I. DESCRIPTION - This work consists of furnishing the required materials and construction of geosynthetic reinforced slopes, to the lines and grades indicated, and as directed by the Representative. Specified are the geometric criteria, the required design tensile strength of primary geosynthetic reinforcement, the required minimum length of geosynthetic reinforcements, allowable type(s) of geosynthetic reinforcements, the required minimum shear strength (angle of internal friction - $\phi$) for reinforced fill, the required minimum unit weight for slope fill, and the distribution and spacing of all geosynthetic materials as indicated in these provisions. Provide the ultimate and allowable primary geosynthetic tensile strengths.

II. MATERIAL

(a) Geosynthetic - Primary. Consisting of either a geogrid or geotextile, meeting the requirements of these provisions, as indicated and as follows:

Furnish geosynthetic consisting of either a polypropylene (PP), polyester (PET)*, or high-density polyethylene (HDPE) polymer. Use geotextiles of woven or non-woven construction. Do not use woven slit films. Determine geosynthetic parameters in accordance with methods indicated in Table A.

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grid</td>
</tr>
<tr>
<td>Ultimate Tensile Strength, $T_{ult}$</td>
<td>ASTM D4759</td>
</tr>
<tr>
<td></td>
<td>ASTM D6637</td>
</tr>
<tr>
<td>Creep</td>
<td>ASTM D5262</td>
</tr>
<tr>
<td></td>
<td>GRI:GG4</td>
</tr>
<tr>
<td>Installation Damage</td>
<td>GRI:GG4 $^a$</td>
</tr>
<tr>
<td>Durability</td>
<td>-</td>
</tr>
</tbody>
</table>

$^a$ With modifications indicated in Section II.(a).3

*PET geosynthetics will only consist of: PET Geotextiles and coated PET Geogrids with a number average molecular weight ($M_n$) of 25,000 or greater and a carboxyl end group (CEG) of less than 30.
1. Determine ultimate strength values based upon minimum average roll values (MARV) determined in accordance with ASTM D4759, using ASTM D6637 – Test Method for Determining Tensile Properties of Geogrids by Single or Multi-Rib Tensile Method, and ASTM D4595 - Test Method of Tensile Properties of Geotextile by Wide Width Method for fabrics, except as follows:

\[ T_{\text{ult}} = T_{\text{avg}} - 2\sigma \]

Where: \( T_{\text{avg}} = \text{average ultimate strength of a minimum of ten ultimate tensile tests} \)
\( \sigma = \text{statistical standard deviation of all ultimate tensile test results} \)

2. Determine long-term tension-strain-time polymeric geosynthetic behavior (creep) from results of controlled laboratory creep tests. Conduct tests for minimum duration of 10,000 hours. Conduct testing according to ASTM D5262, Standard Test Method for Evaluation of Unconfined Tensile Creep Behavior of Geosynthetics, using GRI:GG4 - Standard Practice for Determination of the Long-Term Design Strength of Geogrids, and/or GRI:GT7 - Determination of Long-Term Design Strength of Geotextiles. Test samples unconfined in the direction in which the load will be applied.

Creep test data at a given temperature may be directly extrapolated over time up to one order of magnitude. Use accelerated testing to extrapolate 10,000-hour creep test data to a minimum 100-year design life. Test in accordance with GRI:GG4 (1990, 1991) for geogrids, and GRI:GT7 (1992) for geotextiles.

Maximum allowable strain of the geosynthetic is 10% for 100-year design life. Determine the creep reduction factor, \( RF_{\text{cr}} \), the ratio of ultimate strength to creep-limiting strength. Required minimum reduction factor for creep is polymer dependent as follows:

<table>
<thead>
<tr>
<th>Polymer Type</th>
<th>Creep Reduction Factor (( RF_{\text{CR}} ))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyester</td>
<td>2.0</td>
</tr>
<tr>
<td>Polypropylene</td>
<td>4.0</td>
</tr>
<tr>
<td>High Density Polyethylene</td>
<td>3.0</td>
</tr>
</tbody>
</table>

A default reduction factor for creep is not permitted.

