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GRI Standard Practice GG4(a)*

Standard Practice for

"Determination of the Long-Term Design Strength of Stiff Geogrids"

This specification 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 It is completely optional in this regard and can be superseded by other existing or new specifications on the subject matter in whole or in part.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 specification 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 stiff geogrids for use in the reinforcement of such structures as embankments, slopes, retaining walls, improved bearing capacity, and other permanent geotechnical and transportation engineering systems. By "stiff" the Standard Practice is meant to be applicable to those geogrids exhibiting more than 1000 g-cm flexural rigidity in the ASTM D1388 stiffness test.

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 stiff geogrid 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, chemical degradation, biological degradation, junction strength (depending on the type of short-term laboratory strength test procedure) and joints (seams and connections).

* 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.

1.4 These reduction factor values can be obtained by direct experimentation and measurement, or by using default values which are given for the various applications which use geogrids.

2. Reference Documents

2.1 ASTM Standards

D123 Terminology Relating to Textiles
D1388 Test Methods for Stiffness of Fabrics
D4354 Practice for Sampling Geotextiles
D4439 Terminology for Geotextiles
D4595 Tensile Properties of Geotextiles by the Wide Width Strip Method
D5262 Tension Creep Testing of Geosynthetics
D5322 Practice for Laboratory Immersion Procedures for Evaluating the Chemical Resistance of Geosynthetics to Liquids
D6213 Practice for Tests to Evaluate the Chemical Resistance of Geogrids to Liquids
D6637 Test Method for Determining Tensile Properties of Geogrids by the Single or Multi-Rib Tensile Method
D7737 Test Method for Individual Geogrid Junction Strength
G22 Determining Resistance of Synthetic Polymer Materials to Bacteria

2.2 EPA Standards

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

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 Geogrids - A synthetic planar structure formed by a regular network of tensile strength elements with apertures of sufficiently large size to allow for interlocking with the surrounding soil so as to perform the primary function of reinforcement.

3.2.2 Stiff Geogrids - Those geogrids exhibiting a stiffness, or flexural rigidity, of 1000 g-cm or higher as tested via ASTM D1388. These geogrids are made from punched and drawn continuous polymer sheets or welded straps of polypropylene or polyester.

3.2.3 Apertures - The open spaces formed between the interconnected network of longitudinal and transverse ribs of a geogrid.

3.2.4 Strike-Through - The ability of the soil backfill to be continuous through the apertures of the geogrid allowing for bearing capacity against the transverse ribs.

3.2.5 Longitudinal Ribs - The continuous elements of a geogrid which are in the machine direction as manufactured, or in the major principal stress direction as placed in the field.

3.2.6 Transverse Ribs - The continuous elements of a geogrid which are in the cross machine direction as manufactured, or in the minor principal stress direction as placed in the field.

3.2.7 Junctions (or Nodes) - The interconnections between the longitudinal and transverse ribs of a geogrid which hold the grid structure together providing dimensional stability and load transfer mechanisms.

3.2.8 Joints (or Connections) - The connections made between separate geogrid rolls or between geogrids and wall panels or other parts of the structural system.

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

3.2.10 Ultimate Geogrid Strength - The ultimate or maximum geogrid strength, Tult, as determined by a short-term strength test in accordance with an accepted ASTM test method. Examples of these test methods are ASTM D4595 and D6637.

3.2.11 Allowable Geogrid Strength - The long-term, allowable strength, Tallow, to be used in design taking into account all of the phenomena which could influence the geogrid during its service lifetime.

3.2.12 Factor-of-Safety - A numeric comparison of the geogrid'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.

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

3.2.14 Atmosphere for Testing Geogrids - 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 geogrid 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 factor-of-safety for the site-specific situation under consideration.

4.2 The focus of the standard is toward stiff geogrids with a flexural rigidity of 1000 g-cm, or higher.

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 geogrid 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 geogrid material.

5.2 The reduction factors to be discussed are those of installation damage, creep deformation, chemical degradation, biological degradation, junction strength (unless accounted for in prior testing) and joints (seams and connections). The result of compensating for these phenomena is an allowable geogrid 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, junction strength 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 geogrid reinforcement application.

5.5 The standard practice is site specific, application specific, and geogrid product specific, the latter being for stiff geogrids of flexural rigidity of 1000 g-cm or higher.

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 reduction factors.

