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**GRI Standard Practice GT7***

Standard Practice for

**"Determination of the Long-Term Design Strength of Geotextiles"**

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## 1. Scope

1.1 This standard practice is to be used to determine the long-term design load of geotextiles for use in the reinforcement of such structures as embankments, slopes, retaining walls, improved bearing capacity, and other permanent geotechnical and transportation engineering systems.

1.2 The method is based on the concept of identifying and quantifying partial factors-of-safety for those phenomena which can impact the long-term performance of geotextile reinforced systems and are not taken into account in traditional laboratory testing procedures.

1.3 The partial factors-of-safety to be considered are for installation damage, creep deformation, chemical degradation, biological degradation and joints (seams and connections).

1.4 These partial factor-of-safety values can be obtained by direct experimentation and measurement, or by using default values which are given for the various applications which use geotextiles.

*This GRI standard is developed by the Geosynthetic Research Institute through consultation and review by the member organizations. This specification will be reviewed at least every 2-years, or on an as-required basis. In this regard it is subject to change at any time. The most recent revision date is the effective version.

## 2. Reference Documents

2.1 ASTM Standards

D123 Terminology Relating to Textiles
D4354 Practice for Sampling Geotextiles
D4439 Terminology for Geotextiles
D4595 Tensile Properties of Geotextiles by the Wide Width Strip Method
D5262 Tension Creep of Geosynthetics
G22 Determining Resistance of Synthetic Polymer Materials to Bacteria

2.2 EPA Standards

Method 9090: Compatibility Tests for Wastes and Membrane Liners

## 3. Terminology

3.1 General - Many of the terms used in this standard are relatively new and undefined by standards groups such as ASTM, ISO, etc. Therefore a section devoted to definitions follows.

3.2 Definitions

3.2.1 Geotextiles - Any permeable textile material used with foundation, soil, rock, earth, or any other geotechnical engineering related material, as an integral part of a humanmade project, structure, or system.

3.2.2 Joints (or Connections) - The connections made between separate geotextile rolls or between geotextiles and wall panels or other parts of the structural system.

3.2.3 Design Strength - The design, or required, strength of a geotextile needed for successful functioning of the system. It is often arrived at by an appropriate geotechnical design model.

3.2.4 Ultimate Geotextile Strength - The ultimate or maximum geotextile strength, $T_{ult}$, as determined by a short-term strength test in accordance with an accepted ASTM test method. For geotextiles this test method would be ASTM D4595.

3.2.5 Allowable Geotextile Strength - The long-term, allowable strength, $T_{allow}$, to be used in design taking into account all of the phenomena which could influence the geotextile during its service lifetime.

3.2.6 Global Factor-of-Safety - A numeric comparison of the geotextile's allowable tensile strength to the required or design tensile strength. The minimum acceptable value reflects the accuracy in defining load conditions, uncertainties in design methods, definition of soil strength and other design parameters.

3.2.7 Partial Factors-of-Safety - A set of numeric values each of which is focused on a particular phenomenon which may negatively impact the geotextile's performance.

3.2.8 Atmosphere for Testing Geotextiles - Ambient air conditions maintained at a temperature of 21 2 deg. C (70 4 deg. F) and a relative humidity of 65 5%.

## 4. Summary

4.1 This standard practice is meant to adjust a laboratory generated short term ultimate geotextile tensile strength value to a site specific allowable tensile strength value by using partial factors-of-safety on selected phenomena. It is then to be used with a global factor-of-safety for the site-specific situation under consideration.

4.2 The focus of the standard is toward all types of geotextiles.

4.3 Specific procedures for quantifying each of the partial factors of safety are provided. If these procedures are not followed default values are provided.

## 5. Significance and Use

5.1 Rather than use an unusually high overall factor-of-safety for geotextile reinforced structures (in comparison to those factors-of-safety used in a conventional design involving soil, concrete or steel), this standard of practice uses partial factors-of-safety for those particular phenomena which may diminish the long-term performance of the as-received geotextile material.

