STATE OF OHIO
DEPARTMENT OF TRANSPORTATION

SUPPLEMENTAL SPECIFICATION 863
REINFORCED SOIL SLOPES

October 17, 2014

863.01 Description
863.02 Materials
863.03 Construction
863.04 Method of Measurement
863.05 Basis of Payment

863.01 Description. This work consists of constructing an embankment or slope that is reinforced with geogrid.

863.02 Materials

A. Geogrid. Geogrid is a geosynthetic material formed by a regular network of integrally connected polymer elements (ribs) with apertures of sufficient size to allow interlocking with the surrounding soil.

Furnish geogrid which is dimensionally stable and able to retain its geometry under construction stresses. Furnish geogrid that is resistant to ultraviolet degradation and to all forms of chemical and biological degradation encountered in the soil being reinforced. Furnish geogrid that is recommended by the manufacturer for use in reinforced soil slope construction. Furnish geogrid that conforms to the requirements presented in Table 863.02-1 for the type of geogrid shown on the plans.

Furnish geogrid consisting of either high density polyethylene (HDPE), polypropylene (PP), or PVC coated polyester (PET). For geogrids manufactured from PET, ensure that the carboxyl end group content is less than 30 mmol/kg according to ASTM D7409, and the number average molecular weight of the polymer is greater than 25,000 as determined from either gel permeation chromatography or by correlating with the inherent viscosity value determined in accordance with ASTM D4603 and GRI:GG8 (GRI is the Geosynthetic Research Institute). Do not furnish PET geogrid if the pH of the reinforced embankment soil is greater than 9.

Thirty days before reinforced slope construction begins, submit to the Engineer for review and acceptance certified test data according to C&MS 101.03 that verifies the geogrid meets all the requirements. Allow 14 days for review by the Department. Do not begin reinforced slope construction until the Department accepts the geogrid submittal. The Department will accept test data from the National Transportation Product Evaluation Program (NTPEP) as certified test data.

TABLE 863.02-1 REQUIRED GEOGRID PROPERTIES

			Geogrid Type							
	Test		Primary						Secondary	
Property	**Method**		**P1**	**P2**	**P3**	**P4**	**P5**		**S1**	**S2**
Ultimate Tensile Strength	ASTM D 6637	lb/ft (kN/m)	-- --	-- --	-- --	-- --	-- --		1400 (20)	2100 (31)
Long-Term Design Tensile Strength	(see below)	lb/ft (kN/m)	1300 (19)	2000 (29)	2500 (36)	3300 (48)	4200 (61)		-- --	-- --
Ultraviolet Stability	ASTM D 4355		70% at 500 hours							

Note: Determine tensile strength according to ASTM D 6637, Method B. Determine long-term design tensile strength according to the procedure described below. All values, except ultraviolet stability, are minimum average roll values, MARV (average value minus two standard deviations.) The strength requirement is for the direction perpendicular to the face of the slope. This is typically in the machine or roll direction for the primary geogrid and in the cross machine direction for the secondary geogrid.

1. Long-Term Design Tensile Strength. Calculate the long-term design tensile strength (T_A) using the equation below. The calculated value must be greater than or equal to the corresponding value in Table 863.02-1 for the specified geogrid type.

$$T_A = \frac{T_{ULT}}{RF_{CR} \times RF_{ID} \times RF_D \times RF_{JNT}}$$

Where:

T_A = Long-term design tensile strength
T_{ULT} = Ultimate tensile strength according to ASTM D 6637
RF_{CR} = Reduction factor for creep
RF_{ID} = Reduction factor for installation damage
RF_D = Reduction factor for durability
RF_{JNT} = Reduction factor for joints

With the certified test data, submit calculations that demonstrate the proposed geogrid meets the required long-term design tensile strength based on the specific reduction factors for the geogrid.

2. Reduction Factor for Creep, RF_{CR}. This value is the ratio of T_{ULT} to the creep limited strength determined according to ASTM D5262 and extrapolated for a 75-year design life according to Appendix B of FHWA Publication No. FHWA-NHI-00-043. Do not extrapolate by more than one order of magnitude at a designated temperature. Elevated temperature testing, as well as in-situ temperature testing, for a minimum of 10,000 hours are required in order to extrapolate the creep test data to a 75-year design life. Perform creep testing on representative samples of the product and not on a single component of geogrid. Submit certified test data demonstrating the appropriate value of RF_{CR} for the geogrid. There is no default value for RF_{CR}; the contractor must submit certified test data.