3. Installation Damage. Determine the effect of installation damage on geosynthetic using full-scale construction damage tests. Conduct tests for the selected geosynthetic material with project-specific, representative, or a more severe backfill source. Conduct tests using placement and compaction techniques consistent with the proposed construction. Determine effect of installation damage as described in GRI:GG4 and GRI:GT7 for geotextiles, except as follows:

\[ RF_{\text{ID}} = 1.2 \frac{T_{\text{orig}}}{(T_{\text{exh}} - 2\sigma)} \]  for 2 inch top size reinforced fill

2
where:

\[ \sigma = \text{statistical standard deviation for exhumed strength (T}_{\text{exh}} \text{ of geosynthetic} \]
\[ T_{\text{exh}} = \text{average exhumed strength of geosynthetic, (k/ft), and } T_{\text{exh}} \text{ less than or equal to } T_{\text{orig}} \]
\[ T_{\text{orig}} = \text{average original (undamaged) strength of geosynthetic (use } T_{\text{avg}} \text{ from Section II.(a).1), (k/ft)} \]
\[ \text{RFID} = \text{reduction factor for installation damage} \]

Submit documentation of installation damage testing. If testing is not conducted, use a default reduction factor for installation damage of 2.5. Minimum allowable installation damage reduction factor (RFid) is 1.3 for geosynthetics fabricated from PET, PP and HDPE polymers.

4. Durability Reduction Factor, (RF_D). Use a minimum durability reduction factor of 1.1 for geosynthetics fabricated from PP and HDPE polymers, provided that the pH requirements for the reinforced and retained fill material are met. When using geosynthetics constructed from a PVC coated PET polymer, a minimum durability reduction factor of 1.3 is required.

5. Allowable geosynthetic tensile strength. Determine allowable tensile strength (T_a) of the geosynthetic using the individual reduction factors. Use reduction factors of safety to account for installation damage, durability, and creep deformation of the polymer. The overall factor of safety is the product of the individual reduction factors of safety. Determine the allowable long-term geosynthetic tensile strength, T_a, from:

\[ T_a = \frac{T_{\text{ult}}}{FS_{OV}} \]

with:

\[ FS_{OV} = RF_{CR} \times RFID \times RF_D \]

where:

\[ T_a = \text{allowable geosynthetic tensile strength, (k/ft), for use in stability analyses;} \]
\[ T_{\text{ult}} = \text{ultimate geosynthetic tensile strength, (k/ft);} \]
\[ FS_{OV} = \text{overall factor of safety against geosynthetic failure (dimensionless), minimum value of 3.4 for polyester (PET) materials, 5.7 for polypropylene (PP) materials, and 4.3 for high density polyethylene (HDPE) materials;} \]
\[ RF_{CR} = \text{factor of safety for creep deformation, ratio of Tult to creep-limiting strength, at maximum 10 \% strain (dimensionless);} \]
\[ RF_{ID} = \text{factor of safety for installation damage, (dimensionless);} \]
\[ RF_D = \text{factor of safety for durability, (dimensionless).} \]

Where multiple polymer types are used in the manufacture of a geosynthetic reinforcement, the higher reduction factors (RF’s) are applied.

6. Design tensile strength (T_d). T_d \leq T_a, where T_a = allowable tensile strength of geosynthetic as determined in Section II(a)5.
7. Geosynthetic Vertical Spacing. Maximum allowable spacing for both primary and secondary geosynthetic reinforcements is indicated in Figure 1. The maximum vertical spacing for primary geosynthetic ($S_p$) is 1.5 ft. Provide an additional layer of primary reinforcement at subgrade elevation, when the subgrade elevation is greater than or equal to nine inches above the previous layer of primary reinforcement. The maximum vertical spacing for secondary geosynthetic ($S_s$) is 0.5 ft.

![Figure 1 – Spacing Requirements for Geosynthetic Reinforcement](image)

(b) Geosynthetic - Secondary. Section 735, Class 4, Type A.

