2015 NTPEP Report Series

NTPEP Report 2015-01-002

LABORATORY EVALUATION OF GEOSYNTHETIC REINFORCEMENT

FINAL PRODUCT VERIFICATION REPORT FOR MIRAGRID XT GEOGRID PRODUCT LINE

Report Issued: February 2016
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Next Product Qualification Report: 2018

American Association of State Highway and Transportation Officials (AASHTO)

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2015 NTPEP Report Series

National Transportation Product Evaluation Program (NTPEP)

NTPEP Report 2015-01-002

LABORATORY EVALUATION OF GEOSYNTHETIC REINFORCEMENT

2015 PRODUCT SUBMISSIONS
SAMPLED AUGUST 2015

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PROLOGUE

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- This report contains product data that are intended to be applied to a product line, based on the test results obtained for specific products that are used to represent the product line for the purposes of NTPEP testing. It is expected that the User will estimate the properties of specific products in the line not specifically tested through interpolation or a lower or upper bound approach.
- It is intended that this data be used by the User to add products to their Qualified Products or Approved Products List, and/or to develop geosynthetic reinforcement strength design parameters in accordance with AASHTO, FHWA, or other widely accepted design specifications/guidelines. It is also intended that the User will conduct further, but limited, evaluation and testing of the products identified in this report for product acceptance purposes to verify product quality.
- Products included in this report must be resubmitted to NTPEP every three (3) years for a verification evaluation and every six (6) years for a full qualification evaluation in accordance with the work plan. Hence, all product test results included in this Report supersede data provided in previous Editions of this report.
- The User is guided to read the document entitled "Use and Application of NTPEP Geosynthetic Reinforcement Test Results" (see NTPEP website) for instructions and background on how to apply the results of the data contained in this report.

***Tony Allen* (Washington State DOT)**
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Executive Summary

This test report provides a mid-term verification of the data and evaluation provided in the January 2012 Product Qualification Report for the TenCate Miragrid XT Product Line. The purpose of this report is to provide data for verification of the test results included in the Product Qualification Report for this product line.

The test results contained herein were obtained in accordance with AASHTO R69-15 and the NTPEP work plan (see www.NTPEP.org). All testing reported herein was performed on the materials tested in the direction of manufacture, i.e., the machine direction.

Product Line Description: The product line evaluated includes the following specific polyester, PVC coated geogrid reinforcement products:

Miragrid 2XT, 3XT, 5XT, 7XT, 8XT, 10XT, 20XT, 22XT, and 24XT.

This product line was represented through testing of Miragrid 2XT, 8XT and 24XT. Samples of these three products were taken by an independent sampler on behalf of NTPEP. Qualification samples were taken on June 8, 2011 at the Miragrid manufacturing plant located in Pendergrass, GA. Verification samples of 2XT, 8XT and 24XT were taken on August 13, 2015 at the Miragrid manufacturing plant located in Pendergrass, GA.

Verification Testing: Regarding installation damage, the NTPEP verification testing verified that the qualification installation damage data continues to be valid. See Section 4.3 and Tables 4-2 and 4-3 regarding the validation of the use of the NTPEP qualification installation damage data.

Regarding creep rupture, the NTPEP verification testing verified that the NTPEP qualification data continues to be valid. See Section 5.3.1 and Appendix E, Figure E-5 regarding the validation of the use of the NTPEP qualification creep data.

Regarding durability testing, NTPEP verification testing verified that the products continue to meet the durability requirements outlined in R69-15 as well as the AASHTO LRFD Bridge Design Specifications. See Section 6.2 and Table 6-2 regarding the durability requirements.

Regarding creep stiffness, the NTPEP verification testing verified that the NTPEP qualification data continues to be valid. See Section 7.3 and Figure 7-1 regarding the validation of the use of the NTPEP qualification creep data.

Test Results for T_{ult}: All wide width test results (ASTM D6637) obtained for this product line through the NTPEP testing were greater than the minimum average roll values (MARV's) provided by the manufacturer (see Table 3-1).

Test Results for RF_{ID}, RF_{CR}, RF_{D}, and Creep Stiffness: See the Product Qualification Report for this product line, dated January 2012.

1.0 Product Line Description and Testing Strategy

1.1 Product Description

The **Miragrid XT Series** family of geogrids are high-strength woven, PVC coated geogrids. The product line evaluated consists of the products as manufactured by TenCate Geosynthetics listed in Table 1-1.

Table 1-1. Product designations included in product line.

Miragrid Reinforcement Product Designations (i.e., Styles)		
Miragrid® 2XT	Miragrid® 7XT	Miragrid® 20XT
Miragrid® 3XT	Miragrid® 8XT	Miragrid® 22XT
Miragrid® 5XT	Miragrid® 10XT	Miragrid® 24XT

The scope of the evaluation is limited to the strength in the machine direction (MD). The cross-machine direction (XD) was not specifically evaluated.

1.2 Product Line Testing Approach

This product line was represented through testing of Miragrid 2XT, 8XT and 24XT. 8XT was used as the primary product for product line characterization purposes (i.e., the baseline to which the other products were compared). Samples of these three products were taken by an independent sampler on behalf of NTPEP. Qualification samples were taken on June 8, 2011 at the Miragrid manufacturing plant located in Pendergrass, GA. Verification samples of 2XT, 8XT and 24XT were taken oin August 13, 2015 at the Miragrid manufacturing plant located in Pendergrass, GA.

Photographs of all the products tested are provided in figures 1-1 through 1-9.

