1.0 General

These guidelines are to be used for all construction projects that require subgrade compaction and proof rolling. Over 25 million dollars of extra work was used to stabilize soft subgrades during construction seasons of 2000 and 2001. Undercut Design Guidelines were issued from Construction to Design on 09/26/00. Additional Subgrade Guidelines were issued from the Office of Geotechnical Engineering and Office of Construction on 1/11/01 to Production and the Soils Consultants. In a continuation of this effort, these guidelines are issued to construction personnel in order to properly evaluate subgrade conditions that require subgrade stabilization while minimizing costs.

These guidelines will help the project administrate and construct stable subgrades for the pavement construction. Proper treatment of the subgrade will assure a constructible pavement buildup, enhance pavement performance over its life and ensure that the pavement design intent is carried through in the construction phase. These guidelines are based on several past and recent projects and should be used as general guidance. They should not be used as the ultimate answer to solve all subgrade problems. The guidelines are simplified so that construction personnel can easily apply information from the field and subsurface investigation to provide reasonable adjustment to the plan subgrade treatment.

These guidelines supersede the 1996 Earthwork Construction Manual and other directives issued on the matter. This guideline will reference both the 1997 and the 2002 specifications.

2.0 Specification and Plan Requirements

New Item 204 (203.13 in CMS 1997), requires the top 12 inches of the subgrade to be compacted. New Item 204 (203.14 in CMS 1997) requires the subgrade to be proof rolled. If subgrade stabilization or undercutting is designed for the entire project, then the proof rolling will be used to verify the undercut replacement only. If special subgrade treatment is provided in the plans at spot locations, then the proof rolling is specified to identify these areas and then afterwards to verify the undercut stability.

The proof rolling deflections and soil conditions that are observed during construction will determine if there is a need to adjust the plan subgrade treatment. Adjustment of subgrade treatment to fit field conditions is essential and is the responsibility of the
3.0 Subgrade Correction Prior to Proof Rolling

The Engineer will observe the effect of heavy equipment operating on the subgrade at the time of rough grading. When rutting and deflection under heavy equipment indicates soft subgrade, the Engineer shall authorize the correction. See section 2.4 “Elasticity and Deformation of Soils” in the 1996 Earthwork Construction Manual.

Do not delay the correction until it can be later checked by proof rolling. Investigate the extent of the problem by using section 10.0 “The Investigation” of this document. Be aware that the condition can be improved by time, drainage and hauling as detailed in section 4.0 “Draining and Hauling”.

If needed, make the correction by excavating and disposing of soft grade, and replacing it with suitable material as detailed in section 11.0 “The Undercut Depth and Stabilization Determination”.

4.0 Drainage and Hauling

Excess water in fine-grained soil is the principal cause of unstable soil conditions. The Engineer has a responsibility to take steps to secure adequate drainage during construction. If the investigation indicates the need for underdrains or the cleaning of the existing underdrains outlets then the Engineer must order the work as soon as possible. Some examples of these conditions are as follows:

1. Existing underdrains with clogged outlets on rehabilitation projects.
2. Free water in the subgrade.
3. Saturated soils of moderately high permeability, such as sandy silt and silty clay of low plasticity.
4. Ground water seepage through layers of permeable soil.
5. Water seeping in the test pits.
6. Water seeping from higher elevations in cut locations.
7. Water flowing on the top of the rock undercuts.

Significant subgrade stability improvement can be obtained by cleaning out the existing underdrain outlets on rehabilitation projects and by adding construction underdrains on new construction projects. Once the underdrain systems are in place and functioning the drainage system can reduce the subgrade soil moisture contents from plus 3 percent of optimum to optimum in 6 to 8 weeks. Moisture contents that exceed plus 3 of optimum must be dealt with by other means.

