	Ohio Department of Transportation **Division of Production Management** **Office of Geotechnical Engineering** **Geotechnical Bulletin**	**GB 1**

PLAN SUBGRADES

January 18, 2019

Geotechnical Bulletin GB1 was jointly developed by the Offices of Construction Administration and Geotechnical Engineering. It was originally issued under the title of "Interim Guidelines for Plan Subgrade Treatments," dated November 1, 2001. The first edition of GB1 was dated July 11, 2003. This edition supersedes all previous editions.

Use this Geotechnical Bulletin for all projects that include new construction or pavement reconstruction involving pavement replacement, pavement widening, or Rubblize and Roll.

The Designer, based on the subsurface exploration, is responsible for identifying the method, location, and dimensions (including depth) of subgrade stabilization in the plans. Appropriate stabilization of the subgrade, if necessary, will ensure a constructible pavement buildup, enhance pavement performance over its life, and help reduce costly extra work change orders. The information contained in this bulletin is based on several past and recent projects and should be used as general guidance. This bulletin is simplified so the Designer can easily apply the information from the subsurface exploration to provide reasonable limits and quantities for subgrade stabilization in the plans. However, the Designer must use engineering judgment when applying this guidance to a specific project. Limits and quantities must be verified and adjusted, as necessary, in the field based on proof rolling and visual observation.

This bulletin along with the Geotechnical Engineering Design Checklists and Specifications for Geotechnical Exploration (SGE) may be obtained from the web site of the Office of Geotechnical Engineering. The Construction Inspection Manual of Procedures (MOP) may be obtained from the web site of the Office of Construction Administration.

A. Subsurface Exploration

All projects covered in this bulletin shall have a subsurface exploration performed. Perform the subsurface exploration according to the current version of the SGE.

For Laboratory Testing:

1. Perform visual soil classification and moisture content on each sample. Visually inspect each soil sample for the presence of gypsum ($CaSO_4 \cdot 2H_2O$). Gypsum crystals are soft (easily scratched by a knife; they will not scratch a copper penny), translucent (milky) to transparent, and do not have perfect cleavage (do not split into thin sheets). Photos of gypsum crystals are shown in Supplement 1120.

2. Perform mechanical soil classification (Plastic Limit (PL), Liquid Limit (LL), and gradation testing) on at least two samples from each boring within 6 feet of the proposed subgrade, preferably the top two samples if the 6 feet is homogenous.

3. Determine the sulfate content of at least one sample from each boring within 3 feet of the proposed subgrade, per Supplement 1122, Determining Sulfate Content in Soils. Determine the sulfate content of every sample that exhibits gypsum crystals.

4. Never **VISUALLY** classify a soil as A-2-5, A-4b, A-5, A-7-5, A-8a, or A-8b within the top 3 feet of the proposed subgrade.

B. Standard Penetration Test (SPT)

The standard penetration test (SPT) measures the number of blows per foot (N) required to drive the sampler through the soil and is an indicator of its consistency and stiffness. N is corrected to equivalent rod energy of 60 percent (N_{60}). Refer to the SGE for more details.

When evaluating the need for stabilization, the project may be evaluated as a whole or divided into segments, depending on the consistency of the soil conditions. Divide the project into segments if there are areas that have significantly lower or higher N_{60} values.

To determine the stabilization option and depth, use the lowest N_{60} value (N_{60L}) recorded in the top 6 feet of the proposed subgrade from each boring. Calculate an average N_{60L}, to the nearest whole number, for a group of borings that represent a segment being considered for stabilization. Consider the following when calculating an average N_{60L}:

1. When N_{60L} is greater than 30 blows per foot, use 30.

2. When N_{60L} is a blow count in bedrock, exclude it.

Where subgrade requiring stabilization is positively identified (i.e. unstable subgrade), designate subgrade stabilization in the plans for those areas.

C. Moisture Content (MC)

Comparing the existing moisture content of the soil to the optimum moisture content is an indicator of the need for subgrade stabilization. Estimated optimum moisture content for each soil classification is listed in GB1 Figure A. Some estimated optimum moisture contents are based on the PL of the sample. Where the optimum moisture content is calculated, minimum optimum moisture content has been established.