6. Reduction Factor Concept

6.1 Design Strength (T_{design}) - The required design strength of a geogrid is that numeric value needed for successful functioning of the geogrid under consideration. For geogrid applications it is often calculated by a geotechnical engineer using an applicable design model, adapted for the geogrid's 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 geogrid 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 longitudinal ribs (or transverse ribs) resulting in a value in units of kN/m or lb/ft. The standard 200 mm (8.0 in.) width is adjusted mathematically to a unit meter or unit foot width. The test is generally conducted in such a way that only the ribs (not the junctions) are involved.

6.2.2 ASTM D6637 - This test is a single longitudinal rib (or transverse rib) test measuring the rib strength in the units of kN (or lb). This value is adjusted mathematically using the repeat pattern of the geogrid to a unit value of kN/m or lb/ft. The junctions are not involved in resisting the applied stress.

6.2.3 ASTM D7737 - This test is a junction strength test for the connections between longitudinal and transverse ribs in the units of kN (or lb). This value is adjusted mathematically using the repeat pattern of the geogrid junctions to a unit value of kN/m or lb/ft. The rib strength is only involved in mobilizing the stress on the junctions. When the value from this test is compared to the test results of D6637 (on the ribs), a junction strength efficiency can be calculated.

6.2.4 ASTM D5262 (mod.) - This test is a through-the-junction sustained load, or creep test for geosynthetics. It is of the wide width variety in that multiple ribs are evaluated simultaneously. The test is conducted for a minimum time of 10,000 hours.

6.3 Allowable Strength (T_{allow}) - The allowable long-term strength of a stiff geogrid 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 precise laboratory testing, simulating all possible long-term phenomena, has been used in its procedure, i.e.,

$$T_{allow} \leq T_{ult} \qquad (1)$$

After proper evaluation or calculation, Tallow is then used in the following equation to determine the final design factor-of-safety.

$$FS = T_{allow}/T_{reqd} \qquad (2)$$

where

FS = 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 factor-of-safety directly into the geogrid 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 geogrids in reinforcement applications, the following should be used.

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

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_{JCT} = reduction factor for junction strength
RF_{JNT} = reduction factor for joints (seams and connections)

NOTE 1: 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 Stiff Geogrids for Various Reduction Factors
(Terms are Defined in Equation 3)

Application	RF_{ID}	RF_{CR}	RF_{CD}	RF_{BD}	RF_{JCT}*	RF_{JNT}
embankments	1.4	3.5	1.4	1.1	3.0	2.0
slopes	1.4	3.5	1.4	1.1	3.0	2.0
retaining walls	1.4	3.5	1.4	1.1	3.0	2.0
bearing capacity	1.5	3.5	1.6	1.1	3.0	2.0

*To be used if junction strength tests are not utilized in determining the other reduction factor values. If junction strength tests are utilized this value is 1.0 for all applications.

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 Factor Values

8.1 Installation Damage, RF_{ID} - Installation damage of a specific type of geogrid is determined by installing a field test strip on the actual site's subgrade, or on a closely simulated version thereof. The geogrid 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 geogrid test strip is to be 9 sq. m (100 sq. ft.). If possible, the full roll width should be used. Upon completion of the backfilling the geogrid 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 geogrids 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 geogrid.

The exhumed geogrid is now tested for its residual strength in either ASTM D4595 Wide Width Strength, ASTM D6637 Rib Tensile Strength, or D7737 Geogrid Junction Strength, and compared to test values of the comparable geogrid material which was not installed. The non-installed geogrid should be taken from the same roll as was the installed and exhumed geogrid. If D4595 or D6637 test methods are used, a RF_{JCT} will have to be included in Equation 3 (to be described in Section 8.5).