(c) Wire Mesh Forms. Consisting of galvanized welded wire mesh and galvanized wire support struts.

Wire Mesh Units – galvanized welded wire mesh meeting the requirements of AASHTO M 55 and AASHTO M 111, as indicated in these provisions, and as follows:

- Formed to a 90 degree “L” shape with equal 18 inch sides
- Minimum length 10 feet
- Maximum 4 inch by 4 inch mesh opening
- Minimum wire size number W 4
- Minimum Coating Thickness Grade 65
Support Struts – galvanized wire formed to interlock with mesh longitudinal wires, meeting the requirements of AASHTO M 32 and AASHTO M 111, as indicated in these provisions, and as follows:

- Minimum wire size number W 4
- Minimum Coating Thickness Grade 65

(d) **Reinforced Fill.** Embankment Material as specified in Section 206.2(a)1.a and 1.b, and as follows:

Gradation: 100 percent passing 2 inch sieve.

Provide fill that meets the minimum required shear strength parameters. Use peak shear strength parameters. Determine parameters using direct shear or consolidated-drained (CD) triaxial tests. If no minimum shear strength parameters are indicated, then provide material with a minimum angle of internal friction (\(\phi\)) of 32 degrees.

Chemical composition. Provide material with a pH between 3 and 9, when using PVC coated polyester (PET) geosynthetics. Provide material with a pH > 3, when using polypropylene (PP) or high density polyethylene (HDPE) geosynthetics.

(e) **Turf Reinforcement Mat (TRM).** Section 806.2(b)

(f) **Seed and Soil Supplements.** Section 804.2.

III. CONSTRUCTION

(a) **Material Submittals.** Submit six sets of manufacturer’s material information that include identification samples of all primary geosynthetic reinforcements, manufacturer’s test data for all reduction factors, and all data necessary to indicate the geosynthetic(s) meet the requirements set forth in these provisions. Submit six sets of computations for allowable tensile strength of primary geosynthetics, and reinforced fill test results for shear strength (friction angle, \(\phi\)), gradation, pH and as required in Section 206.2. Submit required information for approval by the Department within thirty (30) days of notice to proceed, and at least sixty (60) days prior to the beginning of reinforced slope construction.

Submit verification samples to the Materials and Testing Division (MTD), of minimum six foot by six foot size. Include all primary geosynthetics to be used in the reinforced slope. Provide product data sheets, for all primary geosynthetics, identifying all information necessary for the design and construction of the reinforced slope. Sample geosynthetics in accordance with ASTM D 4354.

(b) **Foundation Preparation.** Prepare foundation to the lines and grade shown on the
Drawings, as specified in Section 206.3, and as follows. Excavation for equipment access beyond the line and grade indicated, is at no additional cost to the Department. Prepare foundation free of deleterious or unsuitable soils. Proof roll the foundation with 5 passes of a static, smooth drum or pneumatic tire roller, with a minimum contact pressure of 120 psi, to provide a uniform and firm surface. Proof roll in a systematic manner ensuring complete coverage of the foundation surface. Operate the roller at a speed between 3 and 5 miles per hour. Excavate and replace any unstable areas with suitable materials, as directed by the Representative. The foundation will be inspected by the Representative prior to placing fill or geosynthetic reinforcements.

(c) Geosynthetics.

1. Delivery Storage and Handling. Protect the geosynthetic materials from temperatures greater than 140°F, and from debris that may damage the material. Protect all geosynthetic materials from sunlight. Reject all geosynthetics with defects, tears, punctures, flaws, deterioration, or damage incurred during installation, manufacture, transportation, or storage. Replace any damaged geosynthetic materials at no additional cost to the Department.