GB1 Figure A – Optimum Moisture Content

Soil Classification	Moisture Content	
	Optimum	Minimum Optimum
A-1	6	
A-3	8	
A-2	10	
A-4a	PL - 5	10
A-4b	PL - 5	10
A-6a	PL - 5	14
A-6b	PL - 5	16
A-7-6	PL - 3	18
Non-Plastic Silt	11	

Moisture contents that exceed the estimated optimum moisture content by more than 3 percent likely indicate the presence of unstable subgrade and may require some form of subgrade stabilization. Functioning drainage can reduce the subgrade soil moisture content. Therefore:

1. For new construction projects, installation of construction underdrains as soon as possible is very important.

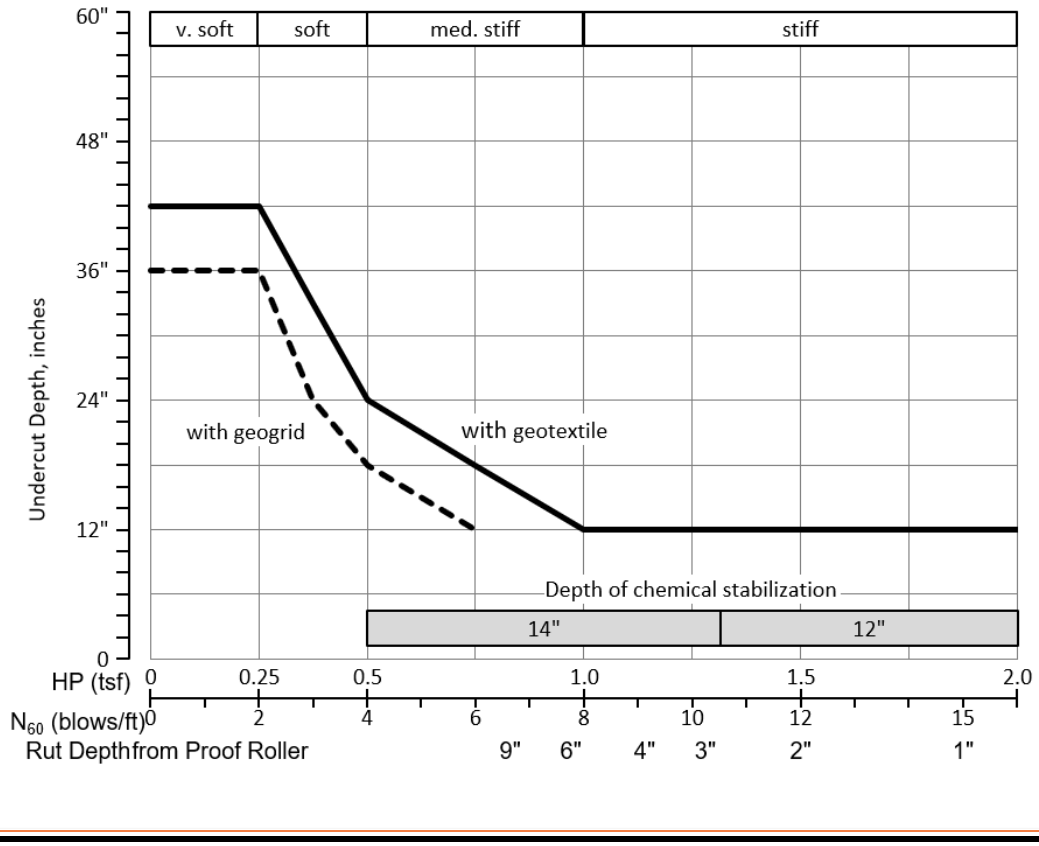
2. For rehabilitation projects, the District should inspect and reestablish drainage as necessary as soon as possible and maintain this drainage until the project is sold. This will improve the subgrade soil conditions. The Contractor should maintain the drainage during the project. As a minimum, reestablishing drainage should include cleaning all of the underdrain outlets.