5.2 The partial factors-of-safety to be discussed are those of installation damage, creep deformation, chemical degradation, biological degradation and joints (seams and connections). The result of compensating for these phenomena is an allowable geotextile strength which can be used directly in design.

5.3 Procedures are given as to how one obtains each of the above partial factors-of-safety for the various phenomenon to be discussed, e.g., installation damage, creep, chemical degradation, biological degradation and joint strength.

5.4 As an option to conducting the above procedures, default values are given for each of the different phenomena depending on the particular geotextile reinforcement application.

5.5 The standard practice is site specific, application specific, and geotextile product specific.

5.6 The standard is not meant to be a test method, but does require various test protocols to obtain the necessary values for the different partial factors-of-safety.

## 6. Partial Factor-of-Safety Concept

6.1 Design Strength (Tdesign) - The required design strength of a geotextile is that numeric value needed for successful functioning of the geotextile under consideration. For geotextile applications it is often calculated by a geotechnical engineer using an applicable design model, adapted for the geotextile's inclusion. It might also be defined in a formal specification or recommended by an owner. The units of Treqd are in kN/m or lb/ft.

6.2 Ultimate Strength ($T_{ult}$) - The ultimate strength of a geotextile is obtained by one of the following tests. Note that some of them are short term tests which are often used for quality control, while others are long term tests used as performance indicators.

6.2.1 ASTM D4595 - This test is a wide width tensile strength test measuring the strength of the geotextile resulting in a value in units of kN/m or lb/ft. The standard width is 200 mm (8.0 in.).

6.2.2 ASTM D5262 - This test is a sustained load (or creep) test for geosynthetics. It is of the wide width variety in that 200 mm (8.0 in.) width is evaluated. The test is generally conducted for a minimum time of 10,000 hours.

6.3 Allowable Strength ($T_{allow}$) - The allowable long-term strength of a geotextile is to be used in a traditional factor-of-safety formulation and compared directly to the design requirement for strength. Note that the allowable strength is always less than the ultimate strength unless complete laboratory testing, simulating all possible long-term phenomena, has been used in its procedure. Thus

$$T_{allow} \leq T_{ult} \tag{1}$$

After proper evaluation or calculation, $T_{allow}$ is then used in the following equation to determine the final, or global, factor-of-safety.

$$FS = T_{allow} / T_{design} \tag{2}$$

where

| | | |
|---|---|---|
| $FS$ | = | global factor-of-safety for design and construction uncertainties and other unknowns (typically 1.25 to 1.5) |
| $T_{ult}$ | = | ultimate strength (kN/m or lb/ft) |
| $T_{allow}$ | = | allowable strength (kN/m or lb/ft) |
| $T_{design}$ | = | design (or required) strength (kN/m or lb/ft) |

For analysis procedures which incorporate the design factor-of-safety directly into the geotextile reinforcement (i.e., like the tie-back wedge analysis procedure for retaining walls) Equation #2 is used as follows:

$$T_{design} = T_{allow}/FS$$

6.4 Partial Factors-of-Safety - A mechanism by which an ultimate strength can be adapted to an allowable strength using values tuned to site specific conditions is affording by using partial factors-of-safety. For example for geotextiles in reinforcement applications, the following should be used.

$$T_{allow} = T_{ult}\left[\frac{1}{FS_{ID} \times FS_{CR} \times FS_{CD} \times FS_{BD} \times FC_{JNT}}\right] \qquad (3)$$

where

$FS_{ID}$ = partial factor-of-safety for installation damage
$FS_{CR}$ = partial factor-of-safety for creep deformation
$FS_{CD}$ = partial factor-of-safety for chemical degradation
$FS_{BD}$ = partial factor-of-safety for biological degradation
$FS_{JNT}$ = partial factor-of-safety for joints (seams and connections)

NOTE 1: Temperature, per se, is not included as a partial factor-of-safety. If site-specific temperatures are of concern the various tests should be suitably accommodated to the mutual agreement of the parties involved.