3. Reduction Factor for Installation Damage, RF_{ID}. Determine RF_{ID} from installation damage tests consistent with ASTM D5818 and Section 5.1 of FHWA Publication No. FHWA-NHI-09-087, *Corrosion/Degradation of Soil Reinforcements for Mechanically Stabilized Earth Walls and Reinforced Soil Slopes*. Do not use a value less than 1.10, or if granular embankment or granular materials are specified or used for the reinforced embankment, do not use a value less than 1.20. If certified test data is not available to determine RF_{ID}, use a default value of 1.80 for granular embankment or granular materials and a default value of 1.40 for natural soil.

4. Reduction Factor for Durability, RF_D. Use the values listed in Table 863.02-2 based on the geogrid material and the retained strength after ultraviolet exposure. Test data is not required.

TABLE 863.02-2 REDUCTION FACTOR FOR DURABILITY

Geogrid material	**Retained Strength at 500 hours ASTM D4355**	**RF_D**
HDPE	retained strength > 90%	1.10
	retained strength between 70 and 90%	1.40
PP	retained strength > 90%	1.10
	retained strength between 70 and 90%	1.40
	pH of Reinforced Embankment ASTM G51	
Coated PET	from 5 to 8	1.15
	less than 5 or greater than 8	1.30

5. Reduction Factor for Joints, RF_{JNT}. If the Contractor will join two strips of primary geogrid together to meet the length requirements shown on the plans, then determine RF_{JNT} by dividing the unjointed geogrid strength by the jointed geogrid strength. Determine both the jointed and the unjointed geogrid strength according to ASTM D5262 with sustained tension tests lasting at least 1,000 hours. For the testing, use the same method and procedure for connecting or joining the geogrid as will be used during construction. Use a value of 1.00 if there is no reduction in strength of the joined samples or if no joints are used. If certified test data is not available to determine RF_{JNT} and joints are required, use a default value of 2.0.

B. Reinforced Embankment. Furnish embankment soil to be used in conjunction with the geogrid reinforcement that is either natural soil as defined in 703.16.A or granular embankment material as defined in 703.16.B. Furnish embankment material that also meets the requirements in the table below. For landslide repair projects, reuse excavated material when the material conforms to these requirements. Submit test results for each source before beginning work and again whenever the source changes.

TABLE 863.02-3
ADDITIONAL REQUIREMENTS FOR REINFORCED EMBANKMENT

Property	Test Method	Required Value
Organic content	AASHTO T 267	≤ 4.0%
Plasticity index	AASHTO T 90	≤ 20

Before using PET geogrid, test the pH of the embankment material according to ASTM G51. If the pH is greater than 9, do not use PET geogrid.

863.03 Construction

A. Storage and Handling. Follow ASTM D 4873 for geogrid labeling, shipment, and storage. Furnish product labels that clearly show the manufacturer's or supplier's name, product type, lot number, roll number, manufactured date, and roll dimension. Furnish a notation for each shipping document certifying that the material is in accordance with the manufacturer's certificate.

During shipment and storage, protect the geogrid from direct sunlight, ultraviolet rays, temperatures greater than 160 °F (71 °C), flames including welding sparks, mud, dirt, dust, and debris. Keep the geogrid dry during storage and do not store directly on the ground.

The geogrid will be rejected if it has defects, tears, punctures, flaws, deterioration, or damage incurred during manufacturing, transportation, or storage. If approved by the Engineer, torn or punctured sections may be repaired by placing a patch over the damaged area and mechanically connecting the edges to the geogrid beneath.

B. Site Excavation. Prepare a level surface for placement of the first layer of geogrid, including removing any deleterious materials, sharp objects, and loose or otherwise unsuitable soils. Prepare the embankment foundation according to C&MS 203.05. The Department will inspect the base of the excavation to verify that the subsurface conditions are the same as those anticipated during the design. Do not place the first layer of geogrid until after the Department inspects the base of the excavation and accepts it.

