruns were large.

Where unsuitable deposits are shallow and the moisture content is generally less than 100% they may be left in place. A 2 to 3 ft. lift of granular material or rock is used to start the embankment construction in these areas.

A construction lift can also be used in areas that are inundated or just wet.

A simple typical section is needed in the plans to show the pay lines for the lift item (usually Select Fill). The upper pay line should be 2 ft. above the water surface or to some predetermined elevation and the lateral limits should be the embankment toe of slopes.

V. Instrumentation

Instrumentation to monitor settlement is required only when the treatment includes a waiting period. A waiting period may be used in conjunction with a displacement treatment or a surcharge treatment. This instrumentation should consist of settlement stakes set after the embankment has been constructed to subgrade or to surcharge grade.

VI. Construction

The Regional Geotechnical Engineer should arrange a preconstruction meeting on the project and review the soils related aspects of design with the Project Engineer and Contractor. He should also be available when the more important soils operations are going on to aid the project personnel with inspection. Some of the problems to avoid are as follows:

A. Excavation

1. Remind the EIC and Contractor that the water level in the excavation should be as high as possible to avoid sloughing at the vertical sides of the excavations. No payment will be made for removal of sloughed material or the backfill required to replace it.

2. The excavation should progress in one direction only and parallel to the roadway.

3. The excavating equipment should work from the wetland surface if the depth of excavation is greater than about 5 ft.

4. The opening between the excavation front and the backfill face must be maintained to allow measurement to be taken. These measurements should be taken often to assure the required depth of excavation is attained.

5. During a displacement operation the inspection is most critical. Measurements are constantly needed to assure the required opening between the toe of the backfill and the excavation face is maintained so displacement can take place. The measurements will also pick up the presence of mud-waves in the opening as the displacement takes place. These mud-waves must be removed as they are formed to allow maximum displacement.

6. A hydraulic dredge may be used to excavate. It is necessary to avoid pollution and settlement basins will be needed. The surface of the settlement basins must be capped with earth after use to prevent a person or animal from being caught or drowned in the soft material.

7. When a close order excavation and backfill operation is taking place, the opening between the excavation and backfill face is critical and a maximum is given to avoid failure of the side(s) into the opening. Very close inspection and measurements are necessary.

8. Unsuitable material disposed of on the side slopes will shrink about 50% upon drying. This must be taken into consideration if a particular slope is designed and wanted.

9. Over-excavation can cause large, unnecessary overruns especially when excavating large shallow areas. The inspector should not use color as a criteria for excavation depth, but should excavate to an elevation. If it is suspected that a deeper deposit exists than thought during design, the Regional Geotechnical Engineer should be involved and further explorations progressed if necessary.

B. Backflll

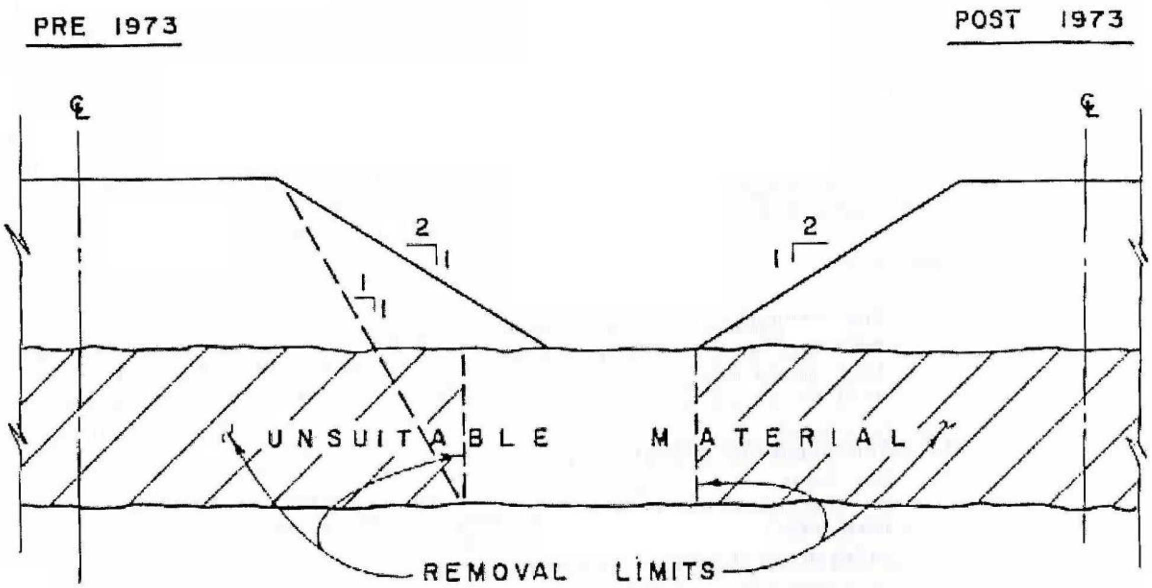
1. The steepness of the backfill face will be dependent on the material used. The finer grained the material, the flatter the face slope will be. The face slope of the rock backfill underwater will be about 1V on 1H, and for sand it will be 1V on 3H or flatter.

