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GRI Standard Practice GT7*

Standard Practice for

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

This practice was developed by the Geosynthetic Research Institute (GRI) with the cooperation of the member organizations for general use by the public. It is completely optional in this regard and can be superseded by other existing or new practices on the subject matter in whole or in part. Neither GRI, the Geosynthetic Institute, nor any of its related institutes, warrant or indemnifies any materials produced according to this practice either at this time or in the future.

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 reduction factors 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 reduction factors to be considered are for installation damage, creep deformation, long-term degradation (chemical and/or biological) and joints (seams and connections).

1.4 These reduction factors 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
D5322 Immersion Procedures for Evaluating the Chemical Resistance of Geosynthetics to Liquids
D5818 Exposure and Retrieval of Samples to Evaluate Installation Damage to Geotextiles
D6389 Tests to Evaluate the Chemical Resistance of Geotextiles to Liquids
D6992 Accelerated Tensile Creep and Creep Rupture of Geosynthetic Materials Based on Time Temperature Superposition Using the Stepped Isothermal Method
G22 Determining Resistance of Synthetic Polymer Materials to Bacteria

2.2 EPA Standards

Method 9090: Compatibility Tests for Wastes and Membrane Liners (depreciated)

2.3 GSI Standards

W.P. #24 – White Paper entitled "Regarding a Reduction Factor for Holes in Geosynthetic Reinforcement, i.e., RF_{holes}", see www.geosynthetic-institute.org/whitepapers.htm.

3. Terminology

3.1 General - Some 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 Holes - On occasion holes are purposely made in the reinforcement for piles, guard fences, lights, signage, etc. A separate reduction factor should then be considered. See GRI White Paper #24 for guidance in this regard.

3.2.4 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.

3.2.5 Ultimate Strength - The ultimate or maximum 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.

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

3.2.7 Global Factor-of-Safety - A numeric comparison of the 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.

3.2.8 Reduction Factors - A set of numeric values each of which is focused on a particular phenomenon which may negatively impact the material's performance.

Note 1: In year's past the term "partial factors-of-safety" was used, but this term is now depreciated and more appropriately called "reduction factors". It will be used throughout this standard.

3.2.10 Atmosphere for Testing Geosynthetics - 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 reduction factors 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 reduction factors 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 geosynthetic reinforced structures (in comparison to those factors-of-safety used in a conventional design involving soil, concrete or steel), this standard of practice uses reduction factors for those particular phenomena which may diminish the long-term performance of the as-received geotextile material.

5.2 The reduction factors 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 strength which can be used directly in design.

5.3 Procedures are given as to how one obtains each of the above reduction factors 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 reinforcement application.

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

5.6 The standard is not meant to be a test method, but does require numerous test protocols to obtain the necessary values for the different reduction factor.

6. Reduction Factor Concept

6.1 Design Strength (T_{design}) - The required design strength of a geotextile is that numeric value needed for successful functioning of the material under consideration. For geosynthetic applications it is often calculated by a geotechnical engineer using an applicable design model, adapted for the geotextile inclusion. It might also be defined in a formal specification or recommended by an owner. The units of T_{reqd} 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 geotextiles. 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.

Note 2: Alternatively, more accelerated test methods such as time-temperature-superposition and curve shifting as well as the stepped isothermal method (SIM) have been successfully used to obtain creep reduction factors.

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.

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

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_{reqd}	=	required strength (kN/m or lb/ft)

Note 3: The value of T_{reqd} is synonymous with the design strength (T_{design}) which is the computed value. In this regard, $T_{reqd} \geq T_{design}$.