For rehabilitation projects, the Contractor should be instructed to unclog the underdrain outlets immediately. Try to perform this work in the time frame listed above. If the
project consists of several phases, then instruct the Contractor to perform the outlet cleaning for the entire project at the same time. Because of the time frames involved construction underdrains should not be used for rehabilitation projects.

For new construction projects, subgrade stability can be achieved by constructing the plan or construction underdrains as soon as the water problem is found. On new construction projects a longer period of time can be allowed for the underdrain system to work. At the beginning of construction and certainly before winter shut down are opportune times for this work.

The plan underdrains should be placed only when they will not be contaminated by further construction. If contamination is a concern then sacrificial or construction underdrains should be used on the project.

Item 605 in the 2002 specifications detail the construction underdrain construction. Construction underdrains are usually placed in the centerline of the roadway. They may also be placed in the ditch line, if the water is coming in from a cut section at a higher elevation. The porous backfill is extended to the subgrade elevation. The outlets for the construction underdrain are the same pipe material and backfill as regular underdrains. The underdrains can be outlet to any convenient location. Some potential outlet locations are catch basins, manholes, pipe or ditches. The project should not be concerned with the contamination in the upper portion of the underdrain backfill. Construction underdrains are sacrificial underdrains that will continue to work throughout the life of the contract and afterwards even though the upper portion is contaminated.

For rock or shale cuts, the design underdrains should extend at least 6 inches (150 mm) into the existing rock formation. If the underdrains are too high, the water will accumulate at the rock and soil interface and cause subgrade instability.

Once the underdrain system is in place the subgrade condition will improve when used as a haul road.

By loading or hauling on the subgrade when the drainage system is in place, it gives the water a place to escape. If the drainage system is not in place before hauling or loading, the subgrade will act like a waterbed and will have a detrimental effect on the subgrade.

Drainage and hauling can work together to correct soft subgrades under the given guidelines.

5.0 When to Proof Roll

For areas where subgrade appears to be stable without undercutting, proof roll after the top 12 inches (0.3 meters) of the subgrade meets the compaction requirements and after the subgrade has been brought to approximate shape within (0.1 to 0.2 feet) (30 to 60 mm) required by plan lines.
For areas that are obviously unstable and require undercutting, do not proof roll unnecessarily to demonstrate that subgrade correction is required.

The proof rolling should be done immediately after the subgrade compaction operation when the moisture content of the subgrade soil is near optimum or at the moisture content that achieved compaction. This will minimize the subgrade becoming too wet or too dry for effective proof rolling evaluation. If the subgrade is too wet, the material will displace and rut. If the subgrade is too dry, a dry hard surface crust may carry the proof roller over an undesirable soft wet underlying material without rutting or deflection, and the soft subgrade may not be detected.

Proof rolling may be done either before or after pipe underdrains are installed. If done after underdrains are installed, rolling should not be done directly over the underdrains. Proof rolling should be done at least 1-½ feet (0.5 meters) away from the underdrains because of the potential damage to the underdrains. This is a specification requirement in the 2002 CMS in 204.06.

6.0 Proof Rolling

Form C-167 “Proof Rolling Documentation Form” is used to document the proof rolling operation. It is imperative that the stations, deflections, weight of the proof roller and comments are well documented. Digital pictures of the subgrade distresses are highly recommended.

The primary purposes of proof rolling is to locate soft areas, check the subgrade compaction, to carry out the intent of the design and to provide uniform support for the pavement structure. Soft subgrade areas that are located will be corrected so that the subgrade density can be maintained throughout the construction. If done correctly, the pavement design intent will be carried through the construction process.

One trip with a proof roller is usually adequate to achieve satisfactory proof rolling results.

An over loaded proof roller for a soil type may cause satisfactory subgrade to become unstable during proof rolling. Visa versa, if the proof roller is too light for the soil type then the soft areas will not be found.