2. Geosynthetic Placement. Place the geosynthetic within the layers of the compacted fill as indicated.

Use wire mesh forms to establish a stepped face to the slope and dimensions indicated. Internally brace wire forms to maintain verticality of step faces. Place pre-formed wire mesh units on the exterior (outside) of all primary and secondary geosynthetic lifts and turf reinforcement mat (TRM). Internally brace wire mesh units with a minimum of six pre-formed wire struts per mesh unit, with a maximum strut spacing of two feet. Puncture turf reinforcement mat (TRM) only as necessary to permit fastening of wire strut to wire mesh. Overlap edges of adjacent mesh units a minimum of four inches to maintain alignment during construction.

Place primary geosynthetic, of the minimum lengths indicated, in continuous strips in the primary direction of stabilization - perpendicular to the slope face. Minimum length of grid type reinforcement is measured beginning and ending at primary transverse ribs. Maximum allowable vertical spacing of primary geosynthetics is 1.5 feet. Place secondary reinforcement, in continuous strips parallel to the slope face. Maximum allowable vertical spacing of secondary geosynthetic is 0.5 feet. Minimum length of secondary reinforcement is 7 feet. Overlap adjacent sections of primary and secondary reinforcements a minimum of six inches along parallel roll edges. Splicing of any primary or secondary geosynthetic, including seams or connections, is prohibited. Slit secondary reinforcement a length only as necessary to permit installation between wire struts.

Overlap adjacent strips of turf reinforcement mat (TRM) a minimum of six inches along parallel roll edges. Overlap adjacent strips of primary and secondary geosynthetic a minimum of six inches along parallel roll edges. For applications involving geometries with
curves requiring overlaps of adjacent primary geosynthetic reinforcements in excess of six inches, vertically separate the full length of overlaps with six inches of compacted fill. For embankments with reinforced slopes on both sides, place primary geosynthetics from opposite slope faces, independent of one another. When primary geosynthetic layers from opposite slope faces overlap, separate the overlapped portions with a minimum of six inches of compacted fill.

All geosynthetics must be backfilled before the end of the workday. The process shall be repeated for subsequent layers of wire forms, geosynthetics, turf reinforcement mat, and fill.

Place geosynthetic to lay flat, pulled tight and anchored in place until backfill is placed. Place geosynthetic within two inches of the design elevations and to the minimum length indicated.

Do not dump fill directly onto exposed geosynthetics. Place fill on previously spread fill and blade out.

No vehicles are permitted on the geosynthetic until eight inches of loose backfill has been placed. Sudden braking and sharp turning of any vehicle on reinforced fill is prohibited. Correct any disturbance or distortion of geosynthetics due to operation of vehicles or equipment, at no additional cost to the Department.

(d) Reinforced Fill Placement. Section 206.3(b) “Placement and Compaction”, Section 206.3(c) “Stability”, and as follows:

Sheepsfoot/padfoot type compaction equipment is not permitted for the compaction of reinforced fill.

Grade the surface of the fill only as necessary to facilitate surface drainage. Seal surface with a smooth drum roller at the end of each workday.

(e) Turf Reinforcement Mat (TRM). Place the TRM against the back face of the wire form as indicated. Lay the excess material that will cover the top of the step over the front face of the wire form. When fill and reinforcement layers reach the top of the wire form, wrap the TRM over the top layer of fill as indicated. Embed the TRM a minimum of six inches horizontally underneath the next wire form. Place the blanket with a six inch overlap between adjacent layers. Place TRM as reinforced slope is constructed.

(f) Vegetation. Hydroseed the TRM with two (2) applications, in accordance with Section 804.3, Formula C, or as otherwise specified.

(g) Drainage. Provide surface and subsurface drainage systems as indicated.

IV. MEASUREMENT AND PAYMENT
(a) **Geosynthetic Reinforced Slope System.** Vertical square foot of reinforced slope.

All materials and construction of reinforced slope system, including required and discretionary laboratory tests, foundation preparation, all geosynthetics, wire forms, all fill materials, turf reinforcement mat, seeding and soil supplements, and all drainage.

(b) **Class 1 Excavation.** Cubic Yard.

Excavation of unsuitable foundation materials as directed by the Representative, beyond the limits of excavation shown on the drawings, will be paid as specified in Section 110.03(a).