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

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

6.4 Reduction Factors - 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 reduction factors. For example, for geotextiles in reinforcement applications, the following should be used.

$$T_{allow} = T_{ult}\left[\frac{1}{RF_{ID} \times RF_{CR} \times RF_{CD} \times RF_{BD} \times RF_{JNT}}\right] \tag{3}$$

where

RF_{ID}	=	reduction factor for installation damage
RF_{CR}	=	reduction factor for creep deformation
RF_{CD}	=	reduction factor for chemical degradation
RF_{BD}	=	reduction factor for biological degradation
RF_{JNT}	=	reduction factor for joints (seams and connections)

Note 4: Temperature, per se, is not included as a reduction factor. 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 Reduction Factors

In the absence of test information and documentation as to the site specific values for the above listed values of reduction factors in Equation 3, the following default values should be used.

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

Application	RF_{ID}	RF_{CR}	RF_{CD}	RF_{BD}	RF_{JNT}
embankments	1.4	3.0	1.4	1.1	2.0
slopes	1.4	3.0	1.4	1.1	2.0
retaining walls	1.4	3.0	1.4	1.1	2.0
bearing capacity	1.5	3.0	1.6	1.1	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 reduction factors. They follow in the order presented in Equation 3.

8. Procedures for Evaluating Individual Reduction Factors

8.1 Installation Damage, RF_{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; see ASTM D5818 for additional details. The exhuming should be done immediately, i.e., it is a survivability test and not a long-term aging type of test.

Note 5: 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 material.

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 reduction factor is formulated in a traditional matter, i.e.

$$RF_{ID} = T_{orig.} / T_{exh.} \qquad (4)$$

where

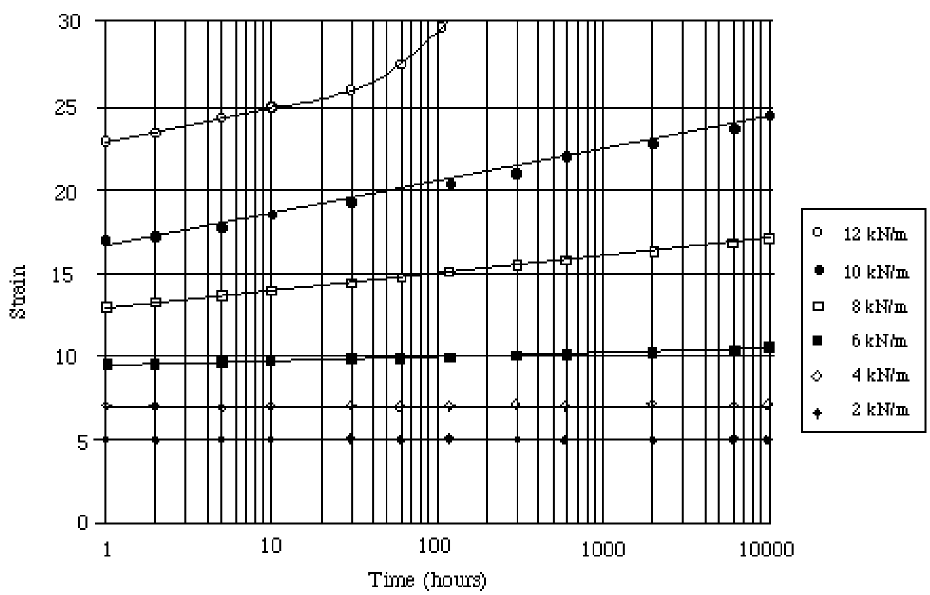
RF_{ID} = reduction factor for installation damage
$T_{orig.}$ = original strength as per D4595
$T_{exh.}$ = exhumed strength as per D4595

A minimum number of thirty tests in the principal stress direction (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 reduction factor for installation damage. The same type of test must be used for both original and exhumed samples.

8.2 Sustained Load Creep, RF_{CR} - The long-term deformation of geotextiles under constant tensile stress can be avoided by using a suitable reduction factor. Called a creep reduction factor, RF_{CR}, it is obtained by hanging a dead weight on a suitably supported test specimen and monitoring its deformation versus time. The recommended test procedure is contained in ASTM D5262 Test Method. 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). RF_{CR} for calculating the T_{allow} for design lifes in excess of 10 years may be determined as outlined in 8.2.2 and 8.2.3 below.