7.0 Selection of Proof Roller Weights and Tire Pressure

In view of the many variations which must be expected in dealing with Ohio soil and moisture conditions, the Engineer is given authority to vary the weight and tire pressure of the proof roller to fit the conditions. The weights and tire pressures for the different soils are detailed in Item 204 in the 2002 specifications.
It is imperative that the project chooses the correct load for the type of soil on the project. These loads and tire pressures are soil type sensitive when evaluating the subgrade.

For A-3, A-4, A-6, and A-7 soils, use a 35 ton (32 metric ton) roller with a tire pressure of 120 psi (820 kPa). This load and tire pressure is used on most projects because these are the most common soils found in the State of Ohio.

For granular soils, and soil, rock and granular mixtures, use a 50 ton (46 metric ton) roller with 150 psi (1030 kPa) tire pressure.

The goal of proof rolling is to maximize the load to point out the soft subgrade. These soft soils could be 3 to 5 feet (1 to 2 meters) deep.

Close inspection throughout proof rolling is necessary in order to observe the effects of the rolling and to mark locations of the soft subgrade for correction or investigation. Inadequate stability is indicated by deflection, cracking or rutting of the surface of the subgrade.

8.0 Failure Criteria

The failure criteria in these guidelines have been expanded over the criteria given in the 1996 Earthwork Construction Manual. The old criterion was based on several passes with the proof roller and was too vague for the inexperienced Project Engineer. In addition, the old criterion was base on new construction projects and did not consider unique circumstances of rehabilitation projects.

The failure criteria between new construction and reconstruction projects is different because of the following reasons:

New construction projects:

1. Longer construction time frames allow the subgrade to stabilize.
2. Haul roads to minimize the loading of the subgrade can be established for new construction projects.
3. Drainage and maintenance of these projects are much easier.
4. Even when rutting does appear during proof rolling, the material may be re-graded, hauled on and re-compacted to meeting the specifications.

Rehabilitation projects:

1. The soil conditions under pavements are highly variable.
2. Water accumulates under the pavement because of the freeze thaw and wet dry cycles, high existing ditches and under drain outlet clogging.
3. Construction time frames are limited.
4. Space limits the ability to dry the material in place.
5. Once the pavement is removed all the drainage is toward the subgrade. This compounds an already poor drainage situation.
6. Alternate haul routes are limited or not available on rehabilitation projects.

8.1 The Criteria

For new construction, permanent rutting in excess of 1 inch (25 mm) should be considered failure. In addition, elastic (rebound) movement or rutting in excess of 1 inch (25 mm) with substantial cracking or substantial lateral movement should be considered failure.

For reconstruction projects, permanent rutting greater than ½ inch (13 mm) should be considered failure. In addition, elastic (rebound) movement or rutting in excess of 1/2 an inch (13 mm) with substantial cracking or substantial lateral movement should be considered failure.

When deflections are greater than these criteria, the overlying pavement cannot be constructed without damaging the subgrade compaction. Although the density and stability of the subgrade can be maintained during the proof rolling, the repetitive loading, hauling of materials and the base and pavement construction can destroy the subgrade compaction. See Figures 1 through 3.

In Figure 1, the soil has been compacted in the top foot of the subgrade and the conditions are good for the top 3 feet (1.0 m). But there is a soft layer at a lower elevation. The soft layer has no effect during the subgrade compaction. In stage 2 in Figure 2 during the proof rolling, the proof roller deflects because of the soft soils. The severity of the subgrade condition can be measured by the amount of the deflection on the surface. In stage 3 in Figure 3, when the deflections exceed the failure criteria, the repetitive loading and pavement construction can destroy the top layers of the subgrade.

In actual field conditions, this soft layer can be just a few inches thick and at any elevation from the top one-foot to as deep as 5 feet. The field excavation detailed in section 10.0 will identify the layer or layers causing the surface distress.

Therefore it is imperative that the project correctly identifies these conditions.

In Figure 6 “Subgrade Treatment Chart” on the two curves, there are yellow triangles. At the locations on the curve to the left of these points the construability of the subgrade is suspect. Further details are given in section 11.0 Undercut Depth and Stabilization Determination”.

