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INTRODUCTION
The purpose of this Engineering Bulletin is to provide information regarding the proper selection of design parameters relating to Geotex® medium strength geotextiles used for soil reinforcement. The following design parameters will be discussed in detail and recommendations for each will be provided:

- Long-Term Design Strength (LTDS)
- Installation Damage
- Creep Resistance
- Biological Degradation
- Chemical Degradation
- Seam/Joint Strength

LONG-TERM DESIGN STRENGTH
The long-term design strength is the allowable design strength of a soil reinforcement product during the service life of a structure. Most permanent structures are designed to a service life of 75 to 100 years whereas temporary structures are defined as having a service life less than 3 years. During this service life there will be occurrences that may tend to reduce the ultimate tensile strength in the reinforcement. The Federal Highway Administration (FHWA) recently published its finding from research on geosynthetic soil reinforcement products and provide similar guidelines, as will be presented in this technical note, for anticipated ranges of tensile strength reduction on each type of soil reinforcement product. These tensile strength reductions occur in four categories. They are:

- Creep Resistance
- Installation Damage
- Biological Durability
- Chemical Durability

Additional reduction factors maybe included when joints/seams are used between adjacent panels and a mechanical
strength transfer is required. Typically these mechanical transfers are required when constructing embankments on soft soils and capping lagoons. For retaining wall and steepened slope applications strength in the minor stress direction (i.e. parallel to the wall or slope face) is not required and as such the adjacent panels are simply butted together or slightly overlapped a few inches.

The determination of the LTDS of a soil reinforcement product, based on Geosynthetic Research Institute GT7 (GRI-GT7), FHWA and American Association of State Highway and Transportation Officials (AASHTO) design methodologies, is determined from the following formula:

\[
LTDS = \frac{T_{\text{ult}}}{RF_{cr} \cdot RF_{id} \cdot RF_{d} \cdot RF_{\text{jnt}}}
\]

Where:
- \(RF_{cr}\) = Reduction Factor for creep resistance
- \(RF_{id}\) = Reduction Factor for installation damage
- \(RF_{d}\) = Reduction Factor for biological and chemical durability
- \(RF_{\text{jnt}}\) = Reduction Factor joints or seams
- \(T_{\text{ult}}\) = Ultimate wide width tensile strength (based on ASTM D-4595)
- LTDS = Long-term Design Strength

The ultimate wide width tensile strength is based on American Society for Testing and Materials (ASTM) D-4595, “Standard Test Method for Tensile Properties of Geotextiles by the Wide-Width Strip Method”. Provided below are brief descriptions of each reduction factor. The associated Geotext product testing results are also shown with recommended reduction factors. Since many of the Geotext soil reinforcement products are grouped into families of similar makeup, some extrapolation from one product to another is accepted and referenced within FHWA DEMO 82.

**INSTALLATION DAMAGE**

Propex has performed full-scale installation damage on our Geotex 4x4 and Geotex 4x4HF medium strength geotextiles. For the Geotex 4x4 and Geotex 4x4HF, installation damage was performed in both the machine and cross-machine direction. Several types of soil were used in the installation damage testing and are shown in Table 1 below.

<table>
<thead>
<tr>
<th>Product</th>
<th>Soil Types Tested</th>
</tr>
</thead>
<tbody>
<tr>
<td>4x4</td>
<td>Clayey Sand (SC) With Gravel Backfill</td>
</tr>
<tr>
<td>4x4HF</td>
<td>Clayey Sand, Graded Gravel, Rounded Sand, Silty Loam</td>
</tr>
</tbody>
</table>

**Table 1 - Installation Damage Testing Soil Types**

Results of the installation damage testing are shown in Table 2 below.

<table>
<thead>
<tr>
<th>Product</th>
<th>Clayey Sand</th>
<th>Graded Gravel</th>
<th>Rounded Sand</th>
<th>Silty Loam</th>
</tr>
</thead>
<tbody>
<tr>
<td>4x4</td>
<td>1.27</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4x4HF</td>
<td>1.10</td>
<td>1.19</td>
<td>1.12</td>
<td>1.01</td>
</tr>
</tbody>
</table>

**Table 2 - Installation Damage Factors**

The installation damage results correspond well with the installation damage values published by FHWA DEMO82. One noticeable item with the installation damage testing is that the compaction effort is much greater than what is typically encountered in the field and the lift height is less than typical. Strength retention at a specific strain rate, such as 5 and 10%, yield much greater values than the ultimate strength retention values, hence lower reduction factors.

