

3

CONSTRUCTION AND ACCEPTANCE TESTING OF SUBGRADE MATERIAL

LEARNING OUTCOMES

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

INTRODUCTION

What is Subgrade?

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

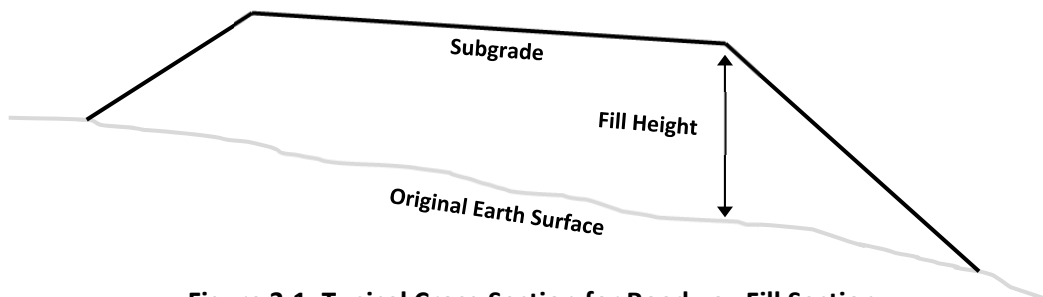


Figure 3.1: Typical Cross-Section for Roadway Fill Section

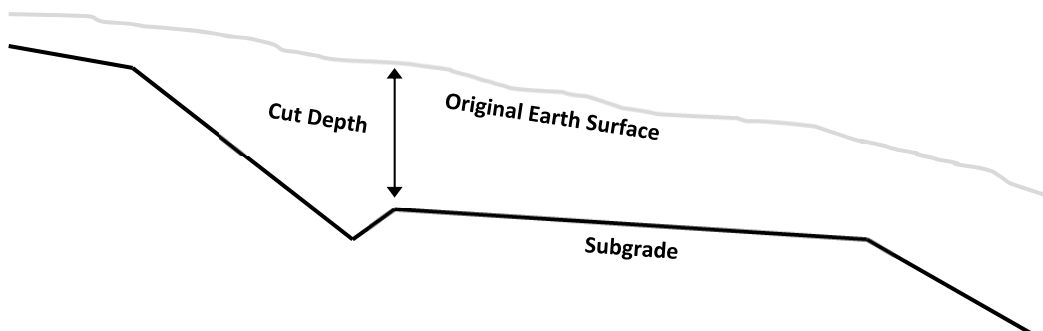


Figure 3.2: Typical Cross-Section for Roadway Cut Section

Importance of Subgrade

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

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

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

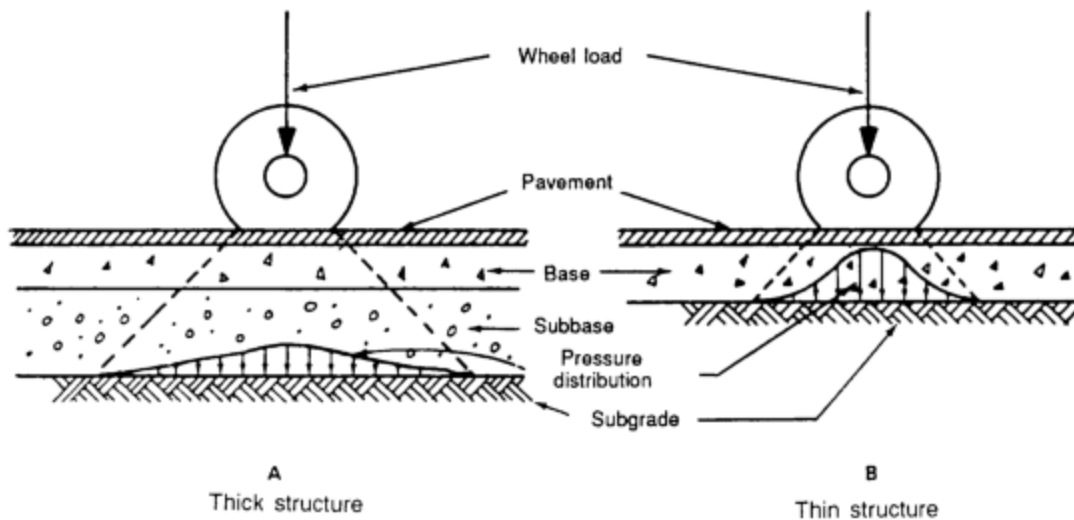


Figure 3.3: Load Distribution Characteristics of Thick versus Thin Pavements

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

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

Types of Subgrade Material

TABLE 3.1 Type of Subgrade Material	
Material Type	Material Description
Material in Place	Soil in a cut section of roadway
Imported Material	Borrow material and regular excavation material
Treated Material	Material in place or imported material May be considered in the design of the pavement structure Improves engineering properties of the soil Provides a solid platform to compact subsequent layers

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

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

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

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

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

COMPACTION REQUIREMENTS FOR SUBGRADE

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

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

The moisture requirement for subgrade is optimum moisture \pm 20%.

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

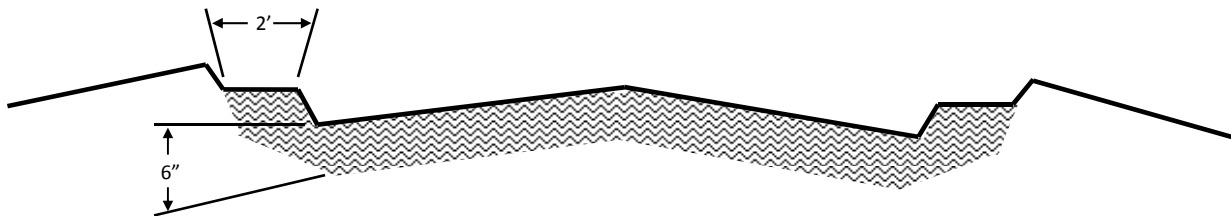