Crusting is a condition that the surface of the subgrade appears to be dry and there is substantial cracking on the surface with or without rutting. This would indicate a need for further investigation and usually indicates soft underlying soil with a very dry the top foot or so.
8.2 Variations in the Proof Rolling Results

The Project should not be concerned about occasional or nominal deflections in excess of the above failure criteria. If the density is checked and an investigation shows that good soil extends throughout the top 5 feet of the subgrade, then the design intent will be full filled and the project can be constructed. All soils will deflect under these loads occasionally.

The pavement design is based on an average CBR. The CBR value was directly correlated to the density of the soil many years ago. By using the average CBR (Density) value, the pavement design accounts for a 30 percent or one standard deviation variation in the subgrade strength from the design CBR. Fifteen percent is expected to exceed this value and 15 percent is expected to be less than this value. Therefore some variation in the subgrade condition is already accounted for in the pavement design.

Another consideration is the fact that these proof rolling loads and tire pressures are about 10 percent of the final in place stresses once the pavement is constructed. The proof rolling tire pressures are between 120 to 150 psi (820 to 1030 kPa) and the stresses once the pavement is constructed are about 8 psi (55 kPa) for a thin asphalt pavement and 4 psi (27 kPa) for a thick concrete pavement. Therefore these loads are the largest loads that the subgrade will encounter. If the project can be constructed then the subgrade design intent will be fulfilled.

The project should not concern themselves with the “Pavement Warrantee” issues that the Contractor will often bring up. If the project follows these guidelines and properly documents the subgrade work, Central Office can defend the warrantee issue.

Once failure is established based on the proof rolling results then the responsibility for the correction of the failure should be determined.

9.0 Responsibility for the Soft or Failed Subgrade

If soft or failed subgrade locations are found, then compaction tests should be taken to determine if the specifications are met in the top 12” (300 mm). The Engineer should instruct the Contractor to correct any deficiencies found in these locations.

The Department is responsible in the following situations:

1. When the soft or failed subgrade is encountered in cuts.
2. On rehabilitation projects.
3. In shallow fill locations
   a. When the soft material is found at lower elevations than the project contract work.
b. Subgrade stability may not be possible by compacting the upper 12 inches (0.3 meters) because of conditions at these lower elevations.

All failed or soft locations in fills are the Contractor’s responsibility to correct. If the Contractor built the fill correctly the proof rolling would do nothing but verify their fine work. If the fill fails then the proof rolling would determine the location of the deficient work.

If the Contractor fails the subgrade due to failing to maintain the subgrade, then the Engineer should instruct the Contractor to repair the failed areas. See the 2002 CMS in 203.04.A for the Contractor’s responsibility to drain and maintain the subgrade. In the 1997 CMS, the responsibilities are detailed in 203.04(a), 203.13(b) and in 105.14.

### 10.0 The Investigation

The investigation into the causes of the failed locations should be done quickly to expedite the corrective treatment. Three pieces of information are needed to make the most economical subgrade treatment: Rut depth, soil boring information, and test pit data.

At this point the rut depth has already been determined.

#### 10.1 Soil Boring Information

For rehabilitation projects or cut sections, the soil borings can be examined to determine an estimated under cut depth or stabilization methods.

The standard penetration test (SPT) results from the soil borings can be evaluated by the project in the failed subgrade locations. The standard penetration test (SPT) measures the number of blows per foot (N) required to drive the soil sampler through the soil. It is an indicator of the soil consistency or strength. The soil data on the boring logs are presented as the number of blows to drive each 6-inch (150mm) increment. The first 6 inches (150mm) of the run is ignored because the sampler may not be seated in the borehole or may be being driven through cuttings. So, for example, standard penetration data shown, as 1/2/3 would have an N value of 5 blows per foot.