2. The backfill should be placed by dumping on the backfill behind the face, and using a dozer to push it forward. The dozer blade should always be in the horizontal position and not push downward into the excavation. This will assure the steepest face for a particular backfill material. The steepness of the face is critical for a displacement operation.

3. Rock backfill should be fairly well graded and not be comprised solely of large pieces to avoid large voids.

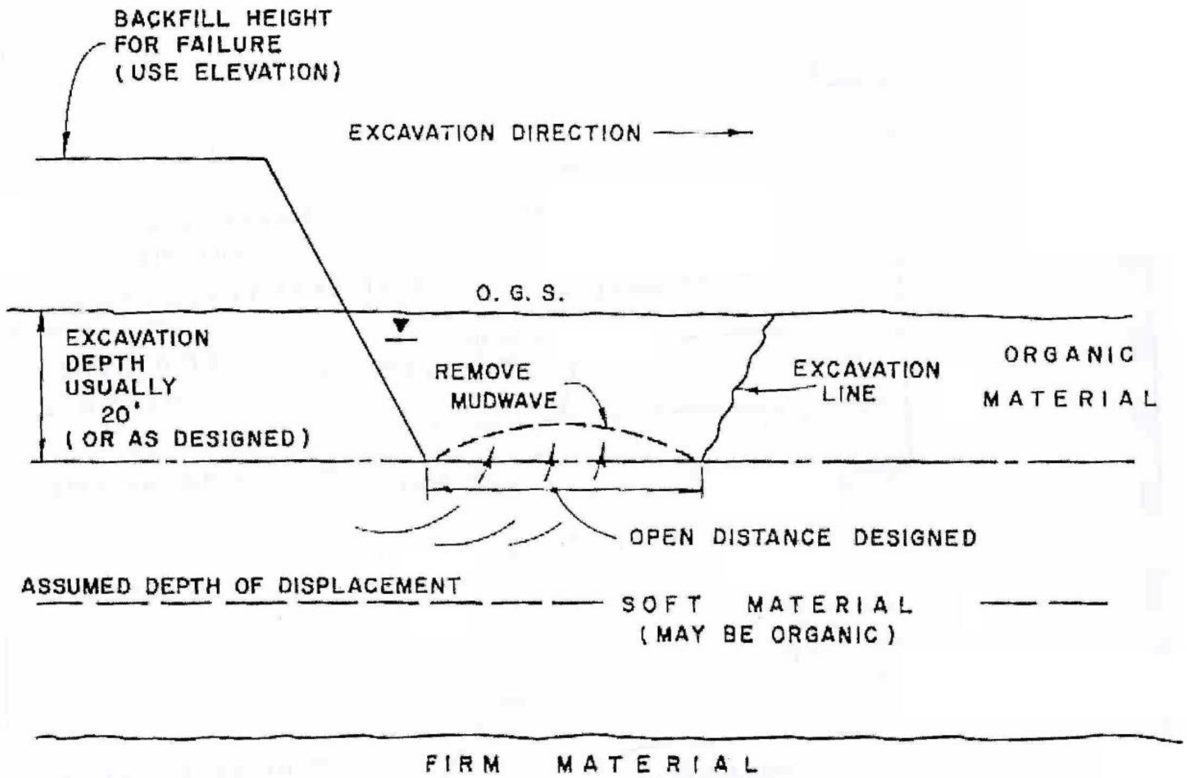
4. If the bottom of the wetland is not level, the backfill front may be skewed to force the unsuitable downslope.

5. Where utilities or pipes are to be placed in an excavation area, the excavation and backfill should be completed and re-excavated to place these conduits.



Organic material can exist under the side slope of old highways. This must be considered when reconstructing projects.

