TECHNICAL NOTE

DETERMINATION OF THE LONG-TERM PROPERTIES FOR MIRAGRID® XT GEOGRIDS

Prepared by:

TenCate Geosynthetics North America
365 South Holland Drive
Pendergrass, GA 30567
Tel 706 693 2226
Fax 706 693 4400
www.tencate.com

May 18, 2010

Miragrid® geogrids are the leading polyester geogrids used for soil reinforcement applications. Starting in the late 1980s, extensive research and testing have been performed on Miragrid® geogrids to determine the long term, in-situ properties.

This technical note describes each of the relevant properties in detail and the appropriate testing conducted on Miragrid® geogrids.

Product Description

Miragrid® geogrids are high strength, high tenacity polyester geogrids in a full range of tensile strengths. Miragrid® geogrids are woven and then coated with a PVC coating to provide dimensional stability.

Miragrid® geogrids are used in a wide variety of soil reinforcement applications including internally reinforced soil walls, segmental retaining wall reinforcement, steep reinforced slopes, and reinforcement in a variety of landfill applications including potential voids bridging and veneer stability. Applications where long term design strength is necessary for the stability of the structure are ideal applications where Miragrid® geogrids can be used.

Figure 1
Miragrid 5XT in SRW

Standard roll dimensions for Miragrid® geogrids are **Product**	**Standard Roll Dimensions Width x Length m (ft)**	**Roll Area m^2 (yd^2)**
2XT	1.8 (6.0) x 45.7 (150)	82.3 (100)
3XT	1.8 (6.0) x 45.7 (150) 3.6 (12) x 45.7 (150)	82.3 (100) 164.5 (200)
5XT	1.8 (6.0) x 45.7 (150) 3.6 (12) x 45.7 (150)	82.3 (100) 164.5 (200)
7XT	1.8 (6.0) x 45.7 (150) 3.6 (12) x 61 (200)	82.3 (100) 220 (267)
8XT	1.8 (6.0) x 45.7 (150) 3.6 (12) x 61 (200)	82.3 (100) 220 (267)
10XT	3.6 (12) x 61 (200)	220 (267)
20XT	3.6 (12) x 61 (200)	220 (267)
22XT	3.6 (12) x 61 (200)	220 (267)
24XT	3.6 (12) x 61 (200)	220 (267)

Polymer type and grade

Miragrid® geogrids are produced from high molecular weight, low CEG, high tenacity polyester (PET) yarns with the following physical properties:

Minimum Average Molecular Weight	*25,000*
Carboxyl End Groups	*<30*

Ultimate Strength, T_{ULT} (Minimum Average Roll Value)

Determination of Ultimate Strength, T_{ULT} , is conducted per ASTM D 6637. The frequency of testing exceeds the requirements in ASTM D 4354, "Practice for Sampling of Geosynthetics for Testing". The machine direction ultimate tensile strength values for Miragrid® geogrids are as follows:

Product	MARV for T_{ULT} kN/m (lbs/ft)	Product	MARV for T_{ULT} kN/m (lbs/ft)
2XT	29.2 (2000)	10XT	138.6 (9500)
3XT	51.1 (3500)	20XT	200 (13705)
5XT	68.6 (4700)	22XT	300 (20559)
7XT	86.1 (5900)	24XT	400 (27415)
8XT	108.0 (7400)		

Quality Control System

Miragrid® quality control testing is conducted in accordance with documented and controlled American Society for Testing and Materials (ASTM) or Geosynthetic Research Institute (GRI) test methods at TenCate Geosynthetics's A2LA and GRI-LAP approved laboratory. In the case of product properties where a method of inspection is not well established, methods are selected that have been published in international or national standards by reputable technical organizations or in relevant scientific texts or journals. The use of these selected methods are verified and approved by the Quality Assurance Manager.

The testing of Miragrid® geogrids is carried out under controlled conditions including the following:

- Overall management of process control is governed by documented procedures.
- Documented test methods and work instructions govern the comprehensive inspection and testing of each lot.
- Testing equipment is selected based upon needs and the ability to satisfy specified requirements with the equipment being suitably maintained.
- Training of personnel is adequate and documented.
- Appropriate Quality Records are maintained.