3. Consider installing new underdrain systems in advance of or at the start of rehabilitation projects.

D. Designing Subgrade Stabilization

Currently the Department uses two options for establishing a stable subgrade, excavate and replace or chemical stabilization. GB1 Figure B can be used to select the stabilization option and estimate the depth. More information on each option can be obtained on the following pages of this bulletin and in the appropriate specification. The figure assumes uniform soil conditions at the bottom of the stabilization.

GB1 Figure B – Subgrade Stabilization (Revised 1/18/2019)



- For N_{60L} greater than or equal to 12 and less than 15, no stabilization is necessary unless MC is greater than optimum plus 3 percent.
- This figure does not apply to A-1-a, A-1-b, A-3, or A-3a soils and soils with an N_{60L} of 15 or more. These soils should be reworked to stabilize the subgrade.

For all Interstates and other divided highways with four or more lanes more than 1-mile in project length, the subgrade of the entire project shall be chemically stabilized (global stabilization). Where it is determined that soil is present where a majority of sulfate content values are found to be greater than 3,000 parts per million (ppm), or individual soil samples with sulfate contents greater than 5,000 ppm are present, contact the District Geotechnical Engineer to discuss options including stabilization as needed using excavate and replace methods.

For all other roadways, if it is determined that 30 percent or more of the subgrade area must be stabilized, consideration should be given to stabilizing the entire project (global stabilization). This consideration should include a cost analysis of the options. Use bid tabs to generate this cost analysis.

Generally, chemical stabilization is more economical when stabilizing large areas (approximately greater than 1 mile of roadway). An exception to this may be segmented areas requiring multiple mobilizations of specialized equipment. It is noted that chemical stabilization may not work in very weak soils (N_{60L} less than 4 blows per foot), soils high in sulfates (greater than 5,000 ppm), and organic soils (A-8a or A-8b).

When choosing the method of stabilization, take into account shallow underground utilities, whether they are active or not. Also consider the maintenance of traffic requirements next to a deep excavation and public access requirements to drives and businesses.

Where it is determined that the sulfate content of the soil is greater than 5,000 ppm do not perform chemical stabilization without prior consultation with the District Geotechnical Engineer to discuss options and risk. Attempting to delineate a high sulfate content area via additional tests is discouraged.

E. Proof Rolling (Item 204) and Test Rolling (Item 206)

According to Item 204, the top 12 inches of the subgrade is compacted, and the subgrade is proof rolled to 18 inches beyond the edge of the surface of the pavement, paved shoulders, or paved medians, including under new curbs and gutters.

Specify proof rolling and test rolling as follows:

1. For global stabilization, using either type of stabilization, the entire subgrade should be stabilized. Do not specify any proof or test rolling prior to the stabilization, since all of the subgrade is being stabilized. After global stabilization, specify proof rolling for the stabilized area (entire project) to verify stability is achieved.

2. For spot stabilization using excavate and replace stabilization, specify proof rolling for the entire project to identify the unstable subgrade requiring stabilization. These locations and quantities may be different than what is shown in the plans. Also specify proof rolling for the planned stabilized areas to verify stability is achieved.

3. For spot stabilization using chemical stabilization, specify test rolling for the entire project to identify the unstable subgrade requiring stabilization. These locations and quantities may be different than what is shown in the plans. Specify proof rolling for the planned stabilized areas to verify stability is achieved. Spot chemical stabilization is discouraged by the Department. If considering this method, please contact the District Geotechnical Engineer.

An estimated quantity for Item 204 Proof Rolling or Item 206 Test Rolling should be determined as follows:

1. Reconstruction: one hour per 2000 square yards of subgrade area
2. New Construction: one hour per 3000 square yards of subgrade area

The proof rolling or test rolling deflections and soil conditions that are observed during construction will determine if there is a need to adjust the plan subgrade stabilization. **Adjustment of subgrade stabilization to fit field conditions is essential and is the responsibility of the Project Engineer.** Project Engineers should refer to the MOP.

F. Excavate and Replace (Item 204)

Estimate the depth and limits of the excavation using GB1 Figure B. Actual depths and limits will be determined by the Project Engineer in the field based on the proof rolling.

An excavation replaced with granular material and underlain with Item 204 Geotextile Fabric can be used in any situation.