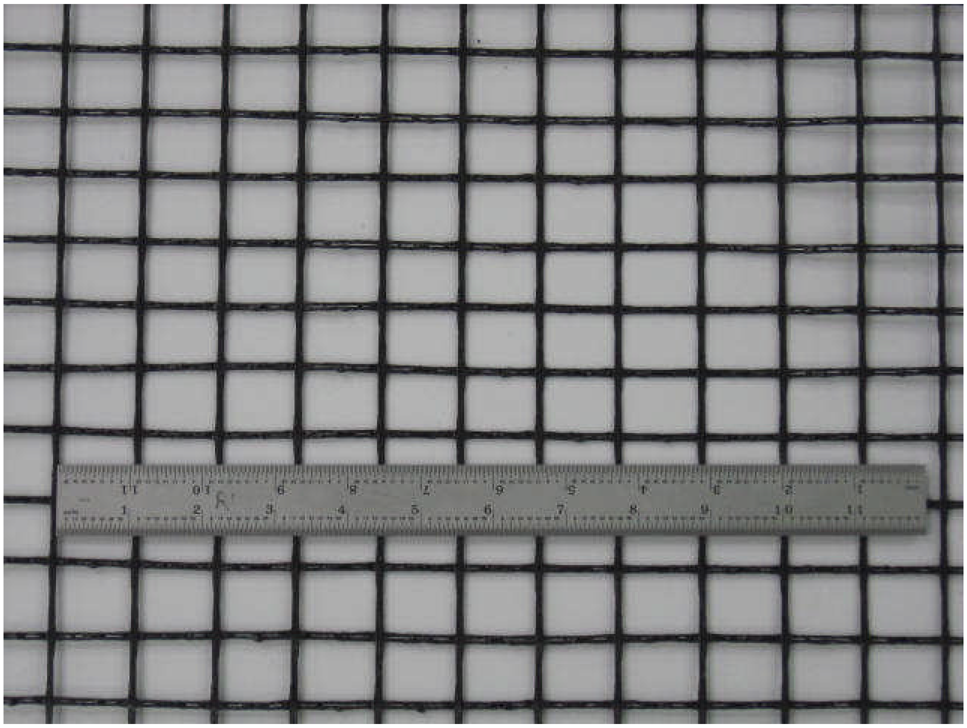
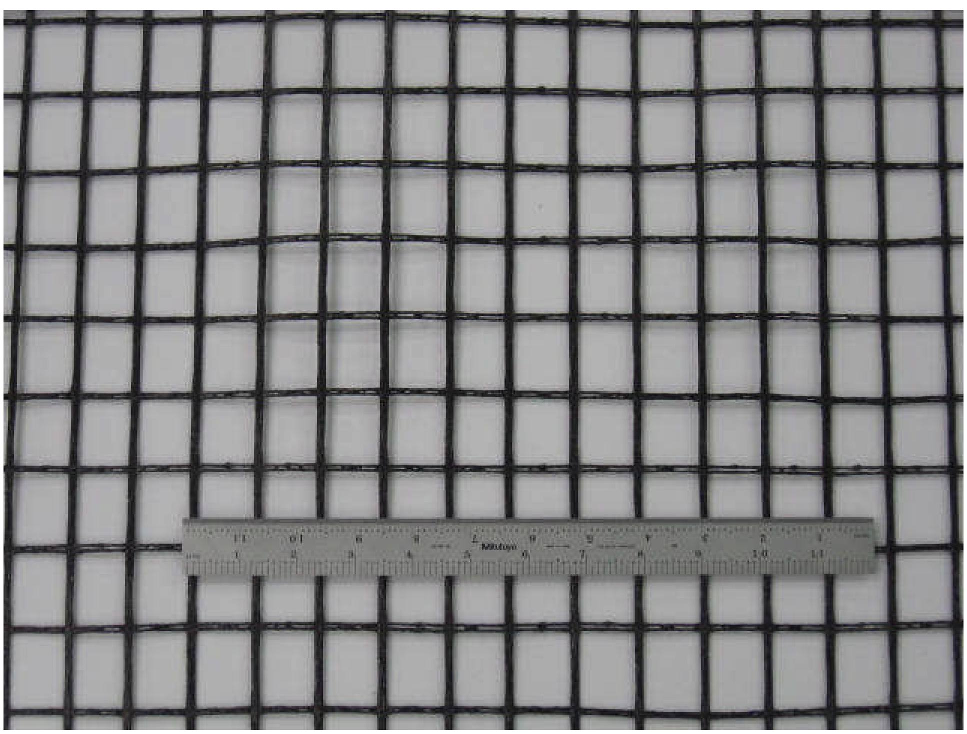


Figure 1-1. Photo of Miragrid 2XT (machine direction is perpendicular to ruler shown).



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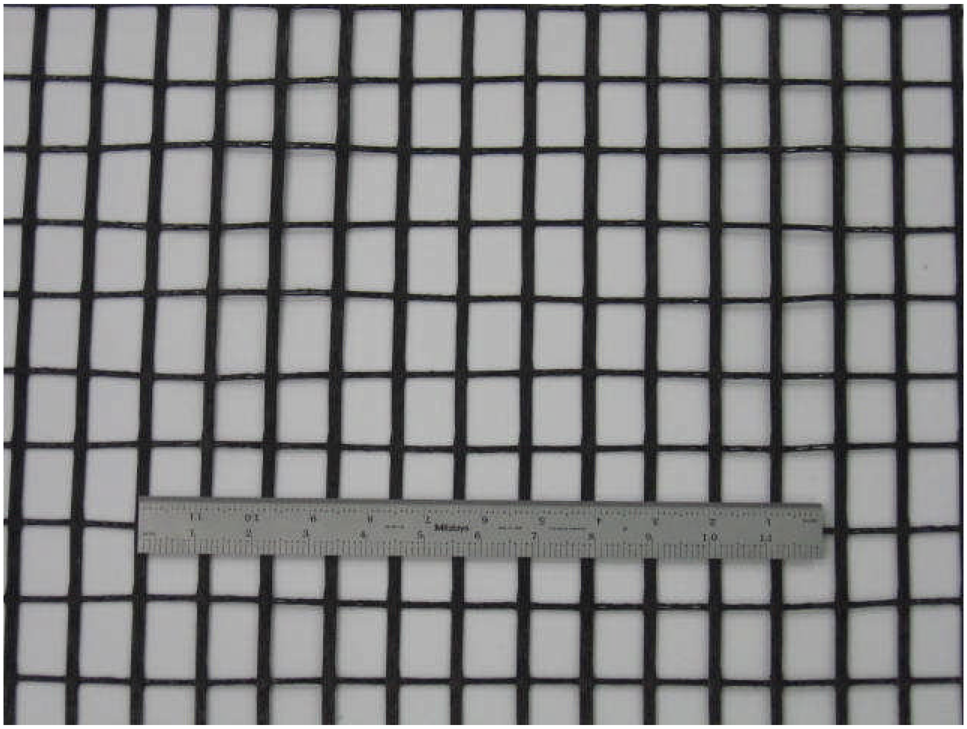

Figure 1-3. Photo of Miragrid 5XT (machine direction is perpendicular to ruler shown).

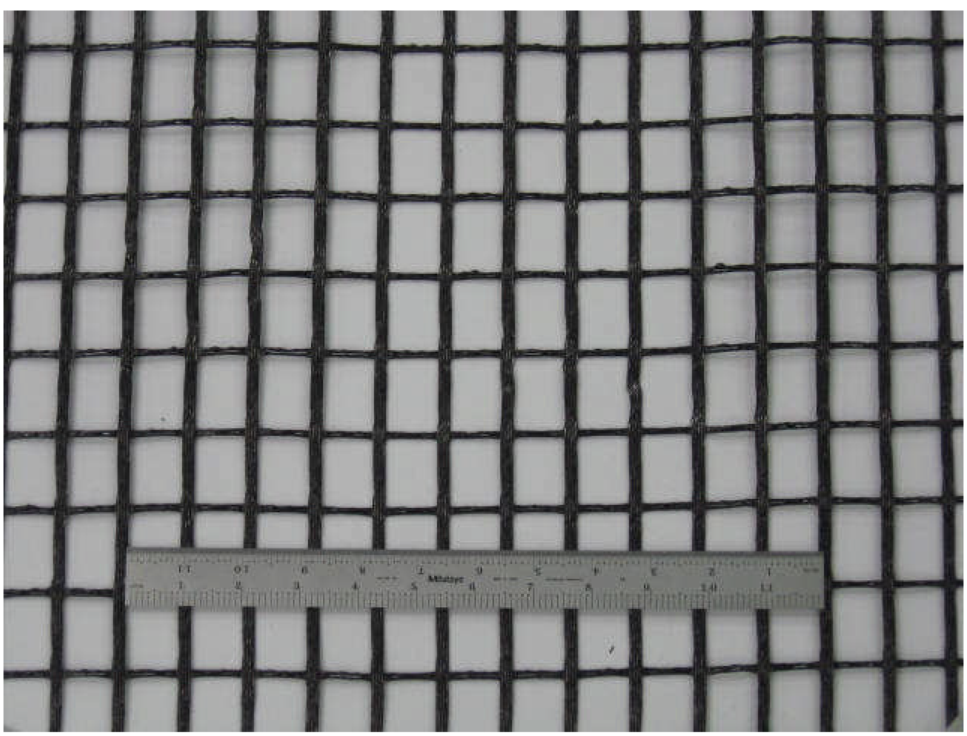

Figure 1-4. Photo of Miragrid 7XT (machine direction is perpendicular to ruler shown).