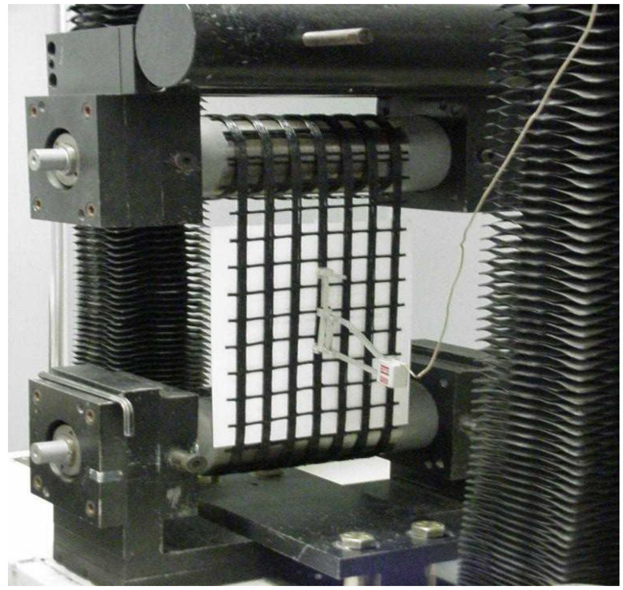


Figure 2: Wide Width Tensile Test of Miragrid

Each sample to be tested is accompanied with a label for the particular manufacturing roll number. Test results are recorded on Quality Control Test Reports by number and then entered into a computer database by roll number.

Once the sample has been delivered to the Quality Control lab, the sample is tested. The standard operating procedure for each test is documented with copies of the appropriate test procedure on file in the Quality Control laboratory.

The preparation for each sample is conducted in accordance with Standard Operating Procedures and ASTM requirements.

Creep Reduction Factor, RF_{CR}

All polymers used in the manufacture of geosynthetics are subject to sustained load deformation or creep [4]. Creep behavior is a function of stress level, time, temperature (environment), and molecular structure [4]. The reduction factor for creep, RF_{CR}, is used to limit the magnitude of creep at specified strain levels over a specific time period.

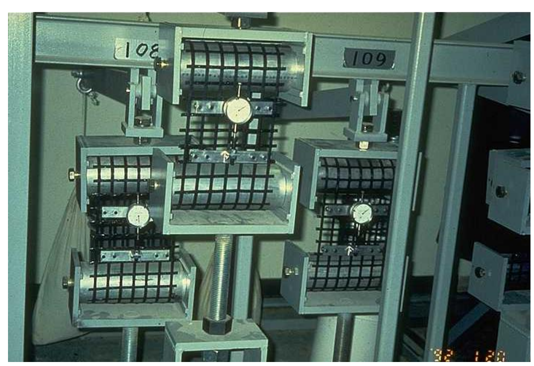


Figure 3
Conventional Creep Testing of Miragrid® Geogrids

There are three methods for measuring geosynthetic creep: Conventional Creep Testing, Time-temperature Superposition (TTS), and Stepped Isothermal Method (SIM) [6].