When investigating the need for undercutting or stabilization in failed locations, look at the borings in those locations in the upper 5 feet (1.5 m) of the subgrade. At each location pick the lowest N value when multiple N values are taken in the top 5 feet (1.5 m) of subgrade.

Average the N value along the failed locations. This value will provide one part of the information needed to determine the undercut depth or stabilization methods.

#### 10.2 Test Pits
Once the soil borings have been evaluated, test pits should be constructed by excavating 3 to 5 feet (0.6 to 1.5 meter) into the subgrade by using the Contractor’s excavation equipment. Construct at least 2 test pits that represent any the failed area. For long areas, use judgment but usually about 2 to 4 test pits per mile is sufficient. Construct the test pits across the width of the subgrade in the failed locations. Pick locations where the deflections are the highest to evaluate the most severe locations.

Warning: These trenches may collapse on the construction personnel. The Construction Personnel performing this work should take a trench safety class offered by the Bureau of Workers Compensation, Division of Safety and Hygiene. These classes are given statewide all year around. (614-466-5563)

An examination of the soil and moisture conditions in these test pits will provide valuable information to make the appropriate correction.

Once the pits are excavated, the Engineer will need to examine the sidewalls of the trench and the bottom of the cut.

Figure 5 “Subgrade Test Pit Investigation” can be used to record the test pit information. The soil conditions will vary with depth and will need quantified. By examining the sidewalls, the Engineer can determine the soil type, layer thickness, soil condition and soil strength by using a hand penetrometer.

The Engineer will need to field classify the soil. See chapter one in the 1996 version of the Earthwork Construction Manual for help in the classification.

Added soil conditions are described on the bottom of the test pit form. These conditions are stated in commonly known consistencies, so that the non-geotechnical can relate to the soil conditions. They are list on the bottom of the form. No explanation is needed for these terms.

10.2.1 Penetrometer Readings

A penetrometer can be used to further classify the soil and to estimate its strength. A penetrometer can be obtained from a test lab supply company. The cost is less than $100. The following companies can be used to obtain a hand penetrometer,

- Gilson Model # HM-500 Phone 800-444-1508
- ELE Model # E129-3729 Phone 724-864-3364
- Humboldt Model H-4200 Phone 800-444-7220

The exact instructions will come with the penetrometer. They are simplified below:

1. Push the penetrometer slowly into the soil at right angles.
2. When the penetrometer penetrates the soil to ¼” groove mark record the reading.
3. Record the readings to the nearest ¼ ton/ ft².
4. Take at least three different readings in each soil layer.

Use Figure 5 “The Subgrade Test Pit Investigation” form to record the readings. Once three readings are taken for the soil layer average the readings.

Evaluate the bottom of the test pit also. The evaluation of the bottom of the cut is extremely valuable information.

Once the averages are determined record the lowest average unconfined reading on the bottom of the form. This would be the most critical soil layer.

Average the unconfined readings (U) of all the test pits in the failed locations. Use this number to further evaluate the undercut depth or stabilization methods.

11.0 Under Cut Depth and Stabilization Determination

Once the proof rolling rut depth (in inches), soil boring information (N) and unconfined data from the test pits (U) are obtained, Figure 6 can be used to determine the under cut depth requirements. On this figure the input values (rut depth, N and U) are on the horizontal axis. The two curves denote the type of project under construction. The left vertical scale shows the under cut depth in feet of granular material. The right vertical scale shows the stabilization depth required in inches of lime or cement.

The horizontal dash line at about the ½ foot line indicates that no treatment is required for results below this line. The top portion of Figure 6 details the general subgrade condition. Figure 6 takes into account the standard deviation of the averaging, anticipated truck loading, and type of project under construction.

Use the rut depth, N values and unconfined numbers (U) to draw a vertical line to the curve for the type of project under construction. At that intersection draw a horizontal line to the left and right. This will determine the granular undercut depth or stabilization needs.

The undercut chart will give the required stabilization method to obtain stability when the undercut or stabilization is completed.