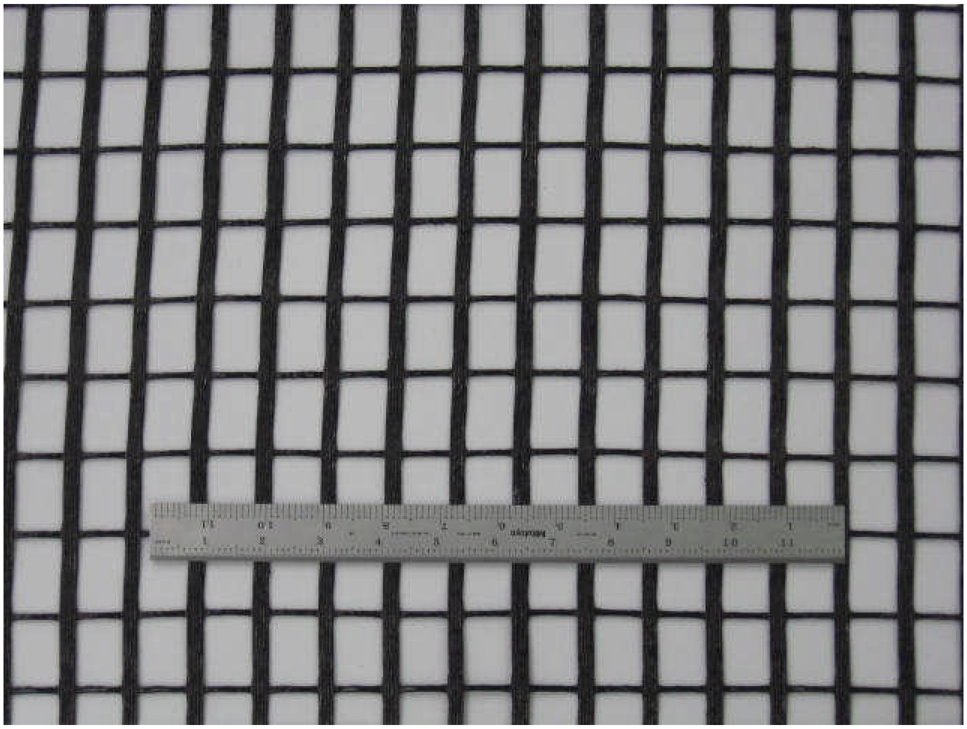

Figure 1-5. Photo of Miragrid 8XT (machine direction is perpendicular to ruler shown).

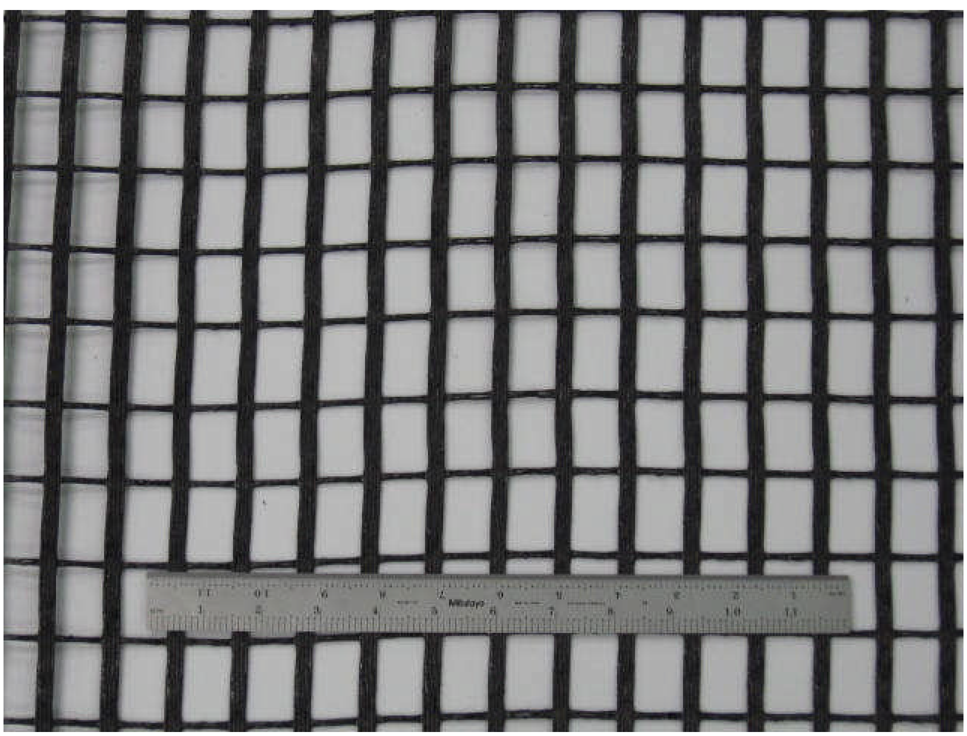

Figure 1-6. Photo of Miragrid 10XT (machine direction is perpendicular to ruler shown).

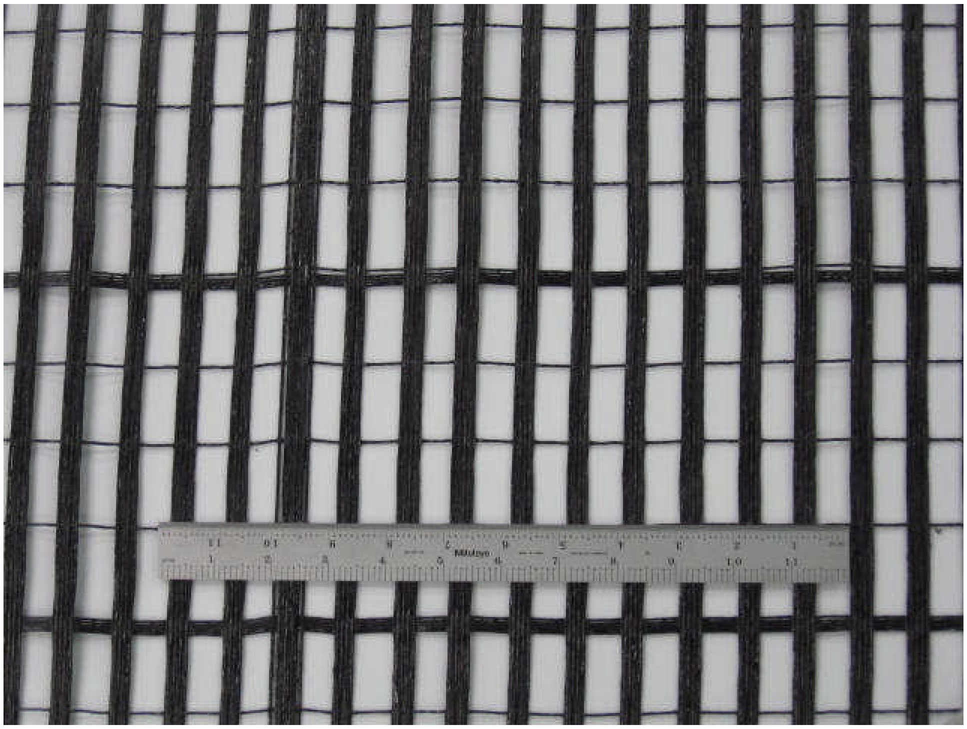

Figure 1-7. Photo of Miragrid 20XT (machine direction is perpendicular to ruler shown).