7. Default Values for Partial Factors-of-Safety - In the absence of test information and documentation as to the site specific values for the above listed values of partial factors-of-safety in Equation 3, the following default values should be used.

Table 1 -Default Values for Geotextiles for various Partial Factors-of-Safety
(Terms are Defined in Equation 3)

| Application | $FS_{ID}$ | $FS_{CR}$ | $FS_{CD}$ | $FS_{BD}$ | $FS_{JNT}$ |
|---|---|---|---|---|---|
| embankments | 1.4 | 3.0 | 1.4 | 1.3 | 2.0 |
| slopes | 1.4 | 3.0 | 1.4 | 1.3 | 2.0 |
| retaining walls | 1.4 | 3.0 | 1.4 | 1.3 | 2.0 |
| bearing capacity | 1.5 | 3.0 | 1.6 | 1.3 | 2.0 |

It should be mentioned that the values given in Table 1 are considered to be upper-bound values. Since the impact of multiplying these numbers together for a particular application is very significant in decreasing the ultimate strength, it is usually worthwhile to consider the specific procedures for evaluating the individual partial factors-of-safety. They follow in the order presented in Equation 3.

**8. Procedures for Evaluating Individual Partial Factor-of-Safety Values**

8.1 Installation Damage, $FS_{ID}$ - Installation damage of a specific type of geotextile is determined by installing a field test strip on the actual site's subgrade, or on a closely simulated version thereof. The geotextile is positioned in place, tensioned as per the intended final installation, and then backfilled using the site specific backfill material, lift height, placement equipment and compaction equipment. If these details are not known at the time of the test, worst case conditions should be assumed. The minimum size of the geotextile test strip is to be 9 m/sq. (100 sq./ft.). If possible, the full roll width should be used. Upon completion of the backfilling the geotextile should be carefully exhumed so as not to create damage. The exhuming should be done immediately, i.e., it is a survivability test and not a long-term aging type of test.

> NOTE 2: Past exhuming of geotextiles has shown the removal of backfill to be an important consideration in that a significant amount of hand excavation is necessary. If the backfill layer is 30 cm (12 in.) or more, some of it can be removed by a front end loader but the lower 15 cm (6 in.) should be removed by hand. Never use a bulldozer or road grader since the scraping action will surely damage the geotextile.

The exhumed geotextile is now tested for its residual strength in a ASTM D4595 Wide Width Strength test and compared to test values of the comparable geotextile material which was not installed. The non-installed geotextile should be taken from the same roll as was the installed and exhumed geotextile.

The resulting factor-of-safety is formulated in a traditional matter, i.e.

$$FS_{ID} = T_{orig.} / T_{exh.} \tag{4}$$

where

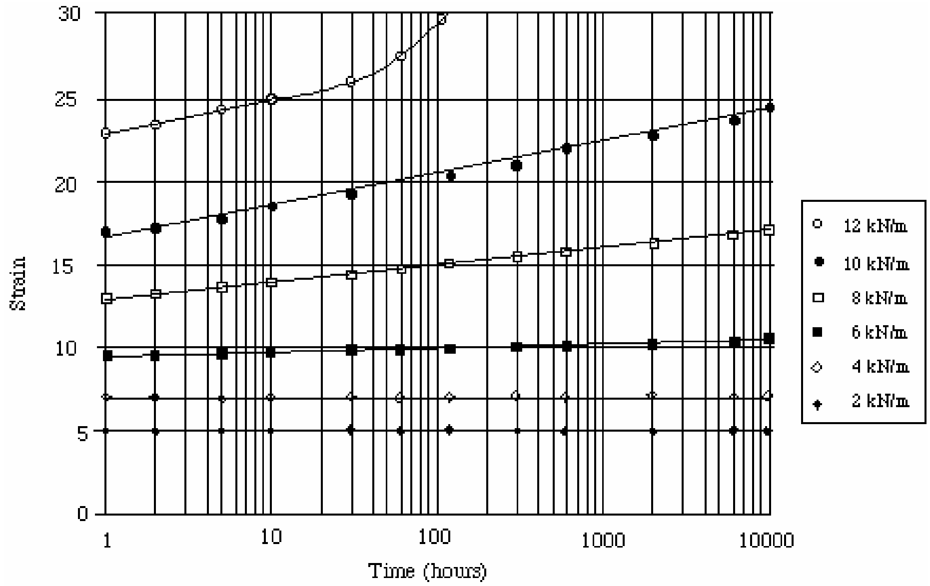
| | | |
|---|---|---|
| $FS_{ID}$ | = | factor-of-safety for installation damage |
| $T_{orig.}$ | = | original strength as per D4595 |
| $T_{exh.}$ | = | exhumed strength as per D4595 |