It would be rare to see a perfect alignment in the results from all three inputs. In some cases one or two of these inputs may not be available. In other cases, some judgment will be needed to re-design the most economical undercut that will work. In order of hierarchy, use the test pit data, then the N values and then the rut depth. The rut depth is the least reliable indicator of the undercut need because it cannot determine which soil layer is causing the deflection.

There is an example in Figure 7.
Given: A 5 mile long Rehabilitation Project
Average N value was 12
\( U = 1.4 \text{ tons/ft}^2 \)
Average Rut Depth was 2-4 inches.

Answer: Use an undercut depth of 2.0 feet (0.6m) or stabilize with 12-16 inches of cement or lime. Since this is a long project serious consideration should be given to the stabilization method. It would probably be more cost effective.

After the undercut is made this depth may need adjustment to meet the actual conditions. See section 12.0 “Implementation during Construction”.

11.1 General Rules

On new construction projects, if all of the soft material can be removed and the bottom of the cuts are stable then soil may be used as replacement material.

For reconstruction projects, soil is usually not available in large quantities and the bottom of the cuts are highly variable. Therefore, soil undercuts are less effective solutions.

If the bottom of the test pit is unstable, when conditions are highly variable or for rehabilitation projects then use granular material, rock, geofabric or lime or cement stabilization, rather than soil.

Undercuts should be used in small locations or in areas where spot locations are identified. Cement or lime stabilization should be considered for long areas greater than one mile.

Only the most unusual cases require removal to depths greater than 3 feet (1 meter).

Seventy five to ninety percent of subgrade problems can be solved with a one foot treatment of granular material and fabric or stabilization with lime or cement.

11.1 Examples

The following are some example solutions. The types of material refer to 2002 specification book in 703.16.C.

1. **Given:** Rehabilitation Project with Silty A-4a material with \( N=15 \) or \( U=2.0 \text{ tons/ft}^2 \). Rut Depth\( >1" \).

   **Solution:** Use 1.5 feet of Granular Material Type B, C or D with fabric.

2. **Given:** Rehabilitation Project with Deep, weak, and wet A-4 with \( N = 12 \) or \( U=1.4 \text{ tons/ft}^2 \). Rut Depth = 2".

11
**Solution:** Use 2.0 feet of Granular Material Type B, C, or D, with fabric.

3. **Given:** New Construction Deep, weak & wet A-4, A-6 or A-7-6 combination with \( N = 10 \) or \( U=1.0 \text{ tons/ft}^2 \). Rut Depth = 4”.

**Solution:** Use 1.5 feet of Granular Material Type B or C with fabric.

4. **Given:** New Construction Jell-O like consistency soil with \( N = 5 \) or \( U=0.5 \text{ tons/ft}^2 \). Rut depth > 6”.

**Solution:** Use 3 feet of Granular Material Type B, C, or D, with fabric.

5. **Given:** Reconstruction Project, Soup like consistency soil with \( N = 2 \) or \( U=0.25 \text{ tons/ft}^2 \). Rut depth = Buried.

**Solution:** Use 5 feet of Granular Material Type B, C, or D, with geotextile.

6. **Given:** Reconstruction Project Sandy, A-4a, A-6a soil, PI < 20, \( N = 8 \) or \( U=1.0 \text{ tons/ft}^2 \), Rut Depth = 6”. (Long Project)

**Solution:** Cement Stabilized Subgrade, 16” deep at 6%.

7. **Given:** New construction A-7-6 clay soil, PI > 20, \( N = 11 \) or \( U=1.2 \text{ tons/ft}^2 \), Rut Depth 3”. (Long Project)

**Solution:** Lime Stabilized Subgrade, 12” deep at 5%.

**11.2 Type of Undercut Materials**

Use Granular Material Types B, C, D, E, and F. They are cheaper than 304.