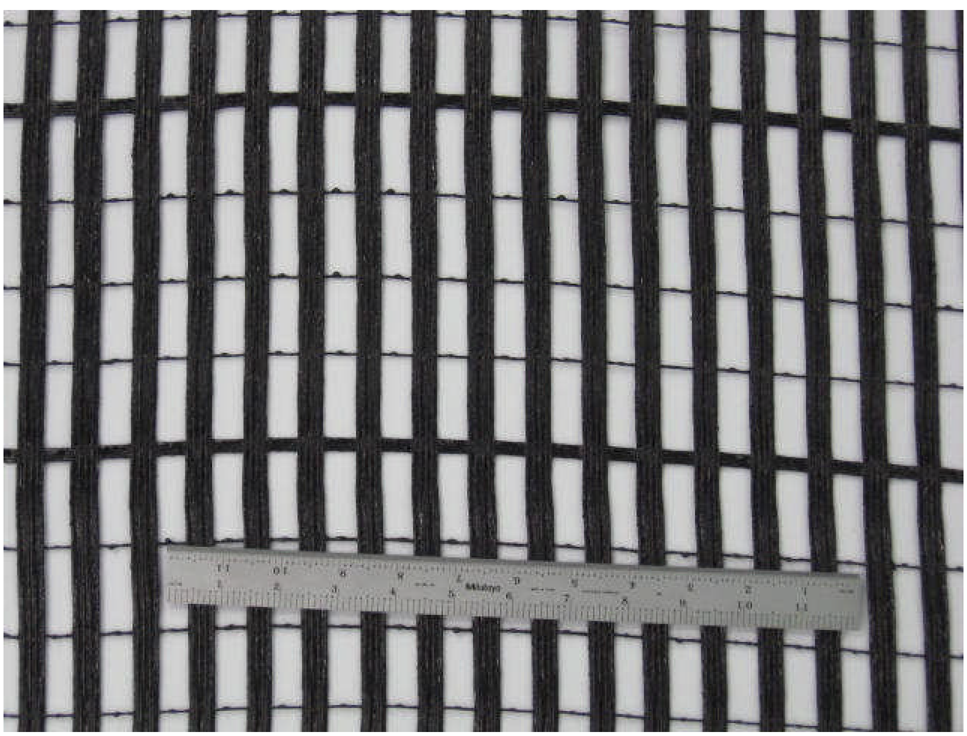

Figure 1-8. Photo of Miragrid 22XT (machine direction is perpendicular to ruler shown).

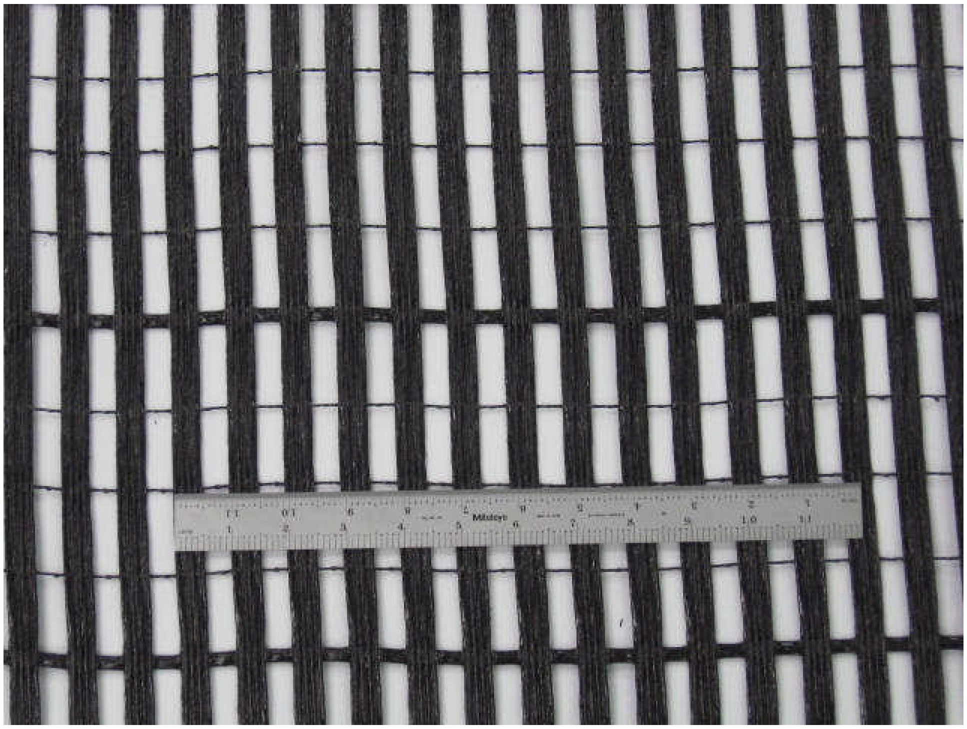

Figure 1-9. Photo of Miragrid 24XT (machine direction is perpendicular to ruler shown).

2.0 Product Polymer, Geometry, and Manufacturing Information

2.1 Product/Polymer Descriptors

Yarn used in all **Miragrid XT Series** geogrids is a high molecular weight, low CEG, high tenacity polyester (PET) with UV inhibitors. Source of Yarn is confidential. Coating used in all **Miragrid XT Series** geogrids is a PVC-based coating with no post-consumer recycled materials. The coating target weight per unit area is between 50-57% of the total weight of the finished product. Source of Coating is confidential.

For the PET yarns, key descriptors include minimum production number average molecular weight (GRI-GG7 and ASTM D 4603) and maximum carboxyl end group content (GRI-GG8):

- Minimum Molecular Weight > 25,000 (independent test values are 34,855 from the product qualification testing and 30,570 from the verification testing)
- Maximum CEG < 30 (independent test values are 15.2 from the product qualification testing and 22.1 from the verification testing)
- % of regrind used in product: 0%.
- % of post-consumer recycled material by weight: 0%

2.2 Geometric Properties of Geogrids

Rib width, spacing, thickness, and product weight/unit area vary depending on geogrid style. While such data are generally not used for design, it can be useful for identification purposes, and to be able to detect any changes in the product. Measurements of geogrid rib spacing are also used to convert tensile test results (i.e., load at peak strength, T_{ult}, and load at a specified strain to obtain stiffness, J) to a load per unit width value (i.e., lbs/ft or kN/m). Detailed measurement results for both product qualification testing and verification testing, as well as the typical values supplied by the manufacturer for each product, are provided in Appendix B, Section B.1.

3.0 Wide Width Tensile Strength Data

Minimum average roll values supplied by the manufacturer and test results obtained on the three products used to represent the product line in this NTPEP testing program are provided in Table 3-1. Wide width tensile tests were conducted in accordance with ASTM D6637. The measured geogrid dimensions discussed in Section 2 and provided in Appendix B, Section B.1, were used to convert test loads to load per unit width values. Note that the independently measured T_{ult} values only indicate that the sampled products have a tensile strength that exceeds the Manufacturer's minimum average roll values (MARV's). As such, these independently measured T_{ult} values should not be used directly for design purposes. However, these independently measured T_{ult} test results have been used as roll specific tensile strengths for comparison to installation damage and creep testing and interpretation. Detailed test results are provided in Appendix C.

Table 3-1. Wide width tensile strength, T_{ult}, for the Miragrid Geogrid XT product line.

Product Style/Type	Test Method	MARV for T_{ult}, in MD (lb/ft)	T_{ult}, Independently Measured in MD (lb/ft)	T_{ult}, Independently Measured in MD (lb/ft)
2XT	ASTM D 6637	2,000	2,691*	2,756**
3XT	ASTM D 6637	3,500		
5XT	ASTM D 6637	4,700		
7XT	ASTM D 6637	5,900		
8XT	ASTM D 6637	7,400	8,463*	8,248**
10XT	ASTM D 6637	9,500		
20XT	ASTM D 6637	13,705		
22XT	ASTM D 6637	20,559		
24XT	ASTM D 6637	27,415	29,809*	28,615**

(Conversion: 1 lb/ft = 0.0146 kN/m)

MD = machine direction

*Average of 5 readings obtained during NTPEP qualification testing.