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

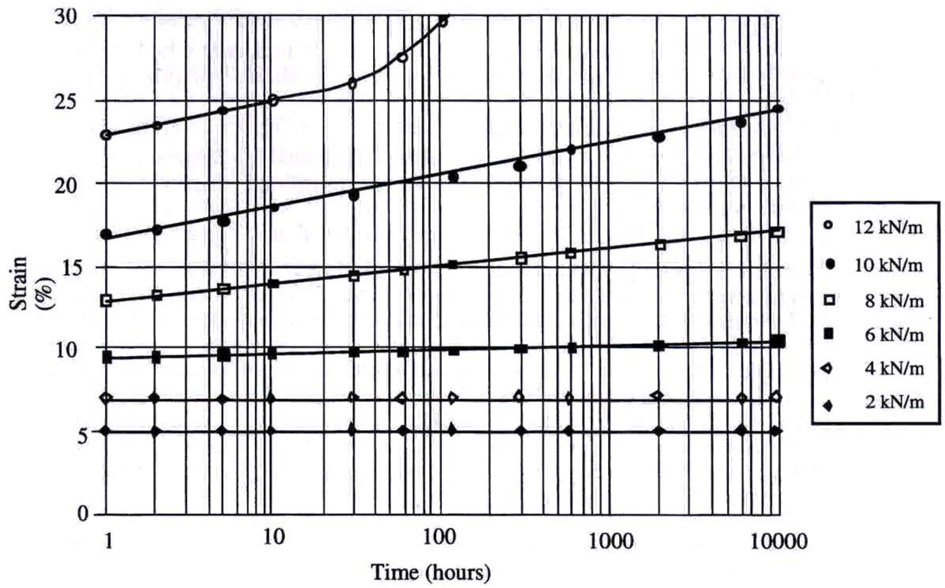
$$RF_{ID} = T_{orig.}/T_{exh.} \qquad (4)$$

where

RF_{ID} = reduction factor for installation damage
$T_{orig.}$= original strength as per D4595, D6637 or D7737
$T_{exh.}$= exhumed strength as per D4595, D6637 or D7737

A minimum number of thirty tests in the machine direction for unidirectional geogrids, and twenty tests in both the machine and cross machine directions for bidirectional geogrids, 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, 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, RF_{CR} - The long-term deformation of geogrids 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 geogrid test specimen and monitoring its deformation versus time. The recommended test procedure for geogrids is contained in ASTM D5262 entitled, "Tension Creep Testing of Geosynthetics". It should be noted that this test method should be through-the-junction creep testing. If a creep test is performed on the ribs only such as D4595 or D6637 there is a need to perform a RF_{JCT} test for inclusion in Equation 3 (to be discussed in Section 8.5). Typical creep response curves are shown in Figure 1 for 10,000 hour duration tests. These are the minimum test times.



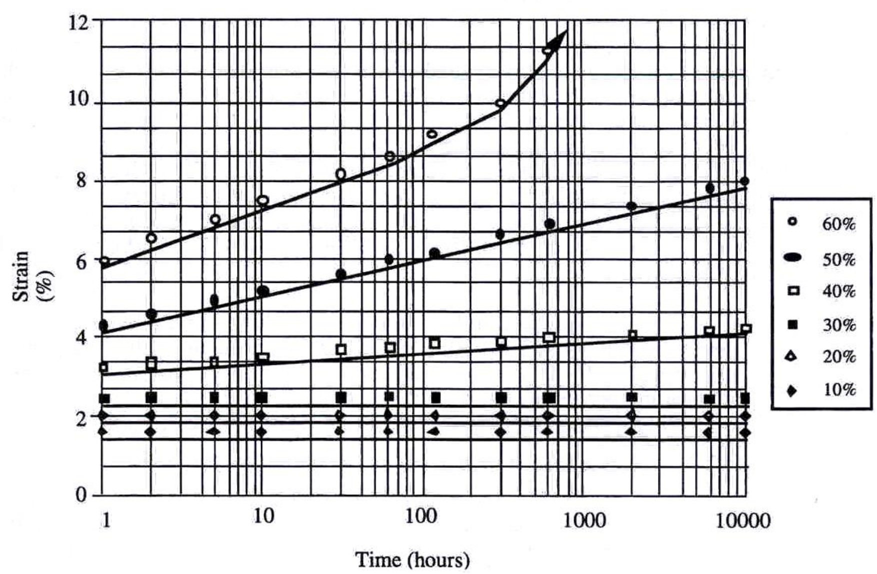


Figure 1. - Typical Geogrid Curves Taken to 10, 000 Hour Duration

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 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 geogrid in D4595, D6637 or D7737 evaluation as follows:

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

where

RF_{CR} = reduction factor against creep

T_{LT} = 10 year design life strength of the geogrid in sustained D4595 or sustained D6637, or ASTM D5262 testing at which curve becomes asymptotic to a constant strain line, of 10 percent or less

T_{ST} = short term strength of the geogrid in D4595, D6637 or D7737 testing whichever is comparable to the long term creep test, i.e., wide width, single rib or through-the-junction 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 geogrid at the desired temperature level in excess of 10 years.

8.3 Chemical Degradation - The reduction factor for potential chemical degradation of the geogrid 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) geogrid 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 23deg. C, the second tank is kept at 50 deg. 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 GRI Test Methods D6637 or D7737. As many replicate test specimens as possible from each sample should be obtained for statistical averaging.