**CREEP RESISTANCE**

Creep resistance is a measure of how much a material elongates under a constant sustained load. Each polymer and its manufactured geometry will have varying creep resistance properties. Propex has conducted creep strain testing based on ASTM D-5262, “Standard Test Method for Evaluating the Unconfined Tension Creep Behavior of Geosynthetics”, having a minimum creep test duration of 10,000 hours. Propex had creep testing performed on our Geotex 2x2HF and 4x4HF medium strength woven polypropylene geotextiles. This testing was conducted by GeoSyntec Consultants of Atlanta, GA.

Loadings of 10, 20, 25, 30, 35, 40 and 50% of the base line wide width ultimate tensile strength were loaded, in accordance with ASTM D-5262 and FHWA DEMO82. Analysis of the creep data, based on FHWA DEMO82, yields maximum service lives of approximately 11 years. Service life reduction factors for greater than 11 years can be obtained through elevated temperature testing. The creep reduction factors are shown in Table 3 for Geotex 2x2HF, 3x3HF, 4x4, 4x4HF, and 4x6 for 1, 5, 11, 25, 50, 75, and 100 years.

<table>
<thead>
<tr>
<th>Creep Reduction Factors1</th>
<th>1 YR</th>
<th>5 YRS</th>
<th>11 YRS</th>
<th>25 YRS</th>
<th>50 YRS</th>
<th>75 YRS</th>
<th>100 YRS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3.20</td>
<td>3.74</td>
<td>4.03</td>
<td>4.37</td>
<td>4.67</td>
<td>4.87</td>
<td>4.99</td>
</tr>
</tbody>
</table>

**Table 3 - Creep Reduction Factors**

Notes: 1. Creep reduction factors extrapolated to 100,000 hours per FHWA DEMO82

The use of this creep data for “similar” products is accepted by FHWA provided that “the chemical and physical characteristics of tested products and proposed products are shown to be similar. The physical characteristics consist of having the product constructed in a similar manner, such as weaving or knitting.”

(continued)
Depending on the desired lifespan of the reinforcement, creep may or may not be necessary to include in the long term design strength. For example, if an embankment’s soft foundation soils are anticipated to gain sufficient strength to withhold the embankment within one year after construction the service life of the reinforcement is considered a short term event and creep is not included. In this case the geosynthetic reinforcement’s allowable design strength is based on the above formula using a creep reduction factor of 1.0.

**BIOLOGICAL DEGRADATION**

Propex conducted biological degradation testing using Geotex medium strength geotextiles. The geotextiles were exposed to biologically active soil for 30 days and tested using ASTM D-4595, “Standard Test Method for Tensile Properties of Geotextiles by the Wide-Width Strip Method”. The testing program was an adopted procedure to assess a biological damage reduction factor based on the Washington State Department of Transportation Transportation Qualified Products List (WSDOT QPL) requirement. The biological stability of the soil was evaluated using ASTM D-3083, “Standard Specification for Flexible Poly(Vinyl Chloride) Plastic Sheeting for Pond, Canal and Reservoir Lining”. Cellulose destroying micro-organisms were confirmed after one and two weeks of exposure by testing control exposure strips of cotton duck material. The cotton duck material was tested in accordance with ASTM D-5035, “Test Method for Breaking Force and Elongation of Textile Fabrics (Strip Test)”. Results for the Geotex medium strength geotextiles yielded strength retained values ranging from 100.1 to 98.2%. Hence the reduction factor for biological degradation is 1.0 and corresponds with previous testing and research sponsored by FHWA.

**CHEMICAL DEGRADATION**

Several studies have been performed on the compatibility of Propex polypropylene fibers and filaments with leachates in various pH solutions commonly encountered in soil or solid waste applications. Since the evaluation of long-term chemical aging of Geotex woven polypropylene geotextiles is nearly impossible due to the inherent stability of the polymer, laboratory immersion tests were conducted at elevated temperatures (50°C) to accelerate anticipated behavior. Variables such as temperature, moisture and oxygen content were controlled in the lab and samples were removed at 30, 60, 90 and 120 day intervals. The results from the testing are shown in Table 4 below.

<table>
<thead>
<tr>
<th>Description</th>
<th>Solution pH</th>
<th>Strength Retained</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 Denier Polypropylene Fibers</td>
<td>6.8</td>
<td>93%</td>
</tr>
<tr>
<td>490 x 1030 Polypropylene Denier Silt Film Yarns</td>
<td>6.8</td>
<td>91%</td>
</tr>
</tbody>
</table>

Table 4 - Chemical Degradation Testing Results

**JOINTS OR SEAMS**

Propex does not recommend splicing reinforcement in the primary reinforcing direction. Hence the reduction factor for joints or seams is 1.0.