Consider replacement using Geogrid when N_{60L} is less than 6, to avoid impact on shallow utilities below the subgrade, or to avoid difficult maintenance of traffic situations when using other stabilization methods, as follows:

1. If the replacement is less than or equal to 18 inches, place the Geogrid at the bottom of the excavation.

2. If the replacement is greater than 18 inches, place the Geogrid in the middle of the granular material and a fabric on the bottom of the excavation.

3. Use only Item 204 Granular Material Type B or C for the replacement material. Determine if the 204 Granular Material Type B meets the natural filter criteria for the subgrade as follows:

   D_{15} (Type B or C) / D_{85} (subgrade) is less than or equal to 5; and

   D_{50} (Type B or C) / D_{50} (subgrade) is less than or equal to 25;

   where D_{xx} is the diameter of the soil particle measured in mm for which xx percent of the material is smaller.

As an example, for Item 204 Granular Material Type B the D_{15} is 0.4 mm and the D_{50} is 7 mm, so:

$0.4/D_{85}$ (subgrade) ≤ 5, so the D_{85} (subgrade) must be greater than or equal to 0.08 mm; and

$7/D_{50}$ (subgrade) ≤ 25, so the D_{50} (subgrade) must be greater than or equal to 0.28 mm

Use average gradation values for the subgrade. If both criteria are met, no fabric is necessary. Otherwise, include a fabric at the bottom of the excavation.

If not using Geogrid, replacement material will be Item 204 Granular Material Type ___ considering the following:

1. Types B, C and D are all well-graded materials. Type B has a top size of 2 inches. Type C has a top size of 3 inches. Type D has a top size of 8 inches. The larger top size material will bridge unstable subgrade better than the smaller material.

2. Use Type D or E when water levels are high and cannot be drained. Always choke the Type D or E with Type B or geotextile.

3. Underdrains cannot be placed through Types D, E, or F or the geotextile or geogrid, without great difficulty. Use Type B, with no geotextile or geogrid, in the areas of the underdrains.

Excavate unstable subgrades to 18 inches beyond the edge of the surface of the pavement, paved shoulders, or paved medians, including under new curbs and gutters.

Always drain the excavation to an underdrain, catch basin, or pipe.

Include plan note G121 in the plans.

G. Chemically Stabilized Subgrade (Item 206)

The designer, based on engineering judgment, should specify the chemical used to chemically stabilize the subgrade as follows:

1. Cement may be used to stabilize unstable subgrades which have a Plasticity Index (PI) of 20 or less.

2. Lime may be used to stabilize unstable subgrades which have a PI of 16 or greater, consisting of A-6b, A-7-5, or A-7-6 soils.

Chemical stabilization is not recommended for soils with an N_{60L} less than 4 because it is usually difficult for the stabilization equipment to operate on such soft soils.

Do not perform chemical stabilization if it is determined that soil is present with a sulfate content greater than 5,000 ppm.

Chemically stabilize subgrades to 18 inches beyond the edge of the surface of the pavement, paved shoulders, or paved medians, including under new curbs and gutters. To estimate the quantity of chemical, use the estimated rate and quantity formula from GB1 Figure C for the specified chemical. When performing chemical stabilization design, use the dry density of the soil on the project as determined in the laboratory.

Along with the pay items for chemical stabilization and the chemical, provide the following additional pay items for chemical stabilization:

1. Item 206 Curing Coat, estimated at the same number of square yards as the stabilized area.

2. Item 204 Proof Rolling, estimated according to GB1 Section E using the same number of square yards as the stabilized area.

3. Item 206 Mixture Design for Chemically Stabilized Soil is a lump sum item and requires the chemical stabilization to be designed according to Supplement 1120. This item should only be specified on projects with more than 40,000 square yards of chemical stabilized area.

Do not provide Item 204 Subgrade Compaction for areas that are being chemically stabilized.

When chemical stabilization is to be used on a project with multiple maintenance of traffic phases, coordinate the roadway work with the maintenance of traffic schemes such that an 8-foot minimum width for chemical stabilization exists. Typical chemical stabilization equipment cannot stabilize areas less than 8 feet in width. Small areas of less than 8 feet in width can be excavated out, mixed with the stabilization chemical, and compacted in place. However, excavation and mixing is not practical for large areas.

