ENGINEERING BULLETIN

Propex® GEOSOLUTIONS

EB-530 CALCULATING LONG TERM DESIGN STRENGTH (LTDS) OF MEDIUM STRENGTH GEOTEXTILES

DISCLAIMER

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
- Soil Interaction

These design parameters relate to one or more of the following applications:

- Steepened Slopes
- Wrapped Face or Segmental Retaining Walls
- Lagoon Closures
- Embankments Over Soft Soil
- Lining System Support

Although the information presented in this Engineering Bulletin is consistent with the current state-of-practice in geotechnical and geosynthetic engineering, Propex assumes no liability for this information. The use of the recommendations in final designs must be reviewed by a Professional Engineer familiar with the project and knowledgeable in geotechnical and geosynthetic engineering.

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 provideprovides 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

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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:

$$LTDS = \frac{T_{ult}}{RF_{cr} * RF_{id} * RF_{d} * RF_{jnt}}$$

Where:

RFcr = Reduction Factor for creep resistance

RFid = Reduction Factor for installation damage

RFd = Reduction Factor for biological and chemical durability

RFjnt = Reduction Factor joints or seams

Tult = 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 Geotex product testing results are also shown with recommended reduction factors. Since many of the Geotex 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.

Product	Soil Types Tested
4x4	Clayey Sand (SC) With Gravel Backfill
4x4HF	Clayey Sand, Graded Gravel, Rounded Sand, Silty Loam

Table 1 -Installation Damage Testing Soil Types

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

Product	Clayey Sand	Graded Gravel	Rounded Sand	Silty Loam
4x4	1.27	-	-	-
4x4HF	1.10	1.19	1.12	1.01

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.

Creep Reduction Factors[1]						
1 YR	5 YRS	11 YRS	25 YRS	50 YRS	75 YRS	100 YRS
3.20	3.74	4.03	4.37	4.67	4.87	4.99

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.

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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 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.

Description	Solution pH	Strength Retained
8 Denier Polypropylene Fibers	6.8	93%
480 x 1030 Polypropylene Denier Slit Film Yarns	6.8	91%

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.

$$L_r = \frac{T_g(FS_{po})}{C_t(H)(\gamma_{inf})(\tan[\phi_{inf}])} = \frac{T_g(FS_{po})}{C_t(H)(\gamma_{inf})(\tan[\phi_{inf}]) + (C_t * S_u)}$$

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.

Design Life of 11 - 25 Years	GEOTEX 2X2HF		GEOTEX 4X4HF		GEOTEX 4x6	
	MD	CMD	MD	CMD	MD	CMD
Polymer	PP	PP	PP	PP	PP	PP
Ultimate Wide-Width Tensil Strength (lbs/ft) ASTM D-4595	2400	2400	4800	4800	4800	7200
Creep Reduction Factor, 11 YRS	4.03	4.03	4.03	4.03	4.03	4.03
Creep Reduction Factor, 25 YRS	4.37	4.37	4.37	4.37	4.37	4.37
Installation Damage Reduction Factor, RF_{id}						
Sand, Silts And Clays	1.11	1.11	1.11	1.11	1.11	1.11
Sandy Gravel	1.25	1.15	1.25	1.15	1.25	1.15
Chemical Degradation Reduction, RF_{ch} (3<pH<10)	1.10	1.10	1.10	1.10	1.10	1.10
Biological Degradation Reduction Factor, RF_b	1.00	1.00	1.00	1.00	1.00	1.00
Joint Strength Reduction Factor, RF_{jnt}	1.00	1.00	1.00	1.00	1.00	1.00
GRI-GT7 / FHWA Method (lbs/ft)						
10% Strain Limit	531	655	903	1217	903	1354
Sands, Silts and Clays Sandy Gravel	417	632	802	1174	802	1203
GRI-GT7 / FHWA Method (lbs/ft)						
5% Strain Limit	428	N/A	589	864	589	1296
Sands, Silts and Clays Sandy Gravel	380	N/A	523	833	523	1250

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

1. "GRI Standard Practice GT7", Geosynthetic Research Institute, Philadelphia, PA, 2012.

2. ASTM, 2011, "ASTM D-4595-11, Standard Test Method for Tensile Properties of Geotextiles by the Wide-Width Strip Method," American Society for Testing and Materials, West Conshohocken, PA.

3. ASTM, 2012, "ASTM D-5262-07(2012), Standard Test Method for Evaluating the Unconfined Tension Creep Behavior of Geosynthetics," American Society for Testing and Materials, West Conshohocken, PA.

4. ASTM, 1989, "ASTM D-3083-89, Standard Specification for Flexible Poly (Vinyl Chloride) Plastic Sheeting for Pond, Canal and Reservoir Lining," American Society for Testing and Materials, West Conshohocken, PA.

5. Publication No. FHWA-SA-93-025, USDOT/FHWA, Washington, D.C., January 1993.

6. ASTM, 2014, "ASTM D-4884-14a, Standard Test Method for Strength of Sewn or Bonded Seams of Geotextiles," American Society for Testing and Materials, West Conshohocken, PA.

7. Koerner, R. M., Designing with Geosynthetics, Third Edition, Prentice Hall, Englewood Cliffs, NJ, 2012.

8. ASTM, 2014, "ASTM D-5321-14, Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method," American Society for Testing and Materials, West Conshohocken, PA.

9. Berg, R.R., Guidelines for Design, Specifications & Contracting of Geosynthetic Mechanically Stabilized Earth Slopes on Firm Foundations, Publication No. FHWA-SA-93-025, USDOT/FHWA, Washington, D.C., January 1993.

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