Figure A – Comparison of Typical Removal Sections



1. Do not dewater.
2. Maintain max. wt. of backfill and steep face by dumping on backfill and pushing forward. Do not drop dozer blade beyond horizontal.
3. Maintain min. 25' excavation opening.
4. Remove mudwave as necessary.
5. The excavation depth is 20 feet.
6. Almost constant sounding for removal is necessary because of expected mudwaves.

Figure B – Displacement Procedure

Widening over organic material where the existing roadway would be unstable during excavation. (Close order excavation and backfill)

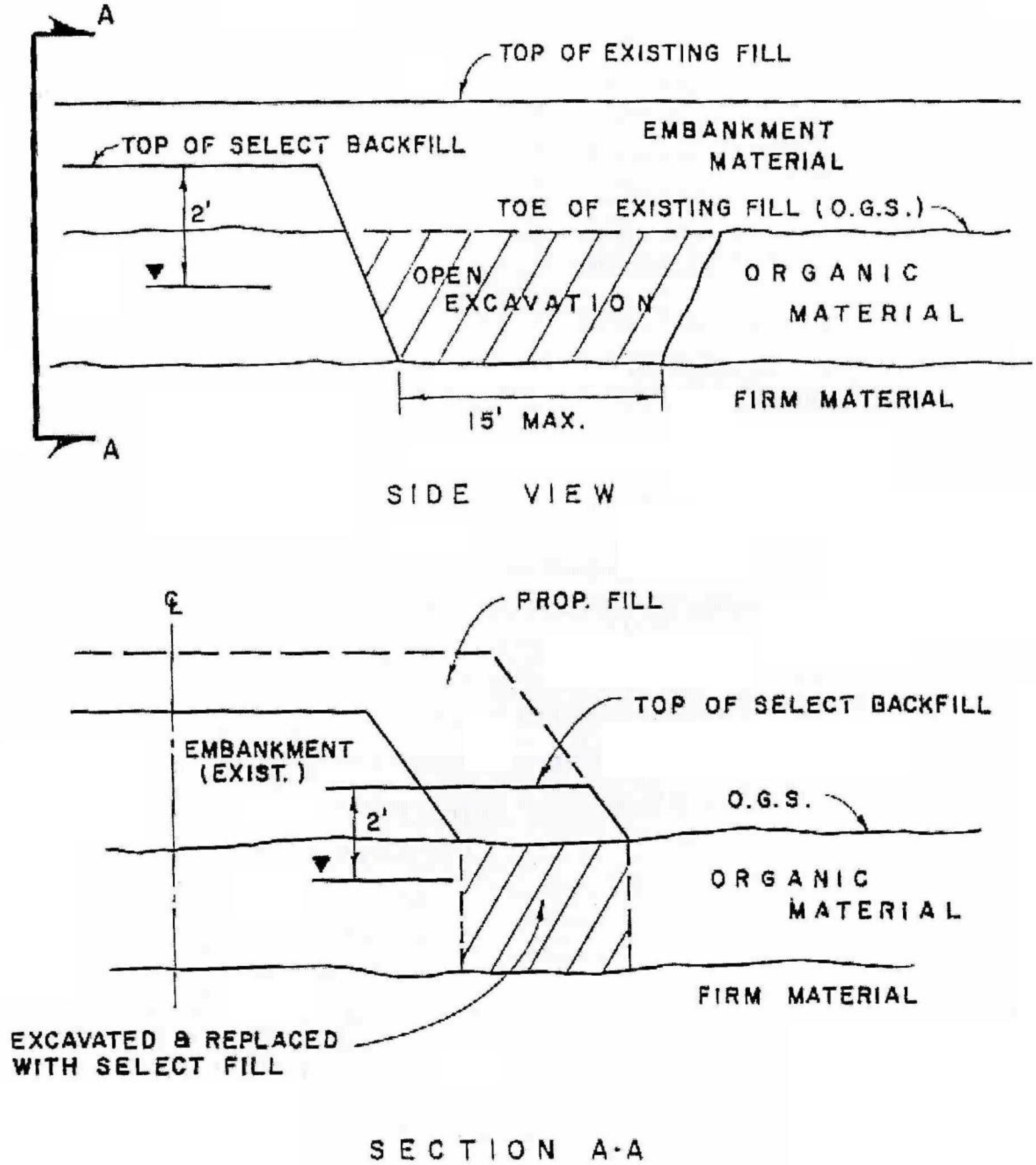
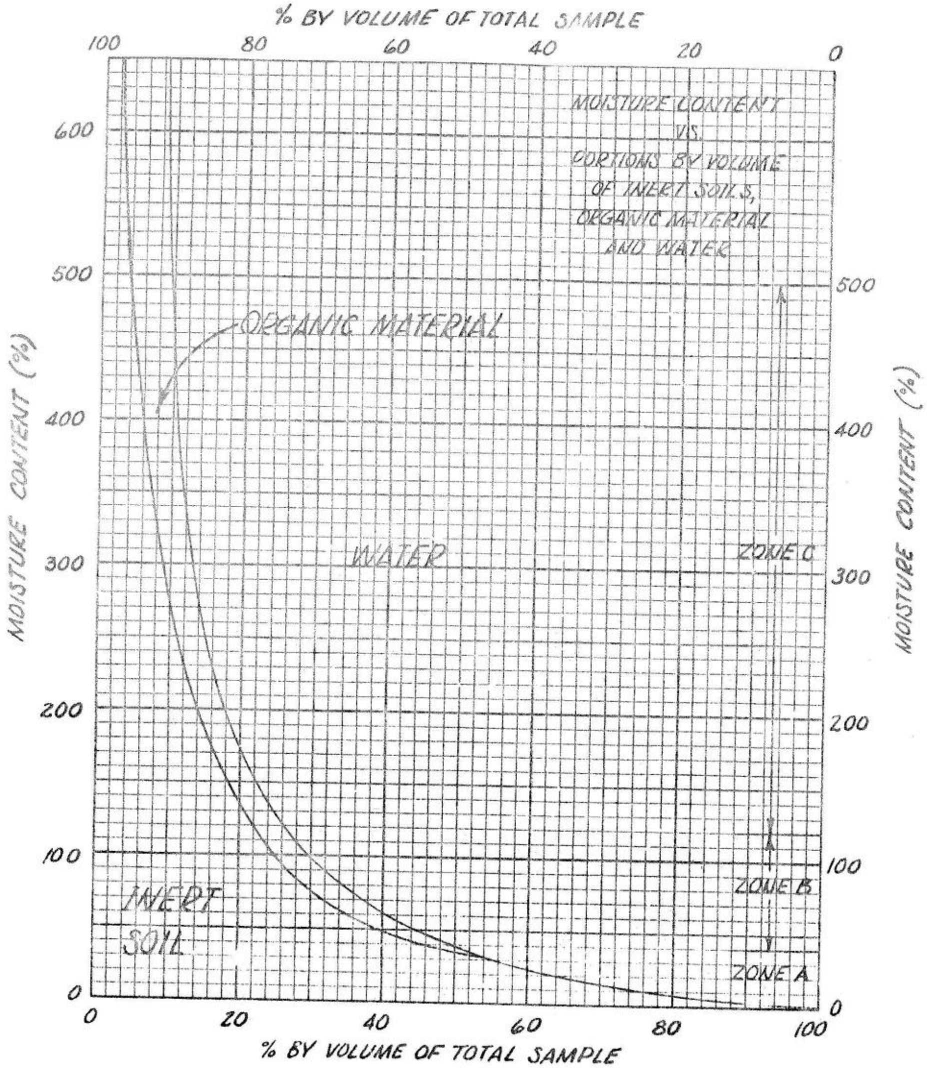