**Average of 5 readings obtained during NTPEP verification testing.

4.0 Installation Damage Data (RF_{ID})

4.1 Installation Damage Test Program

Installation damage testing and interpretation was conducted in accordance with AASHTO R69-15, except as noted herein. Qualification samples were exposed to three “standard” soils: a coarse gravel, a sandy gravel, and a sand. The verification sample was exposed to laboratory installation damage testing in accordance with ISO/EN 10722. The specific installation damage test program is summarized in Table 4-1.

Table 4-1. Independent installation damage testing required for NTPEP qualification and verification.

Manufacturer: TenCate Geosynthetics **PRODUCT Line:** 2XT to 24XT			
Tests Conducted	**Qualification (every 6 yrs) / Verification (every 3 yrs)**		
	Products Tested		**# of Tests (see Note 1)**
	Qualification	**Verification**	
Index tensile tests on undamaged material (ASTM D 6637)	2XT, 8XT, 24XT	NA	3
Three field exposures, including soil characterization and compaction measurements (ASTM D5818)	2XT, 8XT, 24XT in Types 1, 2, and 3 soils	NA	9
Tensile tests on damaged specimens (ASTM D 6637)	2XT, 8XT, 24XT in Types 1, 2, and 3 soils	NA	9
Laboratory installation damage testing –as basis for future verification (ISO/EN 10722)	2XT, 3XT, 5XT, 7XT, 8XT, 10XT, 20XT, 22XT, 24XT	2XT	9
Note 1 Each test is performed using the number of specimens required by the test standard. For example, for index tensile testing, a test is defined 5 to 6 specimens. See the specific test procedures for details on this.			

4.2 Laboratory Installation Damage Test Results per ISO/EN 10722

For qualification testing, three “standard” soils: a coarse gravel, a sandy gravel, and a sand were used for the field exposure of the geogrid samples to installation damage. In addition, laboratory installation damage testing and interpretation was conducted in accordance with ISO/EN 10722. In this procedure, geosynthetic specimens are exposed to simulated installation stresses and abrasion using a standard “backfill” material in a bench scale device. Once exposed, they are tested for tensile strength to determine the retained strength after damage. Five baseline and five exposed specimens from each product were tested. New installation damage tests were conducted using the verification principles provided in the REGEO work plan and in accordance with AASHTO R69-15 to verify that the installation damage data generated during qualification testing is still applicable for current geogrid production. For verification testing, 2XT was subjected to laboratory installation damage.

The verification installation damage test results are provided with the product qualification installation damage test results to facilitate direct comparison between the two sets of data. The roll specific ultimate tensile strength (ISO 10319) test results for the baseline, T_{lot} (i.e., undamaged tensile strength tested prior to sample installation in the ground) and the ultimate tensile strength of the installation damaged geogrid samples, T_{dam}, are provided in Table 4-2. Strength retained is calculated as the ratio of the average exposed strength T_{dam} divided by the average baseline strength T_{lot} for the product sample. Detailed test results for the verification testing for each specimen tested are provided in Appendix D, Table D-1.

Table 4-2. Summary of laboratory (ISO procedure) installation damage test results.

Miragrid XT Style	Mean Baseline Tensile Strength (lb/ft)	Coefficient of Variation (%)	Mean Exposed Tensile Strength (lb/ft)	Coefficient of Variation (%)	Strength Retained (%)
2XT	2,744	1	2,552	8	93
2XT Verification	2,788	2	2,689	1	96

(Conversion: 1 lb/ft = 0.0146 kN/m)

The verification test results technically meet the R69-15 requirement that the maximum difference between the two means shall be no greater that what is defined as statistically insignificant based on a one-sided student-t distribution at a level of significance of 0.05 (see Table 4-2 and 4-3). Therefore the verification data for the Miragrid XT series confirms the product qualification data results according to R69-15.

5.0 Creep Rupture Data (RF_{CR})

5.1 Creep Rupture Test Program

Creep testing and interpretation has been conducted in accordance with AASHTO R69-15. A baseline (i.e., reference) temperature of 68° F (20° C) was used. For the product qualification testing, Miragrid 8XT was used as the primary product to establish the creep rupture envelope, with limited creep testing of the other Miragrid geogrids (i.e., 2XT and 24XT) to verify the ability to interpolate creep rupture behavior to the XT geogrid products not specifically tested (i.e., to treat all the products submitted for evaluation as a product line per R69-15 and the NTPEP work plan).

The product qualification testing verified that SIM (ASTM D 6992) could be used to accelerate the creep testing, and that furthermore single rib tests could be conducted to represent wide width tensile strengths obtained per ASTM D6637.

Verification creep testing and interpretation has been conducted in accordance with the verification principles provided in the REGEO work plan and in accordance with R69-15. The focus of this creep testing (specifically, testing of 8XT as the primary product for product line characterization) was to provide verification data to confirm the qualification creep data. Creep testing for product verification was conducted using SIM (ASTM D 6992) on single rib specimens.

The qualification and verification creep rupture testing programs are summarized in Table 5-1.

Table 5-1. Independent creep rupture testing required for NTPEP qualification and verification.

Manufacturer: TenCate Geosynthetics **PRODUCT Line:** 2XT to 24XT			
Tests Conducted	**Qualification (every 6 yrs) / Verification (every 3 yrs)**		
	Products Tested		**# of Tests (see Note 1)**
	Qualification	**Verification**	
Index single rib tensile tests on lot specific material (ASTM D 6637)	2XT, 8XT, 24XT	8XT	3
Index wide width tensile tests on lot specific material (ASTM D 6637)	NA	NA	0
PRIMARY PRODUCT 6 Rupture Points – Conventional Creep testing @ 10, 100, 500, 1000, 2500, 10000 hrs (ASTM D5262)	8XT @ 6 load levels	NA	6
PRIMARY PRODUCT 6 Rupture Points – Accelerated Creep rupture testing (SIM). (ASTM D6992)	8XT @ 6 load levels	8XT @ 4 load levels	6
SECONDARY PRODUCT(S) Conventional Creep Testing (ASTM D5262)	None	NA	0
SECONDARY PRODUCT(S) Accelerated Creep rupture testing (SIM). (ASTM D6992)	2XT and 24XT @ 4 load levels	NA	8
Note 1: Each test is performed using the number of specimens required by the test standard. For example, for index tensile testing, a test is defined as 5 to 6 specimens. See the specific test procedures for details on this.			

5.2 Baseline Tensile Strength Test Results

Sample specific geogrid dimensions were used to convert tensile test loads on single rib specimens to load per unit width values. The tensile test specimens tested were taken from the same rolls of material that were used for the creep testing. The measured geogrid dimensions discussed in Section 2 and provided in Appendix B, Section B.1, were used to convert tensile test loads to load per unit width values.

Table 5-2. Ultimate tensile strength (UTS) and associated strain.

Product	Single Rib UTS per ASTM D6637, T_{lot} (lb/ft @ % Strain)
8XT	8,714 @ 12.8%
8XT Verification	8,691 @ 12.0%

(Conversion: 1 lb/ft = 0.0146 kN/m)

5.3 Creep Rupture Test Results

A total of four Stepped Isothermal Method (SIM) tests were run to fulfill the verification requirements. Load levels were selected in accordance with AASHTO R69-15 (i.e., one that results in an approximate rupture time of 500 hours, and three at a load level that results in an approximate rupture time of 100,000 hours, based on the product qualification rupture envelope). Table 5-4 summarize the tests performed and their outcomes. Detailed test results, including creep curves for each specimen tested, are provided in Appendix E, Figures E-1 through E-4.