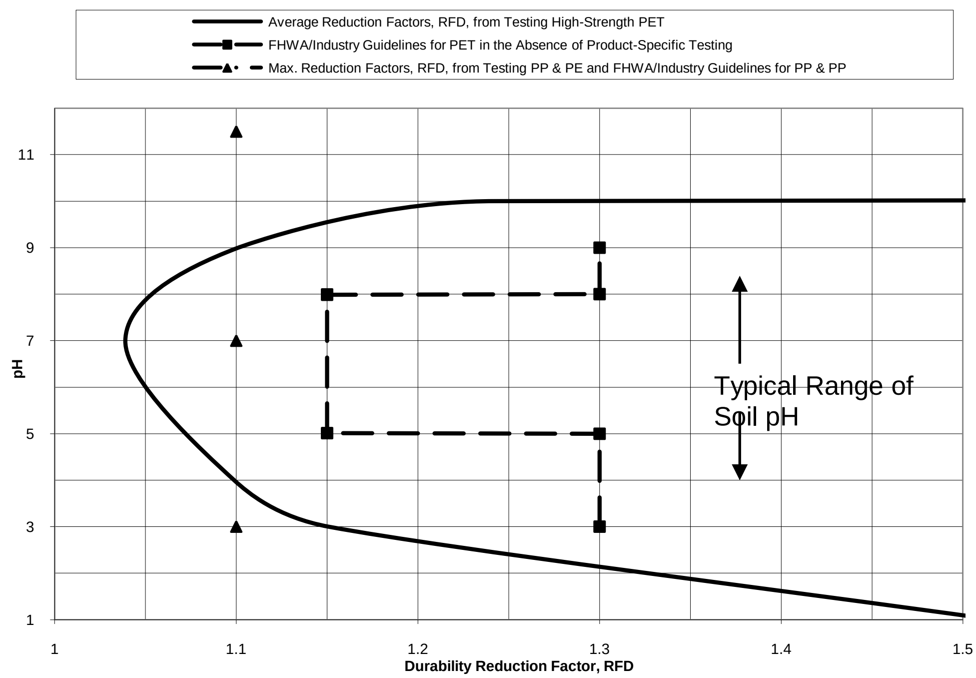
The validation of the creep factors currently used for Miragrid® geogrids is based on conventional and Stepped Isothermal creep rupture data generated in compliance with Washington DOT T925 test procedure and NHI (National Highway Institute) guidelines. This test data demonstrate that loads of at least 63.17% (**RF_{CR} = 1.58**) of the ultimate tensile strength (per ASTM D 6637) is reasonable for use with Miragrid® geogrids [5].

Durability Reduction Factor, RF_D

Geosynthetics, like all other construction materials, slowly degrade over time. The rate of degradation depends on the molecular make-up of the geosynthetic polymer and the nature of the environment to which the geosynthetic is exposed. Since most geosynthetics are buried in non-aggressive soil environments, geosynthetic degradation normally occurs at a very slow, almost unmeasureable, rate. Still, it is possible for significant rates of degradation to take place if unstable polymers are used or extreme conditions are encountered as described in subsequent sections.

The partial reduction factor for durability, RF_D, is derived from testing. Figure 4 compiles the reduction factors associated with durability testing reported [7]. These reduction factors are compared with the more conservative FHWA/Industry guidelines [8][10]. TenCate Geosynthetics geosynthetics were included in several of the referenced tests.

Figure 4. Durability Reduction Factors, RF_D, for High Strength Geosynthetics @ 75 Years



“Default” partial reduction factors for durability, RF_D , are recommended where polymer stability can be demonstrated and where the anticipated soil environment is non-aggressive. FHWA has given some conservative guidance on the selection of the RF_D in the absence of product-specific testing [6][8]. Yet, specific product testing and field experience has demonstrated that the RF_D value shown in the table below are commonly applicable to polyester geotextiles and coated geogrids as long as minimum molecular weight and maximum number Carboxyl End Groups are maintained.

Recommended RF_D for Miragrid Geogrids in Typical Soils

Geosynthetic Type	Minimum PET Yarn Criteria	RF_D
Woven Polyester (PET) Geotextiles Woven/Coated Polyester (PET) Geogrids	M_n>25,000; CEG<30	1.1

The FHWA Demonstration Project 82 “Mechanically Stabilized Earth Walls and Reinforced Soil Slope Design and Construction Guidelines,” recommends electrochemical properties for backfills when using geosynthetic reinforcement of $3 < pH < 9$. Based on research outlined in “The Effect of pH, Resin Properties, and Manufacturing Process on Laboratory Degradation of Polyester Geosynthetics” by V. Elias, A. Salman, and D. Goulias [9], a **RF_D = 1.10** is reasonable for all Miragrid® geogrids in the recommended pH range. Soils exhibiting pH ranges beyond the 3 to 9 limits may be used in the construction of MSE structures. However, adjustments to the reduction factor may be required.
The geogrid product evaluated in this study is a PVC coated polyester grid manufactured from Type 811 yarn from Kosa (Hoechst Trevira). This yarn and coating process are the same as on all Miragrid® geogrids.