8.2.1 RF_{CR} for 10 Year Design Life - The reduction factor 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 material in D4595 evaluation as follows:



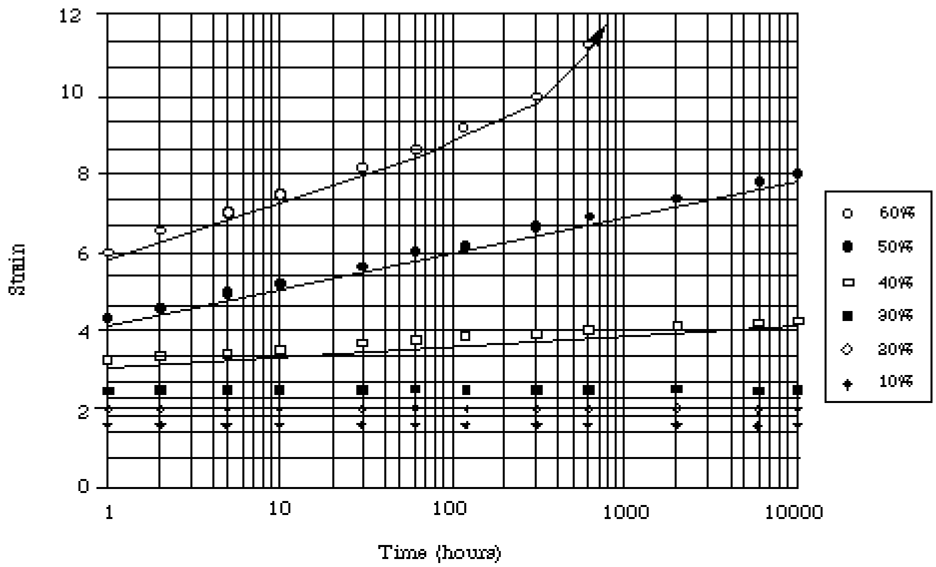


Figure 1 - Typical Creep Curves Taken to 10,000 Hour Duration

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

where

RF_{CR}	=	reduction factor against creep
T_{LT}	=	10 year design life strength of the material 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 material in D4595 testing which is comparable to the long term creep test, i.e., the same type of wide width or rib test

8.2.2 RF_{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 material at the desired temperature level in excess of 10 years.

8.2.3 Temperature Accelerated Methods for RF_{CR} for Design Times Greater Than 10-Years - By using a series of elevated laboratory testing temperatures sustained load (creep) deformations will occur accordingly. Using the concept of time-temperature-superposition (TTS) the resulting curves can be shifted (usually horizontally) on the time axis to obtain very long prediction times. This concept is illustrated by the stepped isothermal method

(SIM) which has the further advantage of using a single test specimen at each temperature increment. The standard to be used in this regard is ASTM D6992.

8.3 Chemical Degradation - The reduction factor 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 ASTM D5322. 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 ASTM document.

Note 6: 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.

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 the standard test method. For geotextiles use ASTM D6389. As many replicate test specimens as possible from each sample should be obtained for statistical averaging.

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.

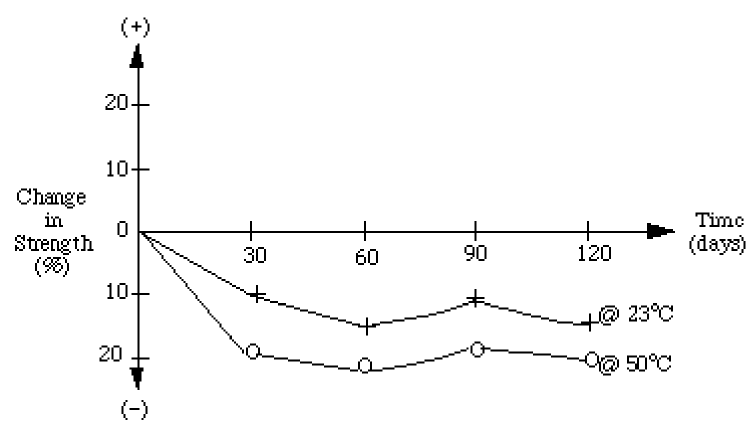


Figure 2. - Example Trend Curves from Chemical Incubation

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 reduction factor is obtained as follows.