Figure 3.4: Typical Cross-Section of Roadway Subgrade Requiring Scarification

SUBGRADE STABILIZATION

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

Mechanical Stabilization

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

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

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

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

TABLE 3.3 Types of Mechanical Stabilization		
Stabilization Type	Equipment/Material Used	Construction Benefits
Rolling (Compaction)	Fine-Grained Soils (Clays/Silts) <ul style="list-style-type: none"> ▪ Sheepsfoot Roller ▪ Rubber-Tire Roller ▪ Smooth Wheel Roller Coarse-Grained Soils (Gravel/Sand) <ul style="list-style-type: none"> ▪ Crawler Tractor ▪ Vibratory Roller ▪ Rubber Tire Roller 	<ul style="list-style-type: none"> ▪ Increases density ▪ Increases strength ▪ Decreases permeability ▪ Decreases compressibility
Geosynthetics	<ul style="list-style-type: none"> ▪ Geotextiles ▪ Geogrid ▪ Geocomposites 	<ul style="list-style-type: none"> ▪ Increases subgrade strength ▪ Bridges soft subgrade areas ▪ Reinforces base material ▪ Resistance to spreading

Geotextiles are the most widely used geosynthetic. In this chapter we will discuss how we use geotextiles at the subgrade and under embankments. The geotextile performs the primary functions of reinforcement and separation when used at the subgrade and on the embankment footprint. Typically the geotextile is placed in the desired area, pulled tight to limit wrinkles, and if at the subgrade, an overlap of 2 feet is provided at the

seams. However, to reinforce an embankment, all seams are to be sewn to allow for the tensile stress to be transmitted. It is critical that the correct geotextile is used in the appropriate place, since the properties of various styles will affect the overall performance of the structure.