Installation Damage Reduction Factor, RF_{ID}

Placement of the geosynthetic in the field can result in installation damage to the material. This is typically reflected by a reduction of the tensile strength properties of the geosynthetic. Installation damage is determined by subjecting the geosynthetic to a backfill and compaction cycle, exhuming the material, and determining the strength retained [1].

Extensive research has been conducted on Miragrid® geogrids with the effects of construction damage. The most comprehensive study was conducted by TRI/Environmental. The test procedure was based on the Washington State

Department of Transportation Qualified Products List (WSDOT QPL) requirements (Test Method 925).

Installation damage testing was conducted on the following products:

Miragrid® 3XT, 5XT, 8XT – October 2002

Miragrid® 10XT – September 2004, May 2005
Miragrid® 20XT – December 2003
Miragrid® 2XT, 7XT – May 2005
Miragrid® 24XT – May 2005

Each report contains summary tables that list the retained product strength and the calculated reduction factor per soil type [5]. The testing program was as follows:

- A lightweight geogrid (Miragrid 3XT) was tested in three soil types with d_{50} values of 0.3mm, 4.5 mm, and to 22mm.
- The heaviest geogrid (Miragrid 24XT) was tested in two soil types with a d_{50} of 4.5mm and 42 mm.
- Medium weight geogrids (Miragrid 5XT, Miragrid 8XT, and Miragrid 10XT) were tested in tested in three soil types with d_{50} values of 0.3mm, 4.5 mm, and to 22mm.
- An additional medium weight geogrid (Miragrid 7XT) was tested in two soil types with d_{50} values of 0.3mm and 4.5 mm.

The strength reduction factors to account for installation damage to the reinforcement, **RF_{ID}**, for the Miragrid® geogrids are shown below.

Soil Type	**2XT**	**3XT**	**5XT**	**7XT**	**8XT**
Type 3 (Sand, Silt, Clay)	1.05	1.05	1.05	1.05	1.05
Type 2 (Sandy Gravel)	1.10	1.10	1.10	1.10	1.10
Type 1 (Gravel)	1.25	1.25	1.25	1.25	1.25

Soil Type	**10XT**	**20XT**	**22XT**	**24XT**
Type 3 (Sand, Silt, Clay)	1.05	1.05	1.05	1.05
Type 2 (Sandy Gravel)	1.10	1.10	1.10	1.10
Type 1 (Gravel)	1.25	1.25	1.25	1.25

Interaction Coefficients for Pullout and Sliding

Reinforcement applications using geosynthetics require an estimate of two interaction coefficients [1]. The Coefficient of Shear Stress Interaction (C_i) is required to calculate the reinforcement pullout capacity of the geosynthetic [1]. The Coefficient of Direct Sliding (C_{ds}) is required to calculate the resistance to internal sliding generated along the surface of the geosynthetic [1].

The Coefficient of Shear Stress Interaction, C_i, and Coefficient of Direct Sliding, C_{ds}, for Miragrid® geogrids were determined from independent testing [5] [11] and are as follows:

Soil Type	U.S.C.S.	C_i	C_{ds}
Silty clay, sandy clay, clayey silt	(ML, CL)	0.7 – 0.8	0.7
Silty sands, fine to medium sands	(SM, SP, SW)	0.8 – 0.9	0.8
Dense well-graded sand, sand and gravel	(SW, GP, GW)	0.9 – 1.0	0.9

Extensive research has been conducted on the interaction properties of Miragrid® geogrids. A research paper entitled "Soil Interaction Characteristics of Geotextiles and Geogrids" by Koutsourais, Sandri, and Swan [11] and actual testing by Geosynthec Consultants [14] on Miragrid® geogrids in a concrete sand provide detailed evidence verifying the values listed above.