A minimum number of thirty tests in the principal stress direction of the geotextile (if known) or twenty tests in both the machine and cross machine directions if not known is necessary. The average value of these tests is to be used in the above formulation for the value of factor-of-safety for installation damage. The same type of test must be used for both original and exhumed samples, e.g., if D4595 is being used for the original strength it must also be used to evaluate the exhumed strength.

8.2 Sustained Load Creep, $FS_{CR}$ - The long-term deformation of geotextiles under constant tensile stress can be avoided by using a suitable partial factor-of-safety. Called a creep factor-of-safety, $FS_{CR}$, it is obtained by hanging a dead weight on a suitably supported geotextile test specimen and monitoring its deformation versus time. The recommended test procedure for geotextiles is contained in ASTM D5262 Test Method entitled "Tension Creep Testing of Geotextiles". Typical creep response curves are shown in Figure 1 for 10,000 hour duration tests. These are the minimum test times.

This data can be extrapolated out one order of magnitude, to approximately 10 years, as a standard polymeric rule of thumb (ASCE Manual of Practice No. 66). $FS_{CR}$ for calculating the $T_{allow}$ for design lifes in excess of 10 years may be determined as outlined in 8.2.2 below.

8.2.1 $FS_{CR}$ for 10 Year Design Life - The factor-of-safety for creep is determined from the 10,000 hour curves as being the load at which the creep curve becomes asymptotic to a constant strain line, of 10 percent or less. This value of strength is then compared to the short term strength of the geotextile in D4595 evaluation as follows:



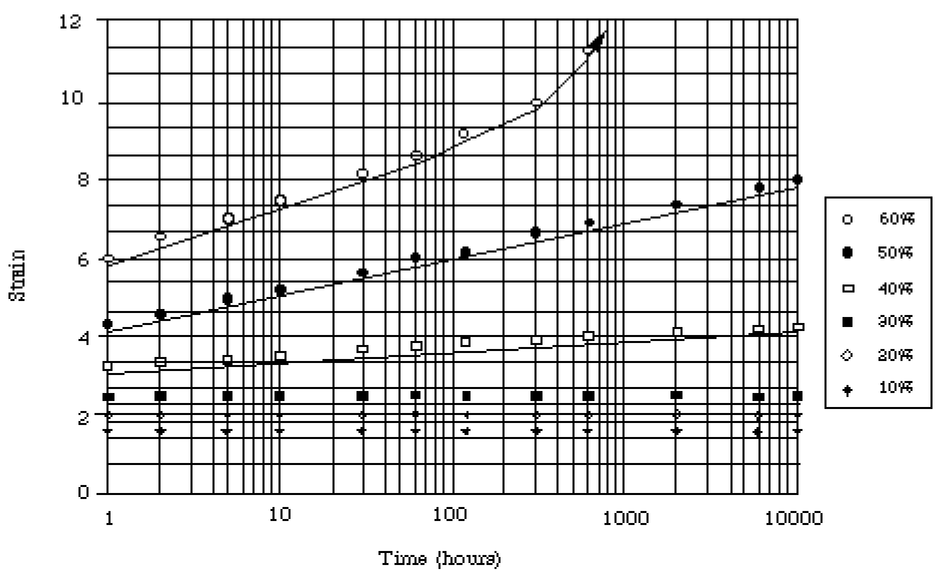




Figure 1 - Typical Creep Curves Taken to 10,000 Hour Duration

$$FS_{CR} = T_{SL} / T_{LT}$$

where

$FS_{CR}$ = factor-of-safety against creep
$T_{LT}$ = 10 year design life strength of the geotextile in sustained D5262 testing at which curve becomes asymptotic to a constant strain line, of 10 percent or less
$T_{ST}$ = short term strength of the geotextile in D4595 testing which is comparable to the long term creep test, i.e., the same type of wide width test

8.2.2 $FS_{CR}$ for Design Times Greater Than 10 Years - Creep performance data of a polymer product at a desired temperature is limited to one order of magnitude in extrapolation with time (as per ASCE). However, creep performance data at an elevated temperature permits an additional order of magnitude in extrapolation with time via time-temperature superposition principles. Creep curves from elevated temperature testing may be overlaid upon the creep curves at the desired temperature by shifting the abscissa time scale. The magnitude of the shift in time for overlay is the magnitude of the extrapolation of creep data beyond 10 years. Thus elevated temperature testing can predict creep performance of a polymer geotextile at the desired temperature level in excess of 10 years.

8.3 Chemical Degradation - The partial factor-of-safety for potential chemical degradation of the geotextile is determined by testing before and after immersion in the specific liquid environment under consideration. Resistivity data is a good indication if a problem may arise. Such resistivity charts should be based on immersion tests. The immersion procedure to be used follows the EPA 9090 Test Method, or equivalent. In this procedure samples are immersed in a closed container made from stainless steel which is filled with the agreed upon liquid and generally with zero head space. Four (4) geotextile samples measuring approximately 30 by 30 cm (12 by 12 in.) are to be used in each of two identical immersion tanks. One tank is kept at a constant temperature of 23°C, the second tank is kept at 50°C . The selection of the incubation liquid should model site specific conditions as closely as possible and be mutually agreed upon by the parties involved in the testing and acceptance. The precise procedure to be followed is set forth in the referenced EPA document.

> NOTE 3: The selection of the liquid to be used for immersion is a critical decision and must be well planned and agreed upon by all parties concerned. If it is an aggressive and/or hazardous liquid, proper laboratory procedures and cautions must be followed. The standard operating procedures used for geomembrane evaluation must be followed.

At time periods of 30, 60, 90, and 120 days one sample from each tank is removed, blotted dry of liquid and cut for test specimens to be used in an agreed upon standard geotextile test method, e.g., narrow strip tensile, burst or puncture. As many replicate test specimens as possible from each sample should be obtained for statistical averaging.

> NOTE 4: This is a geotextile specific decision since the geometric patterns of different geotextiles vary widely. Discussion among the parties involved should agree upon the specimen cutting pattern before incubation of the samples begins.

For applications where the principal stress direction is known, the proper orientation of the geotextile can be determined and the tests can focus in this direction. Where principal stress directions are not known, both machine an cross-machine directions must be evaluated. The results of the average values of the incubated test specimens are to be compared to nonincubated test specimens (in the same type of test) and plotted as per Figure 2.