For applications, such as embankments over soft soils and lagoon closures, where biaxial strength or a mechanical strength transfer is required the edges (cross-machine direction) of the reinforcement can be sewn, however rarely is sewing in the machine direction allowed. Typical seam strengths, based on ASTM D-4884, “Standard Test Method for Strength of Sewn or Bonded Seams of Geotextiles”, are approximately 50% of the ultimate wide width tensile strength in the cross-machine direction. Therefore, when designing and requiring a mechanical stress transfer Propex recommends that the design strength be doubled and specified as the ultimate wide width tensile strength in the cross-machine direction for the high strength woven geotextile.

Please contact Propex for further guidance when specifying seam strengths on project construction specifications and field installation of sewn geotextile panels.

**SOIL INTERACTION**

Propex has completed direct shear testing of Geotex geotextiles using an Ottawa sand, a glacial till, silty sand and a lean clay. The test results for the medium strength polypropylene geotextiles yield soil interaction values of 0.8 to 1.0 for the Ottawa sand, 0.65 to 0.9 for the glacial till and 0.5 to 0.9 for the lean clay. These results correspond well with the published work by Koutsourais, Sandri and Swan (1998) and mostly are greater than the typically assumed design values for these soil types. Koutsourais, et. al. has summarized extensive testing of flexible geotextile and geogrid interaction values and recommends interaction values of 0.9 for sands and 0.7 for clays. For silty or clayey sands a soil interaction value of 0.8 is typically used for both geotextiles and geogrids.

As the geosynthetic reinforcement begins to mobilize its strength, an opposite requirement exists for the soil behind the slip zone to resist pullout. This pullout or anchorage length calculation is dependent on the geosynthetic tensile strength, geosynthetic frictional interaction with the soil, soil shear strength and the estimated overburden of the soil. The following equation, used to determine anchorage or pullout length, has been adopted from Koerner 9.

\[
L_a = \frac{T_g (FS_{pa})}{C_s (H) (\tan \phi_{int})} = \frac{T_g (FS_{pa})}{C_s (H) (\tan \phi_{int}) + (C_t * S_o)}
\]

Sometimes the frictional interaction of the geosynthetic reinforcement is masked within the terms of “interlock” and used in a specification to specify a specific reinforcement physical geometry. The specific geometry is not what governs
the frictional interaction of the geosynthetic reinforcement. More importantly the controlling factor is the texture of the material itself. The state-of-the-practice for determining this frictional interaction of the geosynthetic reinforcement is to perform ASTM D-5321, “Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method”.

APPENDIX A

LONG-TERM DESIGN STRENGTH TABLES

Table 5 has been created to assist design engineers in selecting the most economical medium strength geotextile. This table contains information used to calculate the LTDS of the Geotex medium strength geotextiles for service lives of 11 to 25 years. For more information on the LTDS and where the partial factors-of-safety were obtained, please call Propex. Please contact Propex for additional assistance when selecting a design strength under different conditions than are shown in the tables.

<table>
<thead>
<tr>
<th>Design Life of 11 - 25 Years</th>
<th>GEOTEX 2X2HF</th>
<th>GEOTEX 4X4HF</th>
<th>GEOTEX 4X6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polymer</td>
<td>MD CMD MD CMD MD CMD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PP</td>
<td>PP PP PP PP PP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ultimate Wide-Width Tensile Strength (lbs/ft, ASTM D-4595)</td>
<td>2400 2400 4800 4800 7200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Creep Reduction Factor, 11 YRS</td>
<td>4.03 4.03 4.03 4.03 4.03</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Installation Damage Reduction Factor, RFid</td>
<td>1.00 1.00 1.00 1.00 1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Joint Strength Reduction Factor, RFjnt</td>
<td>1.00 1.00 1.00 1.00 1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geotex® GT7 / FHWA Method (lbs/ft)</td>
<td>531 659 903 1217 903</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10% Strain Limit</td>
<td>411 622 802 1174 802</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5% Strain Limit</td>
<td>429 N/A 189 864 589 1290</td>
<td></td>
<td></td>
</tr>
<tr>
<td>sands, silts and clays sandy gravel</td>
<td>380 N/A 523 833 523 1250</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5 - Calculating the Long-Term Design Strength of Geotex® Medium Strength Geotextiles

Notes: MD - machine or roll direction
CMD - cross-machine direction
PP - Polypropylene

References