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

Chemical Stabilization

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

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

Hydraulic Cement Stabilization

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

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

TABLE 3.4 Hydraulic Cement Stabilization Requirements (By Soil Type)		
Soil Type	Usual Range in Cement Required	
	Percent by Volume	Percent by Weight
Clean Gravel	5 – 7	3 – 5
Clean Sand	7 – 9	5 – 8
Dirty Gravel or Sand	7 – 10	5 – 9
Silt	8 – 12	7 – 12
Clay	10 – 14	10 – 16

Hydraulic cement is usually added to existing material in place. This is normally done with a self-propelled, self-powered, rotary mixing or tilling machine. The subgrade layer is scarified to the specified depth, cement and

water added, and mixed by the same machine in one pass. Other machines which require a separate pass for each operation may be used but are not common.

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

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

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

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

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

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

Example Problem – Application Rate by Volume

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

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

- 1) Determine the Application Rate using the following formula:

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

Where:

W_t = Width of treatment in feet

D_t = Depth of treatment in feet ($8'' \div 12'' = 0.666'$)

D_c = Design cement content (volume in decimal form)

94 = Unit weight of cement in lb/ft³

$$\text{Application Rate} = [(28 \times 0.666) \times [(0.12 \times 94)]$$

$$\downarrow$$

$$18.648 \times 11.28$$

$$\downarrow$$

$$\text{Application Rate} = 210.35 \text{ lb/ft}^3$$

- 2) Determine the Application Length using the following formula:

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

Where:

Cement Weight = Net weight of cement in tons

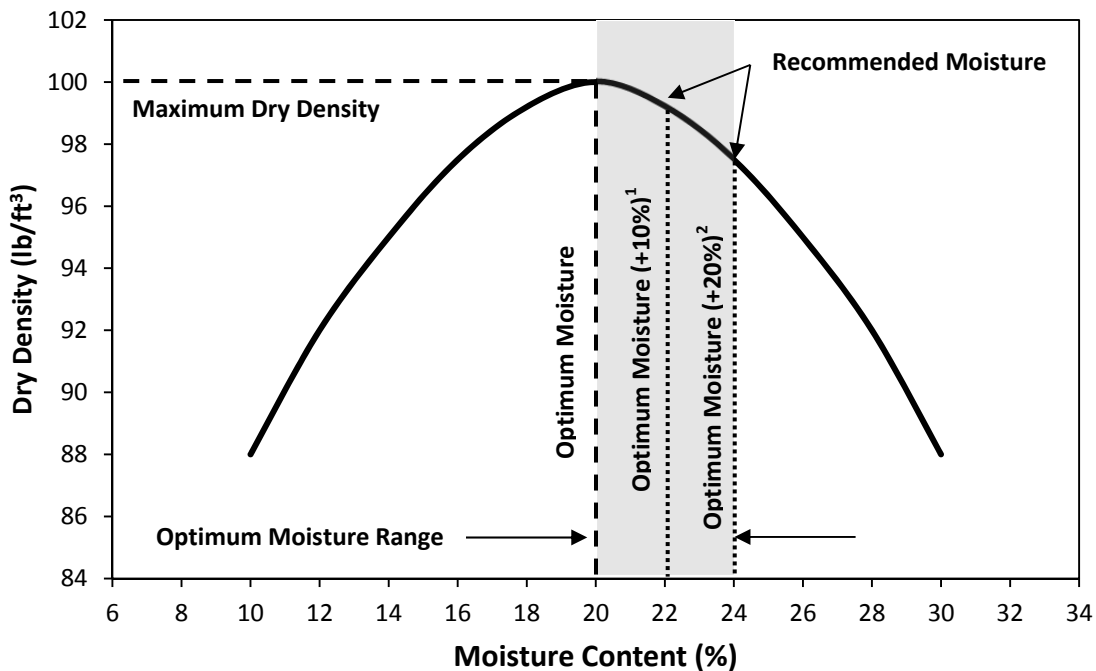
Application Rate = Resulting value calculated from Step 1