GB1 Figure C – Chemical Stabilized Subgrade

Chemical	Estimated Rate (1)	Quantity Formula (2)
Cement	5 percent	C = 0.75 x T x 115 x 0.05
Lime	5 percent	C = 0.75 x T x 115 x 0.05

(1) By dry density of soil (using 115 pounds / cubic foot)
(2) Where: C = amount of chemical (pounds / square yard)
T = thickness of stabilization (inches)

H. Unsuitable Subgrade

1. **A-4b Soil**: When A-4b soil is encountered in natural ground or an existing embankment within 3 feet of top of subgrade, regardless of its consistency or moisture content, remove or chemically stabilize because of its susceptibility to frost heaving. When constructing an embankment, the use of A-4b soils within 3 feet of top of subgrade is prohibited per 203.03.

   When excavating and replacing, A-4b should be excavated to 3 feet below the top of subgrade and replaced with Item 204 Embankment.

   If the subgrade is going to be chemically stabilized to a depth of 14 inches, A-4b soil may not have to be removed.

2. **A-2-5, A-5, and A-7-5 Soil**: According to 703.16.A and B, A-2-5, A-5, and A-7-5 shall not be used in a subgrade.

   a. A-2-5 soil is unsuitable because of its low weight, high optimum moisture, high LL and low PI and its propensity to sloughing in service.

   b. A-5 soil is unsuitable because it is highly elastic as indicated by the high LL.

   c. A-7-5 soil has a lower PI in relation to the LL than other clays. It is unsuitable because it may be highly elastic, and subject to considerable volume change.

   When excavating and replacing, any A-2-5, A-5, and A-7-5 soils should be completely removed or excavated 36 inches, whichever is less. Replace the excavation with Item 204 Embankment if the entire depth is removed. Otherwise, replace with granular material.

   Chemical stabilization may be used to stabilize A-2-5, A-5, or A-7-5 soils. Appropriate laboratory testing should be performed to confirm.

3. **A-8a and A-8b Soil:** These are soils otherwise classified as A-4, A-5, A-6, or A-7, which have a liquid limit value after oven drying less than 75 percent of its liquid limit before drying, indicating an effect of the organic content.

   Excavate and replace is the only acceptable replacement procedure for A-8a and A-8b soils. Do not chemically stabilize A-8a or A-8b soils. If encountered in the subgrade, A-8a and A-8b soils should be completely removed, or excavated to 36 inches, whichever is less. Replace the excavation with Item 204 Embankment if the entire depth is removed. Otherwise, replace with granular material.

4. **Liquid Limit (LL) > 65**: According to 703.16.A, when a soil sample has a LL greater than 65, it shall not be used in an embankment or subgrade. When LL is greater than 65, it indicates a soil of high clay content and low load-carrying capacity.

When excavating and replacing, any material with a LL greater than 65 should be completely removed or excavated 36 inches, whichever is less. Replace the excavation with Item 204 Embankment if the entire depth is removed. Otherwise, replace with granular material.

Chemical stabilization may be used to stabilize soils with a LL greater than 65. Appropriate laboratory testing should be performed to confirm.

5. Rock, Shale, or Coal

When rock, shale, or coal is encountered within 24 inches of the bottom of the asphalt or concrete pavement, it is to be removed according to 204.05 and replaced with Item 204 Embankment. Remove the rock, shale, or coal to 12 inches beyond the edge of the surface of the pavement, paved shoulders, or paved medians, including under new curbs and gutters.

Replacing an existing pavement with a thicker pavement build-up can necessitate excavation of rock, which is difficult and expensive especially in confined work areas. Designers should try to adjust the pavement design and roadway profile to avoid excavating rock whenever possible.

I. Rubblize and Roll (Item 320)

For Rubblize and Roll, consider the following:

1. The Rubblize and Roll rehabilitation technique is not an option when the average N_{60L} value for the subgrade below the existing pavement is less than 12.

2. Rubblize and Roll is not a “piecemeal” rehabilitation technique. It is only considered for the entire project, excluding any sections where vertical grade adjustments are proposed.