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

For uniaxial geogrids the longitudinal ribs are to be tested, for biaxial geogrids both the longitudinal and the transverse ribs are to be tested. If D6637 test method is used, which assesses the rib strength only, a RF_{JCT} will have to be included in Equation 3 (to be discussed in Section 8.5). 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.

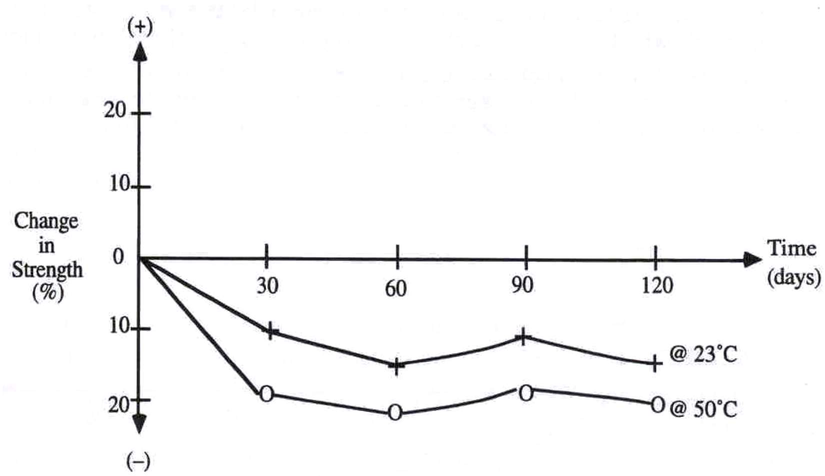


Figure 2. - Example Trend Curves from Chemical Incubation

If the data appears well behaved in that no erratic trends are observed and if the 50 deg. C change is greater or equal to the 23 deg. 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_{50-120} = strength reduction ratio of the 50 deg. 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 geogrid 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 geogrid samples are incubated in dishes with soil containing the agreed upon cultures determined by the parties involved in the testing and acceptance. Four (4) geogrid 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 GRI Test Methods D6637 or D7737. As many replicate test specimens from each sample should be obtained for statistical averaging (see Note 3). For uniaxial geogrids the longitudinal ribs are to be tested, for biaxial geogrids both the longitudinal and transverse ribs are to be tested. If D6637 test method is used, which assesses rib strength only, a RF_{JCT} will have to be included in Equation 3 (to be discussed in Section 8.5). 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.

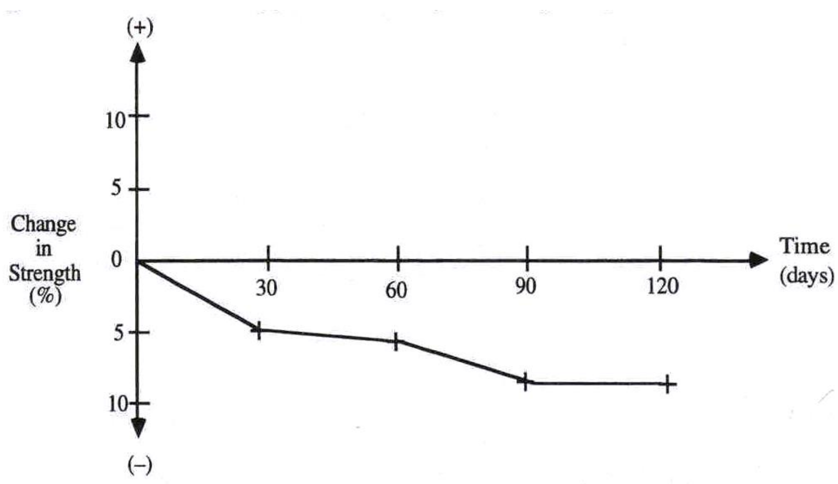


Figure 3. - Example Trend Curve from Biological Incubation

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} = 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.

NOTE 5: Previous versions of this standard practice had a separate reduction factor for "biological degradation". Presently it is the institute's opinion that degradation from bacteria and fungi is so unlikely as to not warrant this remote form of degradation to geosynthetic polymer products. This is clearly not the case for natural biologic products, e.g., jute, coir, etc.