$$RF_{CD} = \frac{1}{1-|R_{50-120}|}$$

where

RF_{CD} = reduction factor 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 reduction factor 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 samples are incubated in dishes with soil containing the agreed upon cultures determined by the parties involved in the testing and acceptance. Four (4) 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 test method, e.g., narrow strip or rib tensile strength and elongation. As many replicate test specimens from each sample should be obtained for statistical averaging. For applications where the principal stress direction is known, the proper orientation of the material 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.

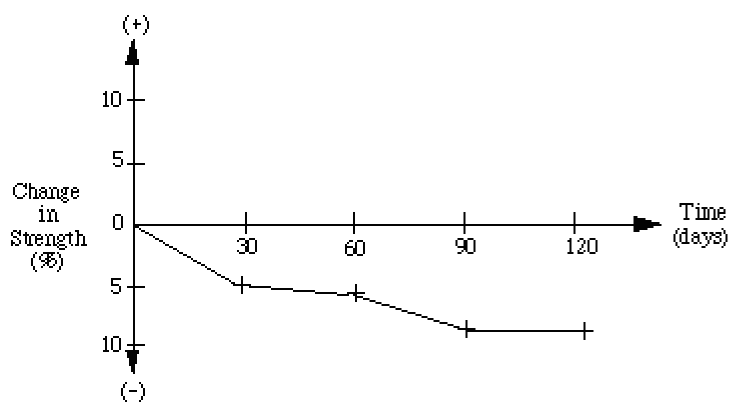


Figure 3. - Example Trend Curve from Biological Incubation

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

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

where

RF_{BD}	=	reduction factor 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.

Note 7: It is generally accepted that neither fungi nor bacteria adversely affect the strength of geosynthetic materials. *As a result it is current practice to not include a reduction factor for biological degradation, i.e.,* $RF_{BD} = 1.0$. If a conservative value were chosen it is recommended to use RF_{BD} = 1.1 as shown in Table 1. This commentary, however, does not apply to burrowing animals which is altogether different and (if present) must be assessed differently. GRI White Paper #24 gives insight in this regard.

8.5 Joint Strength - Whenever seams are required to join geotextiles together or connections are to be made with wall panels or other structural systems, a reduction factor for joint strength must be included. The test procedure to be followed is a sustained tensile 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 RF_{JNT}. Its formulation is as follows:

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

Note 8: This section on joint strength has been written around a mechanically sewn or connected joint. For those cases where the strength is mobilized by overlapping two sheets of material, or a material placed within a structural system (e.g., a block wall), a friction test is necessary. ASTM D5321 can be used in this regard.

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 RF_{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 RF_{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 RF_{CD} and the resulting average value. This must describe the entire process in a step-by-step procedure. If the material 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 RF_{BD} and the resulting average value. This must describe the entire process in a step-by-step procedure. If the material 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. If no biodegradation is involved this item is omitted or used as a value of 1.0 in Eq. 3.

9.6 Details as to determination of RF_{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 value given in Table 1, it should be clearly stated as such. If no seams or connections are involved, this item is to be omitted or used as a value of 1.0.

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 reduction factor 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.

11.3 GSI White Paper #24, "Regarding a Reduction Factor for Holes in Geosynthetic Reinforcement, i.e., RF_{holes}," www.geosynthetic-institute.org/whitepapers.htm.

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 RF_{JNT} since full rolls will be involved and no facing panels are present)

RF_{ID} = 1.25 (< 1.4 default value)
RF_{CR} = 2.5 (< 3.0 default value)
RF_{CD} = 1.2 (< 1.4 default value)
RF_{BD} = 1.0 (< 1.1 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.

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