Figure C – Close Excavation and Backfill



ENGINEERING CHARACTERISTICS OF ORGANIC SOILS

VISUAL IDENTIFICATION AND MOISTURE CONTENT ARE TWO SIMPLE TESTS USED TO ESTIMATE THE ENGINEERING PROPERTIES OF ORGANIC SOILS.

ON THE ADJACENT PLOTS THE SOILS HAVE BEEN PLACED IN THREE GENERAL CATEGORIES:

ZONE A - FINE SANDS AND SILTS WITH SMALL AMOUNTS OF ORGANIC - USUALLY OFFER NO CONSTRUCTION PROBLEMS.

ZONE B - INERT SOIL MIXED WITH ORGANIC MATERIAL - MAY BE STABILIZED IN SOME CASES.

ZONE C - ORGANIC SOIL WITH SMALL AMOUNTS OF INERT - USUALLY UNSUITABLE FOR HIGHWAY FOUNDATION AND MUST BE REMOVED BY EXCAVATION OR DISPLACEMENT.

EXAMPLE SHOWING USE OF CHART:

AT MOISTURE CONTENT OF 200% A SATURATED SOIL CONTAINS BY VOLUME 14% INERT SOIL, 4% ORGANIC MATERIAL AND 82% WATER.

Figure D – Drawing SM 1612A (Top)

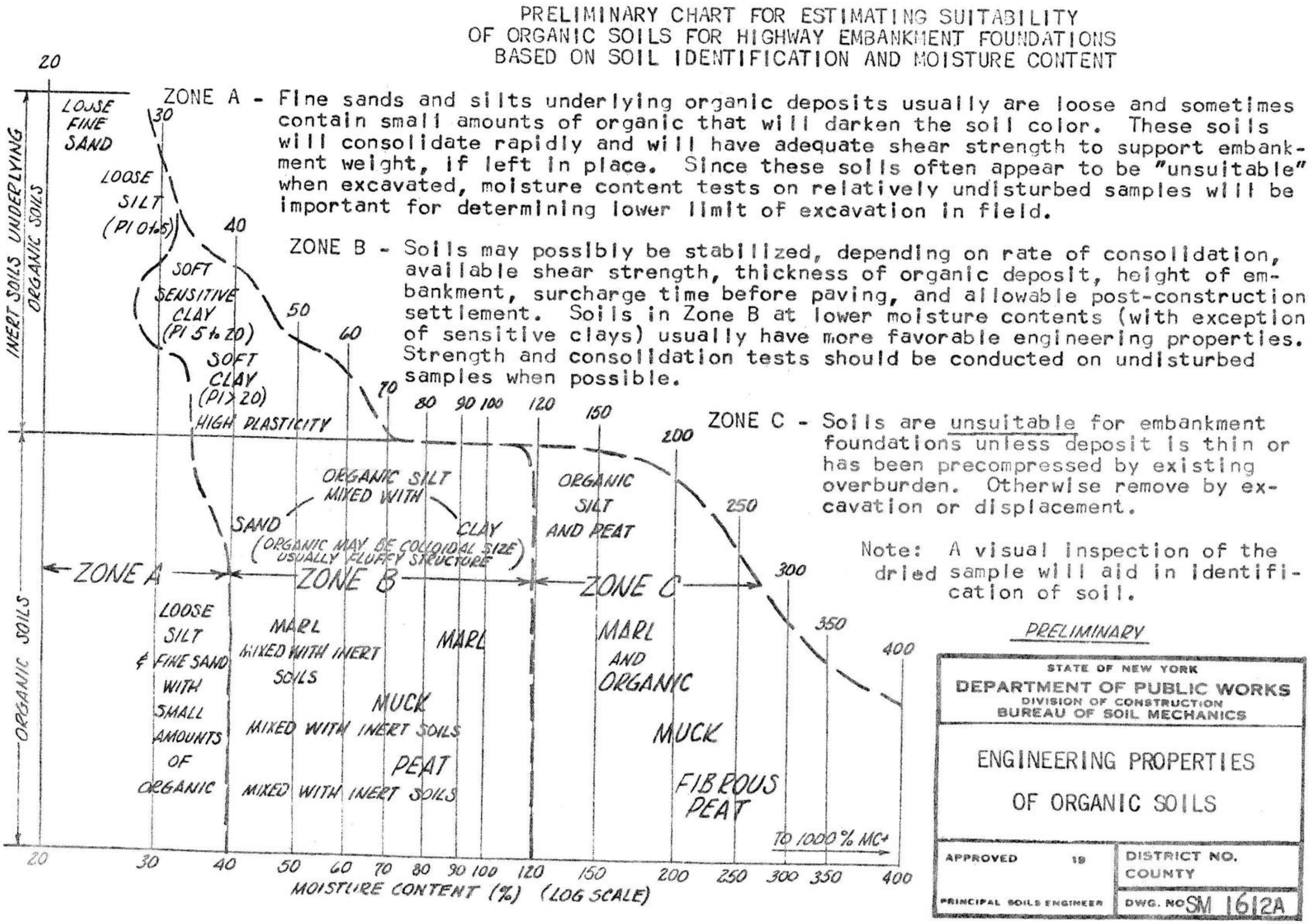


Figure D – Drawing SM 1612A (Bottom)