C. Geogrid Placement. Cut the geogrid to the required length shown on the plans. Measure the length from intact transverse rib to intact transverse rib. Do not include "fingers" (ribs only connected on one end) when measuring the length of the geogrid. Place the geogrid horizontally at the elevations and orientations shown on the plans. Maintain the vertical position of each layer within 2 inches (50 mm) of the design elevation. Verify the correct orientation (roll direction) of the geogrid (see Figure 863.03-1). Primary geogrid (Types P1, P2, P3, P4, and P5) will typically have its roll direction perpendicular to the slope face. Secondary geogrid (Types S1 and S2) will have its roll direction parallel to the slope face. However, the Contractor may place primary geogrid with the roll direction parallel to the face of the slope if the roll width is equal to or greater than the required length and the geogrid meets the specified strength requirements in the cross machine direction.

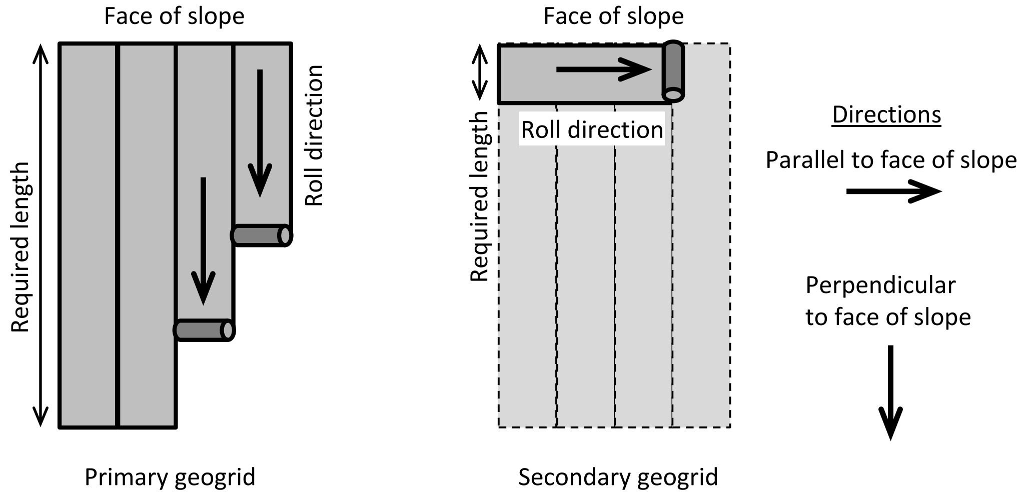

Figure 863.03-1 Typical roll orientation

No overlap is required between adjacent rolls. However, when the geogrid will be exposed as part of a wrap-around facing system, overlap adjacent rolls of geogrid by at least 6 inches (150 mm).

Secure each piece of geogrid in place at all four corners to prevent movement during fill operations. Secure the geogrid with staples or pins. Remove any slack in the geogrid before placing fill on top of it.

D. Mechanical Connections. Place the geogrid in continuous strips for the required length. The Department will allow the Contractor to mechanically join two strips of primary geogrid together to meet the length requirement shown on the plans, provided that the calculation of the long-term design tensile strength of the primary geogrid includes a reduction factor for joints, RF_{JNT}, according to 863.02.A.5. Join the two strips of geogrid using the same method and procedure that was used in the testing for RF_{JNT}. The method must consist of a mechanical connection between the two strips of geogrid. The Department will not allow simply overlapping the geogrid without a mechanical connection.

Use no more than one joint per length of geogrid. Locate joints at least 15 feet (4.5 m) behind the finished slope surface. Stagger joints at least 10 feet (3.0 m) between adjacent strips and between consecutive layers.

E. Fill Placement. Place and compact embankment material according to C&MS 203, except as modified below. Compact embankment material to at least 98 percent of the maximum dry density determined according to Supplement 1015.

Place, spread and compact the embankment in a manner that prevents the development of wrinkles or movement of the geogrid. Do not operate construction equipment directly on the geogrid. Place at least 6 inches (152 mm) of embankment material above the geogrid before operating construction vehicles on it. Do not turn equipment or brake suddenly on the first lift of fill above a layer of geogrid. Replace damaged geogrids at no cost to the Department.