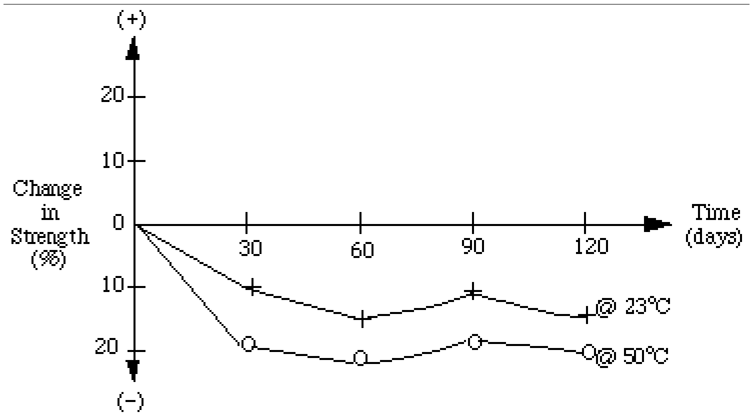



Figure 2. - Example Trend Curves from Chemical Incubation

If the data appears well behaved in that no erratic trends are observed and if the 50°C change is greater or equal to the 23°C change and in the same direction (i.e., increasing or decreasing), the factor-of-safety is obtained as follows.

$$FS_{CD} = \frac{1}{1 - \left| R_{50-120} \right|}$$

where

| | | |
|---|---|---|
| $FS_{CD}$ | = | factor-of-safety for chemical degradation |
| $R_{50\text{-}120}$ | = | strength reduction ratio of the 50°C incubation test at 120 days exposure (absolute value) |

If the data is not well-behaved the entire immersion and subsequent strength tests must be repeated.

8.4 Biological Degradation - The partial factor-of-safety for potential biological degradation of the geotextile is determined by testing before and after incubation in the site-specific environmental medium under consideration. The incubation procedure to be used follows ASTM G22, "Determining Resistance of Synthetic Polymer Materials to Bacteria". In this procedure geotextile samples are incubated in dishes with soil containing the agreed upon cultures determined by the parties involved in the testing and acceptance. Four (4) geotextile samples measuring approximately 30 by 30 cm (12 by 12 in.) are to be used in the incubation. At time periods of 30, 60, 90 and 120 days one sample from each container is removed, cleaned and cut for test specimens to be used in an agreed upon geotextile test method, e.g., narrow strip tensile, burst or puncture. As many replicate test specimens from each sample should be obtained for statistical averaging (see Note 3). For applications where the principal stress direction is known, the proper orientation of the geotextile can be determined and the tests can focus in this direction. Where principal stress directions are not known, both machine and cross-machine directions must be evaluated. The results of the average values of the incubated test specimens are to be compared to nonincubated test specimens (in the same type of test) and plotted as per Figure 3.

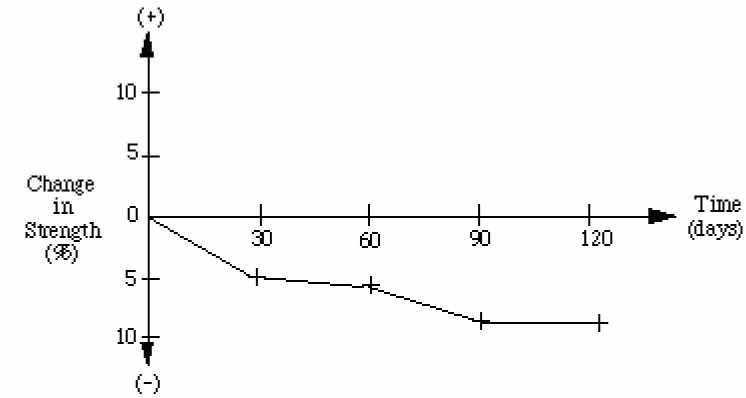



Figure 3. - Example Trend Curve from Biological Incubation

If the data appears well behaved in that no erratic trends are observed the factor-of-safety is obtained as follows:

$$FS_{BD} = \frac{1}{1-|R_{120}|}$$

where

$FS_{BD}$ = factor-of-safety for biological degradation
$R_{120}$ = strength reduction ratio at 120 days incubation (absolute value)

If the data is not well-behaved the incubation and subsequent strength testing must be repeated.