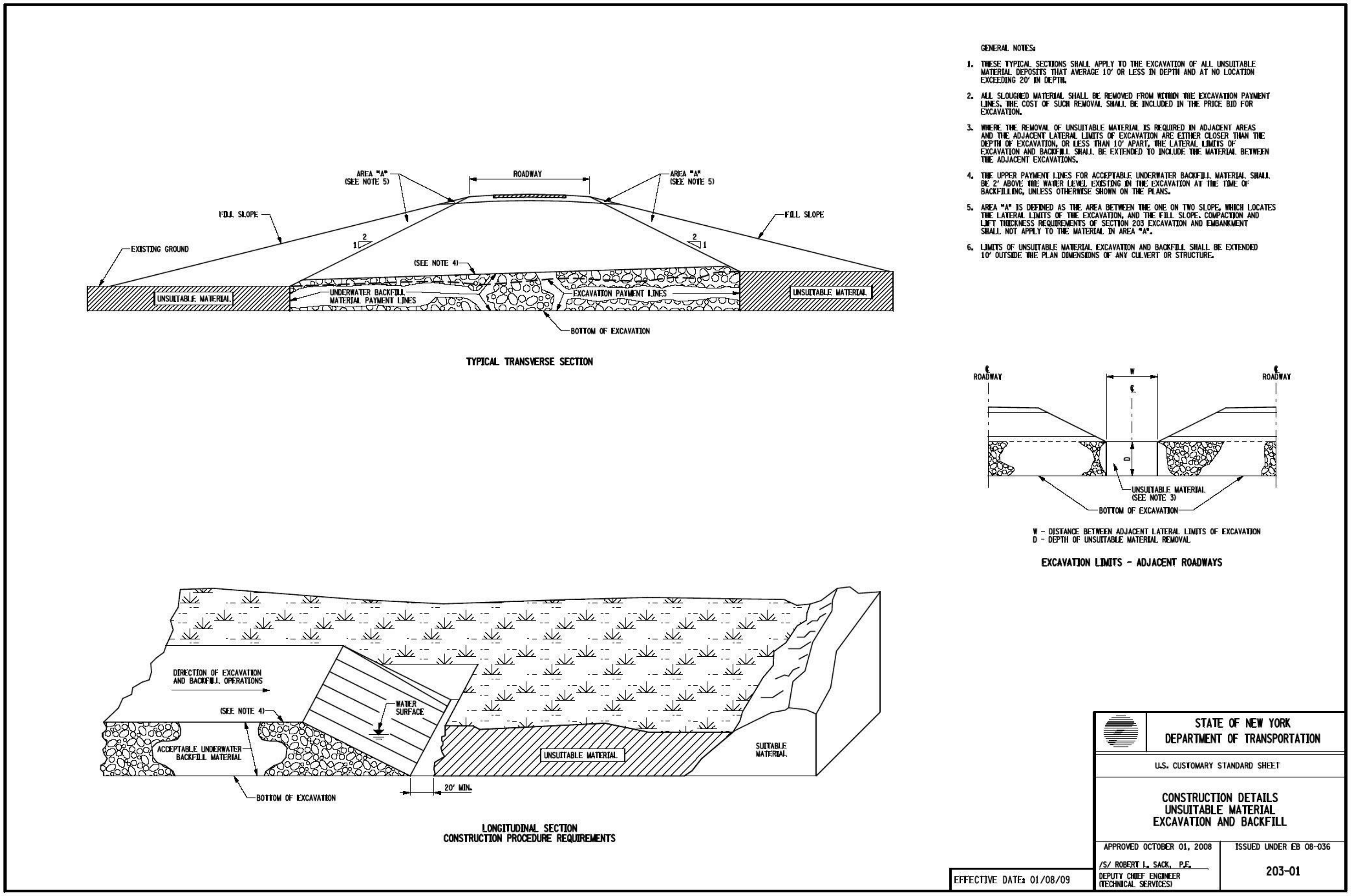


Figure E – Standard Sheet 203-1

https://www.dot.ny.gov/main/business-center/engineering/cadd-info/drawings/standard-sheets-us-repository/203-01.pdf

DESCRIPTION

This work shall consist of removing all unsuitable material from beneath the proposed embankments by a combination of excavation and displacement. The unsuitable material shall be removed according to the procedure and to the limits shown in the contract documents.

The unsuitable material shall be disposed of as shown in the contract documents.

METHOD OF MEASUREMENT

This work will be measured as the number of cubic yards of unsuitable material, computed between the payment lines shown in the contract documents. No payment will be made for the removal of unsuitable material beyond the payment lines shown in the contract documents unless this work is ordered by the Engineer prior to removal. Additional removal quantities ordered by the Engineer will be paid for at the unit price bid for this item.

No field measurements will be made for payment purposes.

Monthly payments will be made in proportion to the quantity of work completed.

No additional payment will be made for any re-handling of unsuitable material involved in the utilization or disposal of unsuitable material.

BASIS OF PAYMENT

The unit price bid shall include the cost of furnishing all labor and materials necessary to satisfactorily complete the work.

Figure F – Lump Quantity Specification