Table 5-3. Creep rupture test results for all tests conducted for verification.

Style & Test Type	Creep Load (% of T_{lot})	Time to Rupture (log hrs)
8XT - SIM	70.40	5.1258
8XT - SIM	70.75	4.7700
8XT - SIM	70.93	4.9525
8XT - SIM	78.88	2.6852

5.3.1 Statistical Verification to Confirm the Qualification Creep Rupture Data

The 8XT verification creep test results were obtained to perform a check on the qualification data for the primary product (8XT) to assess consistency of the current products with the original product qualification composite creep rupture envelope for this product line. The verification check of the 8XT creep rupture data is shown in Figure E-5. This figure illustrates that the 95% single-sided lower confidence limit per R69-15 is met by the test data. Details of the statistical verification evaluation conducted in accordance with R69-15 are contained in Appendix E. The primary product creep rupture verification data for 8XT satisfies the 95% single-sided lower confidence limit per R69-15 (see Figure E-5).The verification test results are provided in Figure 5-1, showing both the original creep rupture envelope and test data provided in the product qualification test report and the verification test results.

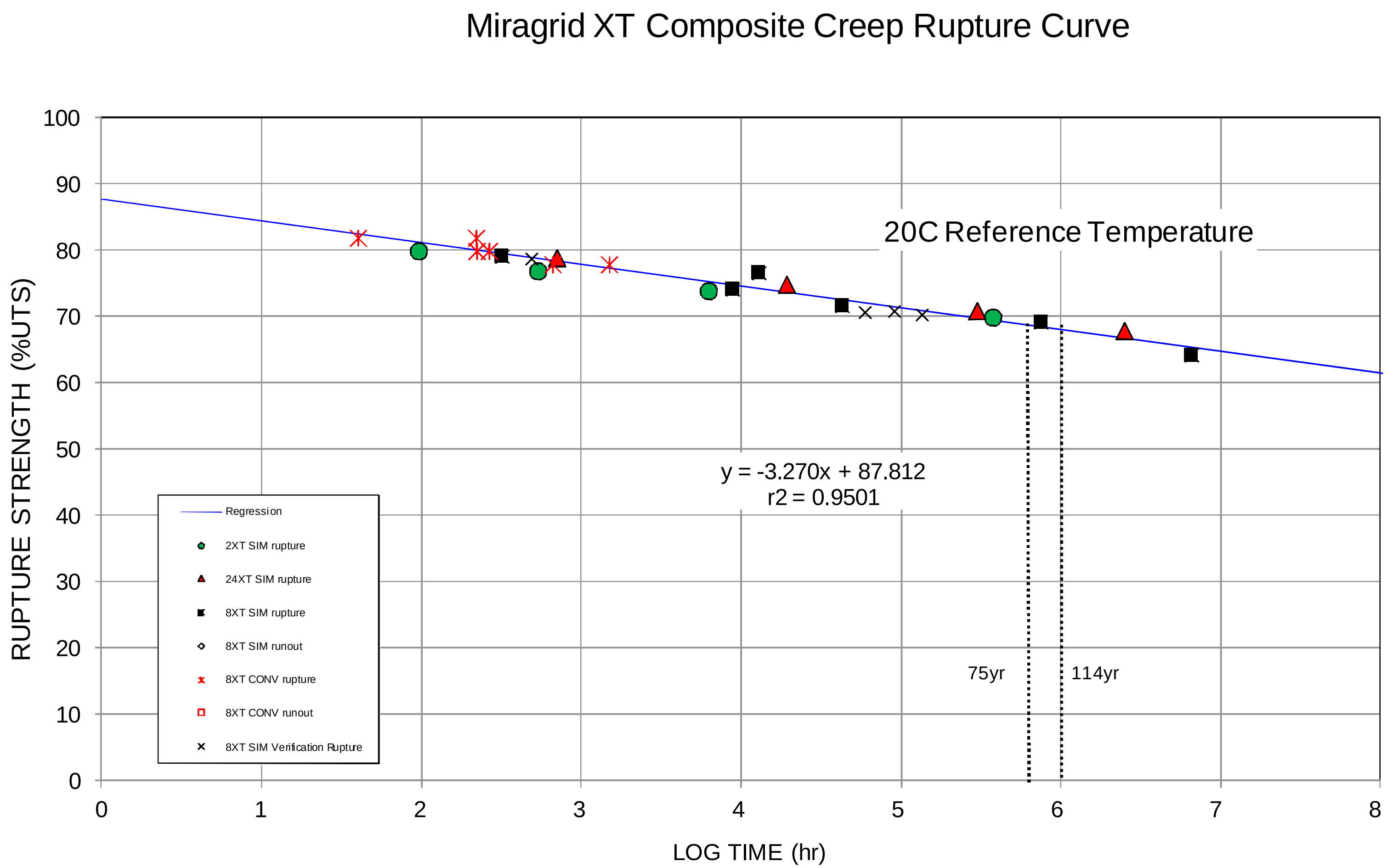

Figure 5-1. Composite creep rupture data/envelope for the Miragrid XT geogrid product line.

6.0 Long-Term Durability Data (RF_D)

6.1 Durability Test Program

Basic molecular properties relating to durability were evaluated, allowing a "default" RF_D to be used in accordance with AASHTO R69-15, provided that the long-term environment in which the geosynthetic is to be used is considered to be non-aggressive in accordance with the AASHTO LRFD Bridge Design Specifications and R69-15.

The index properties/test results obtained can be related to long-term performance of the polymer through correlation to longer-term laboratory durability performance tests and long-term experience. Note that long-term durability performance testing in accordance with R69-15 and the NTPEP work plan to allow direct calculation of RF_D was not requested by the manufacturer for the product qualification testing, nor evaluated as part of the testing program for this product line. Therefore, the durability evaluation was focused on index durability tests only.

For polyester (PET) geosynthetics, key durability issues to address include hydrolysis and ultraviolet (UV) oxidative degradation. To assess the potential for these types of degradation, index property tests to assess molecular weight, carboxyl end group content, and ultraviolet (UV) oxidative degradation are conducted. Criteria for test results obtained each of these tests are provided in R69-15 as well as the AASHTO LRFD Bridge Design Specifications.

The UV degradation tests were conducted on the lightest weight product in the product line (Miragrid 2XT) as recommended in R69-15. Since UV degradation attacks from the surface of the geosynthetic, the heavier the product, the more resistant it will be to UV degradation. Therefore, UV testing the lightest weight product should produce the most conservative result.

The molecular weight and carboxyl end group content tests are conducted on the base yarn for the product series. Since for a product line the base yarn used must be the same for all products in the line, these tests on the base yarn will be applicable to all products in the product line.

For the verification evaluation for the product qualification testing conducted for this product line, these index tests were essentially repeated using the verification sample. The qualification and verification durability testing programs are summarized in Table 6-1.

Table 6-1. Independent durability testing required for NTPEP qualification and verifcation.

Manufacturer: TenCate Geosynthetics **PRODUCT Line:** 2XT to 24XT			
Tests Conducted	**Qualification (every 6 yrs) / Verification (every 3 yrs)**		
	Products Tested		**# of Tests (see Note 1)**
	Qualification	**Verification**	
All polymers, resistance to weathering @ 500 hrs (ASTM D4355), including before/after tensile strength	2XT	2XT	1
For polyesters, molecular weight determination (ASTM D4603 and GRI-GG7) – **on yarn/strip**	2XT yarn	2XT yarn	1
For polyesters, carboxyl end group content determination (GRI-GG8) – **on yarn/strip**	2XT yarn	2XT yarn	1
CEG-MW Testing Coating Removal, if necessary	2XT yarn	NA	1
Brittleness (WSDOT T926)	NA	NA	0
For polyolefins, long-term evaluation via Oxidative degradation (ISO/EN 13438:1999)	NA	NA	0
For polyesters, long-term evaluation via Hydrolytic degradation (AASHTO R69-15)	None	None	0
For polyolefins, long-term evaluation via Oxidative degradation (AASHTO R69-15)	NA	NA	0
Note 1: Each test is performed using the number of specimens required by the test standard. For example, for index tensile testing, a test is defined 5 to 6 specimens. See the specific test procedures for details on this.			