2000 = Number of pounds in one ton of cement material

$$\begin{aligned} \text{Application Length} &= \frac{(22.5 \times 2000)}{210.35} \\ &\downarrow \\ &= \frac{45,000}{210.35} \\ &\downarrow \\ \text{Application Length} &= 214 \text{ Feet} \end{aligned}$$

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

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



¹Acceptable Range = Up to 20% above Optimum Moisture

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

Figure 3.5: Moisture Control Chart with Original Proctor Curve

Depth Control. Having the proper depth of treatment is one of the most important factors affecting the final product. Deviation from the specified depth either by an increase or decrease has an effect on the strength of the treated material (see Figure 3.6 below). As stated earlier, stabilized subgrade is part of the pavement

structure. If the treated depth is less than that specified, we are compromising the pavement's depth. If the treated depth is greater than that specified, the cement will be dispersed throughout a greater volume and the entire course will be weak.

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

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

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

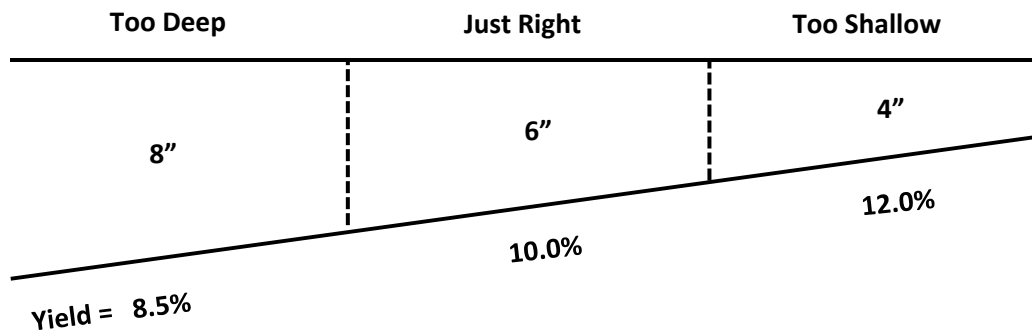


Figure 3.6: Effects of Incorrect Depth on Cement Yield

Compaction. The specifications require that soil cement be compacted to 100% of the maximum density. Compaction equipment is subject to the approval of the Engineer. A sufficient number of compaction units should be provided to ensure that the specified level of density is achieved, and the completion of the compaction of the soil cement section is accomplished within 4 hours from the time water is added to the mixture. The minimum rate of compaction testing is one test per ½ mile for each application width. Any portion on which the density is below the specified density by more than 5 lb/ft³ shall be removed and replaced.

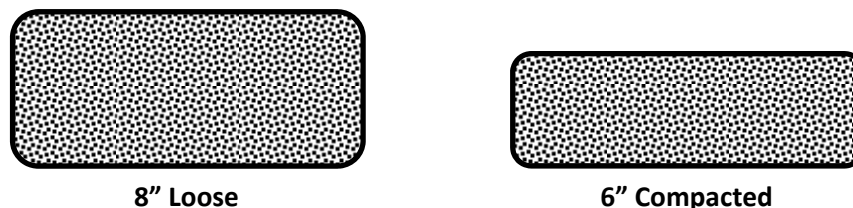


Figure 3.7: Illustration of Typical Compaction Depths (Loose vs. Compacted)