Control drainage to prevent erosion. Reshape slopes that have been damaged by erosion during construction. If seeding and mulching is specified for the slope face, perform the seeding and mulching within 7 days.

863.04 Method of Measurement. The Department will measure the quantity of Geogrid by the number of square yards (square meters) completed and accepted in place. The Department will measure the length of the Geogrid by the distance from intact transverse rib to intact transverse rib. The Department will not include the length of ribs which are only connected at one end. The Department will not measure lengths greater than the required length or overlaps in the measurement for payment.

The Department will measure Reinforced Embankment by the number of cubic yards (cubic meters) according to C&MS 203.09.

863.05 Basis of Payment. The Department will pay for embankment work according to C&MS 203.10. The Department will pay for accepted quantities at the contract prices as follows:

Item	**Unit**	**Description**
863	Square Yard (Square Meter)	Geogrid, Type __
863	Cubic Yard (Cubic Meter)	Reinforced Embankment

Designer Note: Design reinforced soil slopes (RSS) and reinforced embankments using the methods shown in the FHWA manual, *Mechanically Stabilized Earth Walls and Reinforced Soil Slopes - Design and Construction Guidelines* (Elias, et al., 2001). Design for a minimum overall (global) factor of safety equal to 1.5 for slopes and embankments that support structures and equal to 1.3 for all other slopes and embankments.

Select the type of primary geogrid reinforcement from Table 863.02-1 (P1, P2, P3, P4, or P5) that will provide the long-term design tensile strength (T_A) required to produce an adequate factor of safety (FS) for the reinforced embankment. However, you may need to adjust the long-term design tensile strength depending on the slope stability program you use for the analysis. If you use a slope stability program that assumes the reinforcement force contributes to the resisting moment, such as ReSSA, RSS, and many others, then no adjustment is necessary. These programs apply the overall factor of safety to both the soil and reinforcement as part of the analysis, so the factor of safety is already applied within the slope stability analysis. However, if you use a slope stability program that assumes the reinforcement force is a negative driving component, then you need to adjust the long-term design tensile strength. With this assumption, the overall factor of safety is not applied to the tensile force from the reinforcement. In this case, multiply the tensile force from the slope stability program by the required factor of safety to determine the required long-term design tensile strength. See pages 198 and 199 in Elias, et al. (2001) for more information.

Assume a pullout resistance factor, F*, equal to 0.67 tan ϕ and scale effect correction factor, α, equal to 0.8 for geogrids. If you use a program that calculates the long-term design tensile strength based on reduction factors (such as ReSSA), use the long-term design tensile strength values given in Table 863.02-1 and a value of 1.0 for all reduction factors.

When the contractor selects a geogrid manufacturer, that manufacturer will furnish certified test data that determines the reduction factors appropriate for its geogrid. The contractor will then calculate the long-term design tensile strength based on those specific reduction factors and furnish a geogrid that meets the required long-term design tensile strength.

Whenever possible use existing on-site soil for the reinforced embankment, as this will generally be more cost effective. However, when granular embankment is required, use a plan note to specify the type of granular material required (Granular Embankment or Granular Material, Type __) and provide a pay item for Reinforced Embankment, As Per Plan. Use Geotechnical Bulletin 6 to estimate shear strength values for the proposed reinforced embankment.

Depending on site roadway geometrics (e.g., inside superelevations, steep grades, ramps, bridge barrier endings), stormwater runoff may be more concentrated and have a higher flow rate. Evalute the need for enhancing slope erosion protection measures beyond establishing vegetation on the slope. Potential measures that may be necesary include: runoff diversion (curb, gutter, and slope drains); dumped rock surface layer; geosynthetics (erosion control mat, soil or aggregate filled geocells); or tied concrete block mats.

Ensure the plans show the following items, as appropriate:

Face construction details, such as wrap-around facing with geogrid

Item 659 Seeding and Mulching, Class 3B or 3C
Item 670 Slope Erosion Protection

Reference

Elias, V., Christopher, B.R., and Berg, R. (2001) *Mechanically Stabilized Earth Walls and Reinforced Soil Slopes Design and Construction Guidelines*, FHWA-NHI-00-043, Federal Highway Administration, Washington, D.C.