6.2 Durability Test Results

A summary of the test results is provided in Table 6-2, showing both the original product qualification test results and the verification test results. This table also includes the criteria to allow the use of a default reduction factor for RF_D provided in R69-15 and the AASHTO LRFD Bridge Design Specifications. Detailed durability test results are provided in Appendix F.

Table 6-2. NTPEP durability test results for the Miragrid XT geogrid product line and criteria to allow use of a default value for RF_D.

Polymer Type	Property	Test Method	Criteria to Allow Use of Default RF*	Test Result Obtained as Part of NTPEP Program
PP and HDPE	UV Oxidation Resistance	ASTM D4355	Min. 70% strength retained after 500 hrs in weatherometer	NA
PET	UV Oxidation Resistance	ASTM D4355	Min. 50% strength retained after 500 hrs in weatherometer if geosynthetic will be buried within one week, 70% if left exposed for more than one week.	Qualification 85% strength retained Verificaton 82% strength retained
PP and HDPE	Thermo-Oxidation Resistance	ENV ISO 13438:1999, Method A (PP) or B (HDPE)	Min. 50% strength retained after 28 days (PP) or 56 days (HDPE)	NA
PET	Hydrolysis Resistance	Inherent Viscosity Method (ASTM D4603 and GRI Test Method GG8)	Min. Number Average Molecular Weight of 25,000	Qualification 34,855 Verificaton 30,570
PET	Hydrolysis Resistance	GRI Test Method GG7	Max. Carboxyl End Group Content of 30	Qualification 15.2 Verificaton 22.1

Note: PP = polypropylene, HDPE = high density polyethylene, PET = polyester

The product qualification test results demonstrated that the products in the product line meet the minimum durability test results criteria to justify the use of a default value for RF_D, meeting the requirements in R69-15. The verification test results continue to meet the minimum durability requirements outlined in Table 6.2 and therefore justify the use of a default value for RF_D as outlined in R69-15.

7.0 Low Strain Creep Stiffness Data

7.1 Low Strain Creep Stiffness Test Program

Creep stiffness testing was conducted in accordance with AASHTO R69-15 and the NTPEP work plan. The creep stiffness determination was targeted to 2% strain at 1,000 hours.

Products selected to represent the XT product line (i.e., 2XT, 8XT, and 24XT) were tested for creep stiffness for the product qualification testing. Roll specific single rib short-term rapid loading tensile strength tests (T_{lot}) were conducted for each product for correlation purposes and to calculate load levels. A total of nine Ramp and Hold (R&H), 1,000 second creep tests, were conducted on each product. Three specimens were R&H tested at each of the following stresses: 5, 10 and 20% of the ultimate tensile strength (UTS). A linear regression based on %UTS and % strain at 0.1 hour was used to normalize strain curves to reduce the variability of the elastic portion of the strain curve. The % UTS required to obtain 2% strain at 1,000 hours was then determined. Three R&H tests and two 1,000 hour conventional creep tests (ASTM D5262, but as modified for low strain in R69-15 and using a single rib specimen) were conducted at this load. All tests were conducted at 68^o F (20^o C).

Verification testing was conducted on the primary product in the product line (8XT). Roll specific single rib short-term rapid loading tensile strength tests (T_{lot}) were conducted for correlation purposes and to calculate load levels. A total of nine Ramp and Hold (R&H), 1,000 second creep tests, were conducted. Three specimens were R&H tested at each of the following stresses: 5, 10 and 20% of the ultimate tensile strength (UTS). A linear regression based on %UTS and % strain at 0.1 hour was used to normalize strain curves to reduce the variability of the elastic portion of the strain curve. The % UTS required to obtain 2% strain at 1,000 hours was then determined. Three R&H tests were conducted at this load. All tests were conducted at 68^o F (20^o C).

7.2 Ultimate Tensile Test Results for Creep Stiffness Test Program

The values provided in Table 7-1 represent the baseline, roll specific, ultimate tensile strength used to normalize the load level for the verification creep stiffness testing. Sample specific geogrid dimensions were used to convert tensile test loads to load per unit width values.

Table 7-1. Ultimate tensile strength (UTS) & associated strain.

Product	T_{lot} for Single Rib (lb/ft @ % Strain)
8XT	8,714 @ 12.8%
8XT Verification	8,691 @ 12.0%

(Conversion: 1 lb/ft = 0.0146 kN/m)

7.3 Creep Stiffness Test Results

Detailed test results for the verification testing are provided in Appendix G. Table 7-2 provides a summary of the creep stiffness values obtained on the primary product (8XT) for both product qualification and verification testing. Figure 7-1 shows the relationship between the measured tensile strength and the percent strain at 1000 hours for the original product qualification and the verification testing on the primary product (8XT). The percent strain at 1000 hours of the verification testing on 8XT falls above the 95 percent lower prediction limit established by Student's *t*-test of the original product qualification data set. Therefore, the verification testing meets the requirements outlined in R69-15.

Table 7-2. Summary of creep stiffness test results.

Miragrid XT Series Style	Average Creep Stiffness @ 1000 hours for 5% UTS Ramp & Hold (lb/ft)	Average Creep Stiffness @ 1000 hours for 10% UTS Ramp & Hold (lb/ft)	Average Creep Stiffness @ 1000 hours for 20% UTS Ramp & Hold (lb/ft)	Average Creep Stiffness for 2% strain @ 1000 hrs (lb/ft)
8XT	46,030	45,708	43,576	**44,977**
8XT Verification	116,119	72,203	50,920	**61,297**

(Conversion: 1 lb/ft = 0.0146 kN/m)