8.5 Junction Strength - In each of the prior determinations of reduction factors a choice between rib testing (multiple ribs as per D4595, or single ribs as per D6637) or through the junction testing (as per D7737 or D5262 (mod.)) was possible. In the event that the latter was selected (i.e., through-the-junction testing) for RF_{ID}, RF_{CR}, RF_{CD}, and RF_{BD} then the additional term RF_{JCT} in Equation 3 is 1.0 and does not need to be evaluated. In the event that the former was selected (i.e., rib testing) for RF_{ID}, RF_{CR}, RF_{CD}, and RF_{BD} then the additional term RF_{JCT} in Equation 3 must be evaluated and included. The procedure to do this follows.

For an individual rib test and a single junction test the procedures outlined in GRI Test Methods D6637 and D7737 are to be used. At least 30 of each tests for unidirectional geogrids and 20 each in both longitudinal and transverse directions for bidirectional geogrids are necessary to determine statistical averages. The reduction factor is determined using the average values as follows:

$$RF_{JCT} = T_{RIB}/T_{JCT}$$

where

RF_{JCT} = reduction factor for junction strength
T_{RIB} = average rib strength as per GRI Test Method D6637
T_{JCT} = average junction strength as per GRI Test Method D7737

As an option to the above single rib/single junction procedure one could test multiple ribs (as per ASTM D4595) and compare the results to multiple junctions (as per ASTM D5262 (mod.)). The latter test however is for long-term creep and must be modified for rapid testing in a constant rate of extension (CRE) tensile testing machine. The strain rate must be identical to that prescribed in D4595. Calculation of TJCT is the same as above since the same number of ribs and junctions must be involved in each of the respective tests.

8.6 Joint Strength - Whenever seams are required to join geogrid panels 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 ASTM D5262 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. Note that this is **not** a through-the-junction type of test. 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:

$$RF_{JNT} = T_{\substack{\text{as-received}\\ \text{geogrid}}} / T_{\text{joined geogrid}}$$

Note 6: This section on joint strength has been written around a mechanical joint such as a bodkin, pin or clamp. For those cases where the joint strength is mobilized by overlapping two sheets of geogrid, or a geogrid 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 geogrid product tested including the product name, manufacturer and style; longitudinal rib dimensions, repeat pattern and other relevant characteristics; transverse rib dimensions, repeat pattern and other relevant characteristics; junction (node) construction, fabrication and other relevant characteristics; mass per unit area of the product and stiffness as per ASTM D1388.

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 geogrid 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 geogrid 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 RF_{JCT}, if applicable, 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. If all prior testing was through-the-junction type and this reduction factor is one it should be stated as such.

9.7 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 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.

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

9.9 Calculation of the allowable design strength of the geogrid (T_{allow}), as per Equation 3, for use in long-term design of geogrids.

10. Examples

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 factors is illustrated in the following examples.

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 #1: What is the allowable tensile strength of a stiff geogrid to be used in the construction of a permanent wall if the ultimate short-term strength is 4400 kN/m and the reduction factors were specifically evaluated in through-the-junction tests (D7737 and GG3) and resulted in the following values?

RF_{ID} = 1.25 (< 1.4 default value)
RF_{CR} = 3.0 (< 3.5 default value)
RF_{CD} = 1.2 (< 1.4 default value)
RF_{BD} = 1.0 (< 1.3 default value)
RF_{JCT} = 1.0 (since through-the-junction tests were used)

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

$$T_{allow} = T_{ult}\left[\frac{1}{RF_{ID} \times RF_{CR} \times RF_{CD} \times RF_{BD}}\right]$$
$$= 4400\left[\frac{1}{1.25 \times 3.0 \times 1.2 \times 1.0}\right]$$
$$= 4400\left[\frac{1}{4.5}\right]$$
$$= 980\ lb/\ ft$$

Example #2: Repeat the first example except now the reduction factors were evaluated in rib strength tests as per D4595 or D6637 and resulted in the following values.

RF_{ID} = 1.1 (< 1.4 default value)
RF_{CR} = 2.5 (< 3.5 default value)
RF_{CD} = 1.2 (< 1.4 default value)
RF_{BD} = 1.0 (< 1.3 default value)
RF_{JCT} = 2.0 (< 3.0 default value)

Solution: Since the measured values were all less than the default values, the measured values are used in the calculations.

$$T_{allow} = T_{ult}\left[\frac{1}{RF_{ID} \times RF_{CR} \times RF_{CD} \times RF_{BD} \times RF_{JCT}}\right]$$
$$= 4400\left[\frac{1}{1.1 \times 2.5 \times 1.2 \times 1.0 \times 2.0}\right]$$
$$= 4400\left[\frac{1}{6.6}\right]$$
$$= 670\ lb/\ ft$$