3. During construction the Rubblize and Roll is attempted before an area is selected for excavation and replacement. **The actual excavation areas will be selected based on the inability to Rubblize and Roll.**

   Estimate excavation quantities as follows:

   a. Identifying excavation of a rubblized pavement is based on soil samples within 3 feet of the top of the existing subgrade using this bulletin.

   b. The depth of excavation begins at the top of the existing subgrade.

   c. Where Rubblize and Roll is not planned (i.e., where grade is being lowered under a bridge), identify subgrade stabilization according to this bulletin.

J. Report Requirements

Prepare a report titled, "Subgrade Exploration" according to the requirements of the SGE. The analyses and recommendations should include, as a minimum, the following:

1. The method(s), locations, and dimensions (including depths) of planned subgrade stabilization. Identify subgrades as either unsuitable subgrade or unstable subgrade.

2. An **electronic copy of the GB1 analysis** (spreadsheet).

3. Average N_{60L} calculated to the nearest whole number.

    a. Report the average N_{60L} for the entire project.
    b. If the project is broken up in segments, provide an average N_{60L} for each segment considered.
    c. If the project involves rehabilitating the existing pavement and widening, also provide an average N_{60L} for the existing pavement and an average N_{60L} for the area where the pavement will be widened.

4. Average PI, calculated to the nearest whole number.

5. Results of all sulfate content tests, performed in accordance with Supplement 1122. Note the reporting requirements in 1122.04 regarding concentrations greater than 8,000 ppm sulfate. Provide electronic copy of sulfate content test results, either as part of gINT project file submittal or as standalone spreadsheet formatted per Supplement 1122.

6. Average design CBR for the entire project. This should be calculated as an average, to the nearest whole number. Do not calculate as a percentile.

K. Plan Requirements

1. Identify and show excavation and replacement limits of unsuitable subgrade on the individual Cross Sections.

2. Identify and show spot stabilization of unstable subgrade on the individual Cross Sections.

3. If the entire project is being stabilized with the same stabilization method and depth, the stabilization can be shown on the Typical Sections as a box. The height of the box is the depth, and the width should go to 18 inches beyond the edge of the surface of the pavement, paved shoulders, or paved medians, including under new curbs and gutters.

4. If preparing plans with proprietary geogrid as an alternate, use the following guidance:

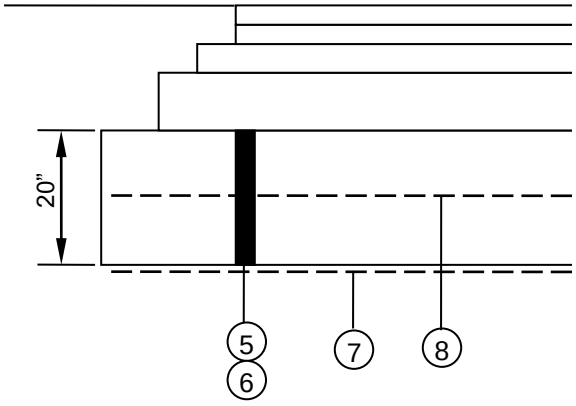
Plan Preparation with Proprietary Geogrid as an Alternate

The FHWA is prohibited from using federal funds to pay for patented or proprietary products, unless such products are obtained through competitive bidding with equally suitable unpatented items (23 CFR 635.411). A proprietary geogrid for subgrade stabilization may be used if it is shown as an alternative in the plans that will be bid against a generic geogrid specified in Item 204. Guidance on preparing a set of plans that presents the two alternates for the subgrade stabilization is provided below.

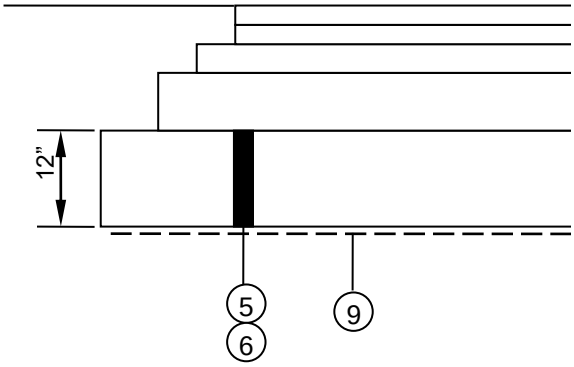
One alternate presents the use of a generic geogrid that conforms to Item 204. The other alternate includes the use of the proprietary geogrid. The contractor bids on both alternates. The sponsoring agency then decides which alternate to include with the awarded contract. If the agency selects the higher cost alternate, then the agency is responsible for funding the difference in cost. More than two alternates may be presented to allow additional types of proprietary geogrids.