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

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

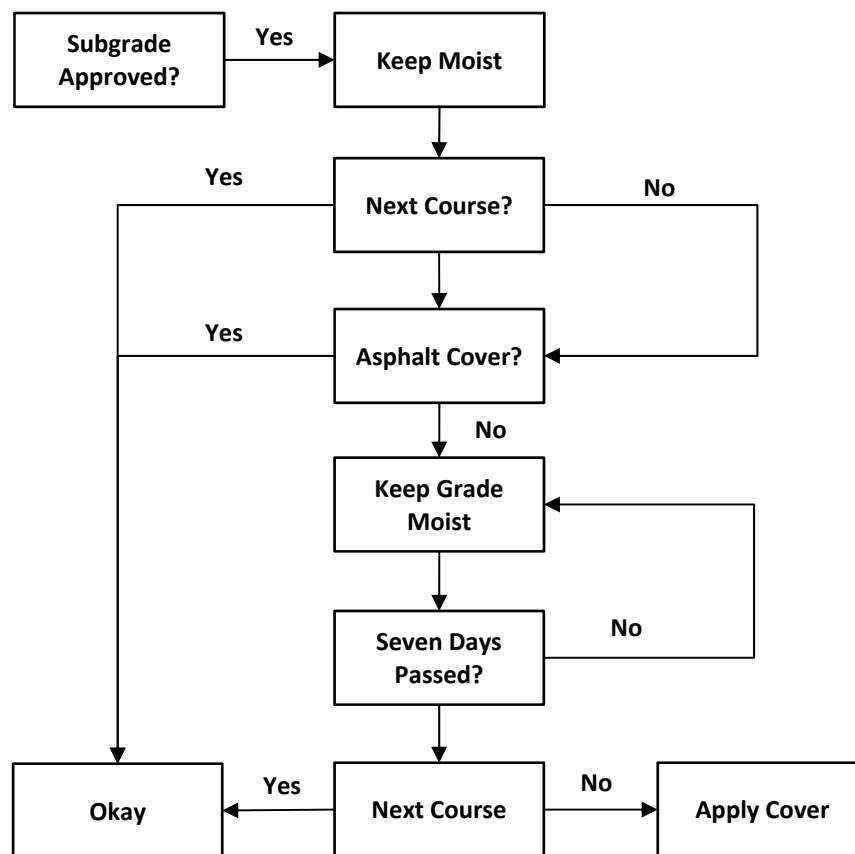


Figure 3.8: Decisional Flow Chart for Curing Process

Lime Stabilization

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

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

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

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

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

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

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

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

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

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

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

Salt Stabilization

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

Lime and Fly Ash Stabilization

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

Lime-Cement Stabilization

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

TREATMENT OF UNSUITABLE SUBGRADE MATERIAL

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

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

PROTECTING THE WORK

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

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

TESTING AND INSPECTION OF SUBGRADE

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

OBSTRUCTIONS AT SUBGRADE

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

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

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

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

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

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

CHAPTER 3 – STUDY QUESTIONS

- 1) _____ is the top surface of the embankment and the foundation for the pavement structure.
- 2) Subgrade must be scarified for a distance of _____ beyond the proposed edges of pavement to a depth of _____ and recompact to the original requirements.
- 3) _____ days after placement of the Cement Stabilized Subgrade the next course of pavement or approved cover material must be applied.
- 4) True or False. Cement is used with soil or aggregate to make the soil or aggregate more workable.
- 5) Why is lime used with soil?
- 6) The tolerance on the optimum moisture content at which aggregate must be compacted is _____.
- 7) The tolerance on the optimum moisture content for cement treated subgrade is _____.
- 8) The most common type of geosynthetic used is a _____.
- 9) True or False. Sewing of embankment stabilization fabric seams is not required.
- 10) What is the minimum number of tests required for finished subgrade from Station 453+60 to Station 553+60?
- 11) Cement Stabilized Subgrade has been placed 48 feet in width from Station 392+20 to Station 550+60, with a paver application width of 12 feet. Determine the number of tests required and the density and moisture requirements.

CHAPTER 3 – PRACTICE PROBLEMS

Practice Problem Number 1

Cement Application Rate (Volume Method)

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

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

Show your work!

CHAPTER 3 – PRACTICE PROBLEMS

Practice Problem Number 2

Cement Application Rate (Volume Method)

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

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

Show your work!