Type B is a well-graded aggregate with the gradations of Items 304, 411 or 617. Type C has a top size of 3” and type D has a top size of 8 inches. Both C and D are well-graded materials. The larger top size material will bridge the soft material better that the smaller size material.

Use Granular Material Type E when water levels are high or cannot be drained. The Type E materials are very porous. Always choke the Granular Material Type E with Granular Material Type B or fabric.

Underdrains cannot be placed through Granular Material Types C, D, E, or F or fabric. Use Granular Material Type B in the locations of the underdrains.

Always drain the undercut to an underdrain, catch basin, or pipe.
Always use 712.09 Geotextile Fabric Type D. The cost is around $1.00 per square yard. In the case of deeper undercuts, multiple layers can be used at a 12-inch vertical spacing if needed. Never use geogrids for subgrade undercuts; they are a waste of money.

11.3 Lime Stabilization

Item 206 Lime Stabilized Subgrade can be used to treat unstable subgrades consisting of A-6b (silty/clay) or A-7-6 (clay) soils which have a plasticity index of 20 or greater.

Use 5 percent lime by dry weight of the soil assuming a dry weight of 110 pounds per cubic foot.

Have the Contractor design the lime percentage under the pay Item 206 Contractor Designed Lime Soil.

11.4 Cement Stabilization

Supplemental Specification 804 Cement Stabilized Subgrade can be used to treat unstable subgrades consisting of A-3 (fine sand, coarse and fine sand), A-2-4 through 7 (gravels), A-4a (sand silt), A-6a (silt and clay), A-6b (silty clay), or A-7-6 (clay) which have a plasticity index less than 20.

Use 6 percent cement by dry weight of the soil assuming a dry weight of 110 pounds per cubic foot.

Have the Contractor design the cement percentage under Item 804 Contractor Designed Cement Soil.

12.0 The Implementation during Construction

Once a stabilization treatment has been chosen, constant monitoring of the construction is required to adjust the treatment to meet the field conditions.

Soil conditions vary, vary and then vary some more.

Soil conditions on rehabilitation projects or in cuts vary the most.

If the undercut option is chosen, the project should monitor the bottom of the cut and evaluate the condition. Take penetrometer readings at the bottom of the cuts and compare them to the test pit or soil boring information. If the condition changes from the earlier evaluation of the test pits or the soil borings, then adjustments to the undercut depth will be required.
In addition, for undercuts that are 2.0 foot or more, consideration should be given to placing multiple layers of fabric. The need for additional layers of fabric can be determined by placing about ½ of the under cut depth. Load the under cut with a fully loaded truck. If the area is unstable, then place another layer of fabric and continue to fill the under cut.

Once the undercut or stabilization is complete, the area must be proof rolled to ensure that the final subgrade meets the rut depth and density requirements as earlier detailed in section 8.0 “Failure Criteria”.

Constant vigilance is needed in order to make the most economical correction. It is easy to over excavate unnecessarily and waste money. It is more difficult to make the right economical choice to stabilize the subgrade and to meet the design and construction needs.
References:

1) Proof Rolling of Subgrades, W.J. Turnbull, 1960
2) Study of Test Rolling of Subgrade, Ken Miller, ODOT, 1969.
4) Subgrade Stability, Marshall Thompson, 1979
6) Embankment Quality, Iowa State University, 1999
Appendix
#### Stage 1

**Compaction of Subgrade**

<table>
<thead>
<tr>
<th>$U$</th>
<th>Subgrade</th>
<th>1.0'</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.5</td>
<td>Specification Work</td>
<td></td>
</tr>
<tr>
<td>4.0</td>
<td>Good</td>
<td>1.0'</td>
</tr>
<tr>
<td>3.5</td>
<td>Good</td>
<td>1.0'</td>
</tr>
<tr>
<td>1.0</td>
<td>Soft “Peanut Butter”</td>
<td>6”</td>
</tr>
</tbody>
</table>