8.5 Joint Strength - Whenever seams are required to join geotextile rolls together or connections are to be made with wall panels or other structural systems, a partial factor-of-safety for joint strength must be included. The test procedure to be followed is a sustained ASTM D4595 Wide Width test. Note that this test is to be conducted for 1,000 hours at a minimum. The comparative tests include one with the joint in the center of the test specimen and the second with no joint included. In both cases, the stress at which a horizontal asymptote is reached is to be used in calculating the value of $FS_{JNT}$. Its formulation is as follows:

$$FS_{JNT} = T_{\substack{as\ received\\ geotextile}} / T_{joined\ geotextile}$$

NOTE 5: This section on joint strength has been written around a mechanically sewn joint. For those cases where the joint strength is mobilized by overlapping two sheets of geotextile, or a geotextile placed within a structural system (e.g., a block wall), a friction test is necessary. ASTM D5321 and GRI Test Method GS6 can be used in this regard, respectively.

**9. Report**

9.1 A complete description of the geotextile product tested including the product name, manufacturer and style; and other relevant characteristics.

9.2 Details as to determination of $FS_{ID}$ and the resulting average value. This must describe the entire process in a step-by-step procedure. If the value obtained is less than the default value given in Table 1, it should be clearly stated as being such.

9.3 Details as to determination of $FS_{CR}$ and the resulting average value. This must describe the entire process in a step-by-step procedure. If the value obtained is less than the default value given in Table 1, it should be clearly stated as being such.

9.4 Details as to determination of $FS_{CD}$ and the resulting average value. This must describe the entire process in a step-by-step procedure. If the geotextile changes in color, texture, appearance or other surface feature it must be described. If the value obtained is less than the default value given in Table 1, it should be clearly stated as being such.

9.5 Details as to determination of $FS_{BD}$ and the resulting average value. This must describe the entire process in a step-by-step procedure. If the geotextile changes in color, texture, appearance or other surface feature it must be described. If the value obtained is less than the default value given in Table 1, it should be clearly stated as being such.

9.6 Details as to determination of $FS_{JNT}$ and the resulting value. This must describe the entire process in a step-by-step procedure. If the value obtained is less than the default vaue given in Table 1, it should be clearly stated as such. If no seams or connections are involved, this item is to be omitted.

9.7 Details as to determination of the ultimate strength of the geotextile ($T_{ult}$) which is to be used in Equation 3.

9.8 Calculation of the allowable design strength of the geotextile ($T_{allow}$), as per Equation 3, for use in long-term design of geotextiles.

**10. Example**

The use of the method of modifying a short term index-type test value of strength into a site specific long term allowable (or performance) value of strength using partial factors-of-safety is illustrated in the following example.

## 11. References


11.1 American Society of Civil Engineers, "Structural Plastics Selection Manual," ASCE Manuals and Reports on Engineering Practice No. 66, prepared by Task Committee on Properties of Selected Plastics Systems of the Structural Plastics Research Council of the Technical Council on Research of ASCE, New York, 1985, pp. 584.

11.2 Environmental Protection Agency (U.S. EPA), "Compatibility Test for Wastes and Membrane Liners," Method 9090, 1985, Washington, DC.


**Example:** What is the allowable tensile strength of a geotextile to be used in the construction of a permanent embankment if the ultimate short-term strength is 4200 kN/m and the partial factors-of-safety have the following values? (Note that this problem does not require a $FS_{JNT}$ since full rolls will be involved and no facing panels are present)

$FS_{ID}$ = 1.25 (< 1.4 default value)
$FS_{CR}$ = 2.5 (< 3.0 default value)
$FS_{CD}$ = 1.2 (< 1.4 default value)
$FS_{BD}$ = 1.0 (< 1.3 default value)

**Solution:** Since the measured values were all less than (or equal to) the default values, the measured values are used in the calculations.

$$\begin{aligned}
T_{allow} &= T_{ult}\left[\frac{1}{FS_{ID}\times FS_{CR}\times FS_{CD}\times FS_{BD}}\right] \\
&= 4200\left[\frac{1}{1.25\times 2.5\times 1.2\times 1.0}\right] \\
&= 4200\left[\frac{1}{3.75}\right] \\
&= 1120\, lb/\,ft
\end{aligned}$$