Typical Sections – The first step is to determine the depth of the undercut for the generic geogrid using GB1 and the subsurface conditions encountered. Then determine the depth of the undercut for the proprietary geogrid using appropriate engineering design methods. Depending on the depth of the undercut and the type of subgrade soil, the undercut may also require a geotextile fabric at the bottom.

On the typical sections in the plans, show the two subgrade stabilization alternates, as shown in the following example.



SUBGRADE STABILIZATION
ALTERNATE 1: GENERIC GEOGRID



SUBGRADE STABILIZATION
ALTERNATE 2: ‘Product Name” GEOGRID

LEGEND

⑤ ITEM 204 – EXCAVATION OF SUBGRADE
⑥ ITEM 204 – GRANULAR MATERIAL TYPE B
⑦ ITEM 204 – GEOTEXTILE FABRIC
⑧ ITEM 204 – GEOGRID
⑨ ITEM 204 – GEOGRID, AS PER PLAN, “Product Name”

Plan Notes – In the General Notes, include the standard plan note G121 "Item 204 – Subgrade Compaction and Proof Rolling" which can be found in Location and Design Manual, Volume 3. Also include plan notes, similar to the following, that describe to the contractor how to bid the subgrade stabilization alternates and that specify the "As Per Plan" proprietary geogrid.

ALTERNATE BID ITEMS FOR SUBGRADE STABILIZATION WITH GEOGRID
THERE ARE TWO ALTERNATES FOR PERFORMING SUBGRADE STABILIZATION WITH GEOGRID. BID ALL ALTERNATE BID ITEMS.

ALTERNATE 1: UNDERCUT AND REPLACE WITH GRANULAR MATERIAL TYPE B USING GEOTEXTILE FABRIC AND A GENERIC GEOGRID CONFORMING TO ITEM 204,

ALTERNATE 2: UNDERCUT AND REPLACE WITH GRANULAR MATERIAL TYPE B AND A PROPRIETARY GEOGRID AS SPECIFIED BELOW.

ITEM 204, GEOGRID, AS PER PLAN, 'Product Name'
FURNISH 'Product Name' GEOGRID FROM 'Manufacturer Name, City, State'. INSTALL ACCORDING TO ITEM 204 AND THE MANUFACTURER'S RECOMMENDATONS. HAVE A REPRESENTATIVE FROM THE GEOGRID MANUFACTURER PROVIDE ON-SITE TECHNICAL ASSISTANCE AT THE START OF THE WORK AND WHEN REQUIRED BY THE ENGINEER OR CONTRACTOR.

Estimated Quantities – In the general summary, include estimated quantities for both alternates. Group each set of alternate bid items and label them as "Alternate 1: Generic Geogrid" and "Alternate 2:" followed by the name of the proprietary geogrid, as shown in the following example.

Example of General Summary with Alternate using Proprietary Geogrid

ITEM	ITEM EXT.	GRAND TOTAL	UNIT	DESCRIPTION	SEE SHEET NO.
				ALTERNATE 1: GENERIC GEOGRID	
204	13000	3110	CU YD	EXCAVATION OF SUBGRADE	
204	30010	3110	CU YD	GRANULAR MATERIAL, TYPE B	
204	50000	7000	SQ YD	GEOTEXTILE FABRIC	
204	51000	7000	SQ YD	GEOGRID	
				ALTERNATE 2: 'Product Name' GEOGRID	
204	13000	2330	CU YD	EXCAVATION OF SUBGRADE	
204	30010	2330	CU YD	GRANULAR MATERIAL, TYPE B	
204	51001	7000	SQ YD	GEOGRID, AS PER PLAN, 'Product Name'	#