*U in Tons/ft$^2$*
### Stage 2
Proof Rolling

<table>
<thead>
<tr>
<th>Subgrade</th>
<th>Good</th>
<th>Good</th>
<th>Soft</th>
</tr>
</thead>
</table>

**Figure 2**
Stage 3
Hauling, Grading &
Placing 304

304
Subgrade
Good (?)
Good (?)
Soft

Figure 3
**Proof Rolling Documentation Form**

Reference: _____  Item Number_____  Project Number__________ Date_______

Total Weight of Roller _______tons (Metric Tons)  Tire Pressure _____PSI (kPa)

<table>
<thead>
<tr>
<th>Time</th>
<th>Station to Station</th>
<th>Lane or Location</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start</td>
<td>Stop</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Areas to Correct or Investigate**

<table>
<thead>
<tr>
<th>Location</th>
<th>Rut Depth (Inches)</th>
<th>Cracking Yes or No</th>
<th>Elastic or Plastic (Rebound or Permanent) Movement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Station to Station</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total of Today’s Time _____ Hours _____ Minutes (To the nearest 6 min.)
Project Engineer/ Inspector_________________ Contractors Signature_________________

Record to the nearest 0.1 Hour 203.15(g) or 204.08
DOT-1637

**Figure 4**
## Subgrade Test Pit Investigation

02/14/02

<table>
<thead>
<tr>
<th>Subgrade Elevation</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Station</td>
<td>Evaluation Stations</td>
</tr>
<tr>
<td>Rut Depth</td>
<td>____________</td>
</tr>
</tbody>
</table>

### Unconfined Compressive (tons/ft²) From Penetrometer

<table>
<thead>
<tr>
<th>Soil Layer</th>
</tr>
</thead>
</table>

| $U_1=$ | Soil Type= |
| $U_2=$ | Layer Thickness= |
| $U_3=$ | Soil Condition= |
| $U_{ave}=$ | Comments: |

| $U_1=$ | Soil Type= |
| $U_2=$ | Layer Thickness= |
| $U_3=$ | Soil Condition= |
| $U_{ave}=$ | Comments: |

| $U_1=$ | Soil Type= |
| $U_2=$ | Layer Thickness= |
| $U_3=$ | Soil Condition= |
| $U_{ave}=$ | Comments: |

<table>
<thead>
<tr>
<th>Bottom of Cut</th>
<th>Soil Type=</th>
</tr>
</thead>
<tbody>
<tr>
<td>$U_1=$</td>
<td>Layer Thickness=</td>
</tr>
<tr>
<td>$U_2=$</td>
<td>Soil Condition=</td>
</tr>
<tr>
<td>$U_3=$</td>
<td>Comments:</td>
</tr>
<tr>
<td>$U_{ave}=$</td>
<td></td>
</tr>
</tbody>
</table>

Soil Type (See Chapter 1 in the 1996 Earthwork Construction Manual)
Examples: Clay, Silt, Sand, Gravel, Sandstone, Shale, Rock or Combinations

Soil Condition= Wet, Dry, Organic, Roots, Water seepage, Soup, Jell-O, Soft or Hard Peanut Butter

**Critical Layer or Design Layer** = $U=__________$

Inspector/ Engineer__________________

---

Figure 5
Figure 6: Subgrade Treatment Chart (03/04/02)
Undercut (Ft)

New Construction Project
Rehabilitation Project or Heavy Hauling
Constructibility Break Point

N(Drops/ft)
Rut Depth
Unconfined (ton/ft^2)

16" Cement
12" Cement or Lime
9" Cement or Lime

Soup    Jello    Soft Peanut    Hard Peanut    Marginal    Fair    Good    Excellent
Butter   Butter

Stabilization

Use Undercut of 2.0 ft or Stabilize with 12-16" Cement or Lime

For 2"-4" Ruts with N=12, U = 1.4 ton/ft^2

Figure 7: Example of Subgrade Treatment Chart (03/04/01)