UV Resistance

Sunlight is an important cause of degradation to all organic materials, including polymers from which geosynthetics are produced [4]. Of the three types of energy produced from the sun, ultraviolet (UV) is the most harmful to geosynthetics. For laboratory simulation of sunlight, artificial light sources (lamps) are generally compared to worst-case conditions [4]. The recommended ASTM test for geosynthetics is D 4355 which exposes samples to simulated UV conditions [4].The minimum UV Resistance of Miragrid® geogrids is 70% strength retained after 500 hours of exposure

UV Resistance data per ASTM D 4355 is provided on two of the lightest strength products (Miragrid® 3XT and BasXgrid® 11). This data shows that a strength reduction of 70% after 500 hours is reasonable for the Miragrid® family of products [5].

DETERMINATION OF Long Term Design Strength (LTDS)

Miragrid® geogrids are used in a variety of long-term reinforcement applications. The determinations of the correct tensile strength and soil interaction properties are critical in the design phase of a project.

There are currently three accepted methods for determining the long-term reinforcement strength of a geosynthetic material. These methods are:

- GRI-GG4 (b), "Determination of the Long-Term Design Strengths of Flexible Geogrids"
- NCMA "Design Manual for Segmental Retaining Walls", 2nd Edition
- AASHTO Standard Specifications for Highway Bridges, 1997 Interim

The three methodologies above differ in the nomenclature used to determine the allowable strength of the reinforcement. The nomenclature for this long term allowable strength is as follows:

GRI-GG4 uses "T_{allow}"
NCMA uses "LTDS"
AASHTO uses "T_{al}"

For this technical note, the Long-Term Design Strength calculation follows the NCMA[1] methodology. In general, however, the reduction factor concept is applicable to all three methods and the long-term reinforcement strength. However, individual reduction factors may vary depending on the requirements of other methods. The design engineer should review and verify the required LTDS calculation method and appropriate reduction factors before design of the reinforced soil structure.

The Long-Term Design Strength (LTDS) of a geosynthetic is the strength at limit equilibrium conditions in the soil [1]. The LTDS is developed by reducing the Ultimate Tensile Strength by Reduction Factors for potential material degradation.

The Long Term Design Strength is determined as follows:

$$LTDS = T_{ULT} / (RF_{ID} \times RF_{CR} \times RF_{D})$$

where,

T_{ULT} is the minimum average roll value (MARV) wide width Ultimate Tensile Strength determined by ASTM D 6637;
RF_{ID} is the Reduction Factor for Installation Damage;
RF_{CR} is the Reduction Factor for Material Creep;
RF_{D} is the Reduction Factor for Durability;

Other reduction factors may be considered depending on the methodology or project requirements.

The following pages contain the calculations for all products in the Miragrid® product family.

Global Factor of Safety

An additional Factor of Safety is often added to reduce the LTDS of the geosynthetic. This "global" or overall factor of safety is to account for uncertainties in the geometry of the structure, fill properties, reinforcement properties, and externally applied loads [1]. This factor of safety is typically between 1.5 to 2.0 and is independent of the geosynthetic reinforcement used in the design.

Additional information can be obtained from TenCate™ Construction Products at (800) 685-9990.

References

1. "Design Manual for Segmental Retaining Walls", NCMA, 2nd Edition (1997).
2. GRI-GG4 (b) – Standard Practice "Determination of the Long-Term Design Strength of Flexible Geogrids", (1991)
3. "1997 Interim Revisions to the Standard Specifications for Highway Bridges", AASHTO, 16the Edition (1996).
4. Koerner, Robert M., Designing with Geosynthetics, 4th edition (1998).
5. "Miragrid® XT Geogrid Submittal Document", Mirafi® Construction Products (2005).
6. Sandri, D., Thornton, J., and Sack, R. (1999) "Measuring Geosynthetic Creep: Three Method," Geotechnical Fabrics Report, August, pp. 26-29.
7. "Technical Note: Durability of High Strength Geosynthetics", TenCate (1999).
8. "Degradation Reduction Factors for Geosynthetics", FHWA Geotechnology Technical Note (1997).
9. Elias, V., Salman, V. and Goulias, D. "The Effect of pH, Resin Properties, and Manufacturing Process on Laboratory Degradation of Polyester Geosynthetics", Geosynthetics International, Volume 5, No.5. p. 459-490.
10. IFAI (1997) "Industry Response to FHWA Technical Note", Geotechnical Fabrics Report, August, pp. 27.
11. Koutsourais, M., Sandri, D., and Swan, R. "Soil Interaction Characteristics of Geotextiles and Geogrids", *Conference Proceedings from the Sixth International Conference of Geosynthetics*, Volume 2, p.739-744

LONG-TERM DESIGN STRENGTHS FOR MIRAGRID® XT

(per NCMA "***Design Manual for Segmental Retaining Walls***", 2nd Edition)
(per GRI Standard Practice GG4(b))

Products	2XT		3XT		5XT		7XT		8XT	
	US lbs/ft	**SI kN/m**	**US lbs/ft**	**SI kN/m**	**US lbs/ft**	**SI kN/m**	**US lbs/ft**	**SI kN/m**	**US lbs/ft**	**SI kN/m**
Ultimate Tensile Strength, T_{ult}[1]	**2000**	**29.2**	**3500**	**51.1**	**4700**	**68.6**	**5900**	**86.1**	**7400**	**108.0**
Creep Reduction Factor, RF_{CR} 114-year design life	1.58		1.58		1.58		1.58		1.58	
Creep Limited Strength 114-year design life	1266	18.5	2215	32.3	2975	43.4	3734	54.5	4684	68.3
Installation Damage Reduction Factor, RF_{ID}										
Type 3 Backfill (Sand, Silt, Clay)	1.05		1.05		1.05		1.05		1.05	
Type 2 Backfill (Sandy Gravel)	1.10		1.10		1.10		1.10		1.10	
Type 1 Backfill (Gravel)	1.50		1.25		1.25		1.25		1.25	
Durability Reduction Factor, RF_D	1.10		1.10		1.10		1.10		1.10	
LTDS (114-year design life)										
Type 3 Backfill (Sand, Silt, Clay)	1096	16.0	1918	28.0	2575	37.6	3233	47.2	4055	59.2
Type 2 Backfill (Sandy Gravel)	1046	15.3	1831	26.7	2458	35.9	3086	45.0	3871	56.5
Type 1 Backfill (Gravel)	767	11.2	1611	23.5	2163	31.6	2716	39.6	3406	49.7

[1] Ultimate Tensile Strength (MARV) in Machine Direction as measured per ASTM D 6637 guidelines

LONG-TERM DESIGN STRENGTHS FOR MIRAGRID® XT

(per NCMA "***Design Manual for Segmental Retaining Walls***", 2nd Edition)
(per GRI Standard Practice GG4(b))

Products	10XT		20XT		22XT		24XT	
	US lbs/ft	SI kN/m	US lbs/ft	SI kN/m	US lbs/ft	SI kN/m	US lbs/ft	SI kN/m
Ultimate Tensile Strength, T_{ult}[1]	**9500**	**138.6**	**13705**	**200.0**	**20559**	**300.0**	**27415**	**400.0**
Creep Reduction Factor, RF_{CR} 114-year design life	1.58		1.58		1.58		1.58	
Creep Limited Strength 114-year design life	6013	87.7	8674	126.6	13012	189.9	17351	253.2
Installation Damage Reduction Factor, RF_{ID}								
Type 3 Backfill (Sand, Silt, Clay)	1.05		1.05		1.05		1.05	
Type 2 Backfill (Sandy Gravel)	1.10		1.10		1.10		1.10	
Type 1 Backfill (Gravel)	1.25		1.25		1.25		1.25	
Durability Reduction Factor, RF_D	1.10		1.10		1.10		1.10	
LTDS (114-year design life)								
Type 3 Backfill (Sand, Silt, Clay)	5206	76.0	7510	109.6	11266	164.4	15023	219.2
Type 2 Backfill (Sandy Gravel)	4969	72.5	7169	104.6	10754	156.9	14340	209.2
Type 1 Backfill (Gravel)	4373	63.8	6308	92.1	9463	138.1	12619	184.1

[1] Ultimate Tensile Strength (MARV) in Machine Direction as measured per ASTM D 6637 guidelines