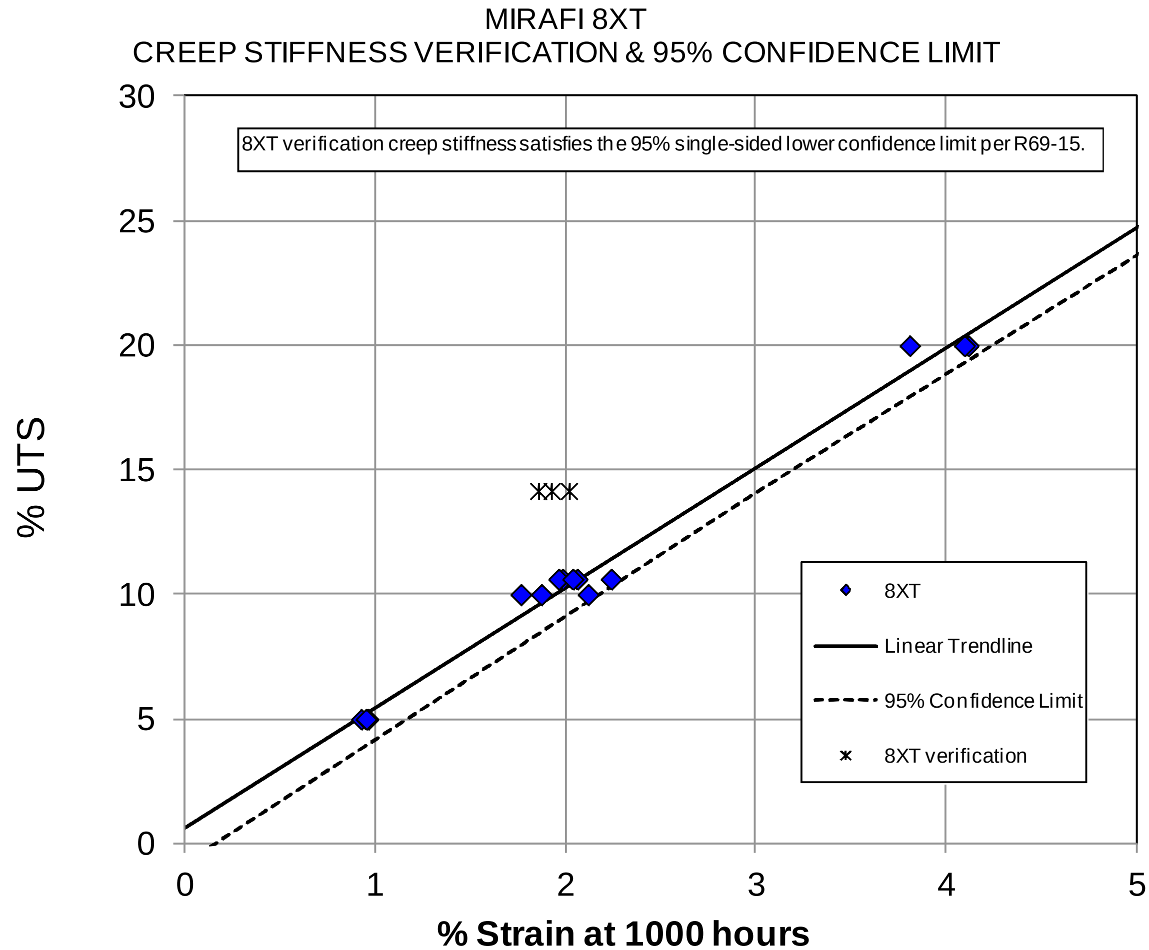

Figure 7-1. Miragrid XT creep stiffness for 2 % strain @ 1000 hours.

APPENDICES

Appendix A: NTPEP Oversight Committee

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Appendix B: Product Geometric and Production Details

B.1 Product Geometric Information

Table B-1. Typical and measured MD geogrid geometry for the Miragrid XT product line.

Machine Direction (MD) Ribs								
Style	Width (in)		Spacing (in)		Aperture Size (in)		Rib Thickness (in)	
	Typical Values	As Measured	Typical Values	As Measured	Typical Values	As Measured	Typical Values	As Measured
2XT	N/A	0.095* 0.093*	N/A	1.118* 1.113**	0.875	0.830* 0.815**	N/A	0.057* 0.052**
3XT	N/A	0.144*	N/A	1.113*	1.0	1.260*	N/A	0.060*
5XT	N/A	0.196*	N/A	1.127*	1.2	1.245*	N/A	0.059*
7XT	N/A	0.223*	N/A	1.121*	1.3	1.214*	N/A	0.057*
8XT	N/A	0.285* 0.265**	N/A	1.237* 1.072**	1.3	1.148* 1.514**	N/A	0.057* 0.053**
10XT	N/A	0.297*	N/A	1.096*	1.3	1.315*	N/A	0.072*
20XT	N/A	0.373*	N/A	1.001*	1.5	5.806*	N/A	0.084*
22XT	N/A	0.471*	N/A	1.003*	1.4	5.796*	N/A	0.101*
24XT	N/A	0.519* 0.492**	N/A	1.006* 0.972**	1.4	5.740* 5.712**	N/A	0.094* 0.101**

(Conversions: 1 in = 25.4 mm)
*Average of 5 readings obtained during NTPEP qualification testing.
**Average of 5 readings obtained during NTPEP verification testing. Full test results in Tables B-5 through B-7.

Table B-2. Typical and measured XD geogrid geometry for the Miragrid XT product line.

Cross-Machine Direction (XD) Ribs								
Style	Width (in)		Spacing (in)		Aperture Size (in)		Rib Thickness (in)	
	Typical Values	As Measured	Typical Values	As Measured	Typical Values	As Measured	Typical Values	As Measured
2XT	N/A	0.114* 0.107**	N/A	0.944* 0.922**	1.0	1.023* 1.019**	N/A	0.061* 0.051**
3XT	N/A	0.126*	N/A	1.385*	1.0	0.969*	N/A	0.061*
5XT	N/A	0.108*	N/A	1.354*	1.0	0.931*	N/A	0.053*
7XT	N/A	0.115*	N/A	1.330*	0.9	0.898*	N/A	0.062*
8XT	N/A	0.117* 0.107**	N/A	1.354* 1.621**	0.9	0.863* 0.807**	N/A	0.058* 0.068**
10XT	N/A	0.116*	N/A	1.431*	0.8	0.799*	N/A	0.062*
20XT	N/A	0.265*	N/A	6.071*	0.6	0.628*	N/A	0.059*
22XT	N/A	0.256*	N/A	6.053*	0.6	0.532*	N/A	0.073*
24XT	N/A	0.258* 0.224**	N/A	5.998* 5.937**	0.5	0.487* 0.480**	N/A	0.067* 0.064**

(Conversions: 1 in = 25.4 mm)
*Average of 5 readings obtained during NTPEP qualification testing.
**Average of 5 readings obtained during NTPEP verification testing. Full test results in Tables B-5 through B-7.

Table B-3. Typical and measured geogrid junction thickness for the Miragrid XT product line.

Style	Junction Thickness (in)		
	Typical Values	As Measured*	As Measured**
2XT	Not tested	0.058*	0.054**
3XT	Not tested	0.066*	
5XT	Not tested	0.060*	
7XT	Not tested	0.065*	
8XT	Not tested	0.069*	0.065**
10XT	Not tested	0.078*	
20XT	Not tested	0.101*	
22XT	Not tested	0.115*	
24XT	Not tested	0.119*	0.129**

(Conversions: 1 in = 25.4 mm)
*Average of 5 readings obtained during NTPEP qualification testing.
**Average of 5 readings obtained during NTPEP verification testing. Full test results in Tables B-5 through B-7.

Table B-4. Typical and measured geogrid unit weight for the Miragrid XT product line.

Geogrid Style/Type	Typical Weight (oz/yd^2)	Measured Weight, per ASTM D5261 (oz/yd^2)*	Measured Weight, per ASTM D5261 (oz/yd^2)**
2XT	7.50	7.21*	7.00**
3XT	8.17	7.98*	
5XT	9.00	8.85*	
7XT	10.21	9.09*	
8XT	11.42	11.23*	11.14**
10XT	14.31	13.26*	
20XT	22.12	18.45*	
22XT	30.50	24.79*	
24XT	38.02	30.27*	31.26**

(Conversion: 1 $oz/yd^2 = 33.9 g/m^2$)
*Average of 5 readings obtained during NTPEP qualification testing.
**Average of 5 readings obtained during NTPEP verification testing. Full test results in Tables B-5 through B-7.

Table B-5. Geogrid geometric measurements for 2XT

TRI Log #: E2378-12-06

PARAMETER	TEST REPLICATE NUMBER					MEAN	STD. DEV.
	1	2	3	4	5		
Mass/Unit Area (ASTM D 5261)							
Specimen Width (in) 8.9							
Specimen Length (in) 8.2							
Mass(g)	11.21	11.08	11.22	11.13	11.27		
Mass/unit area (oz/sq.yd)	7.02	6.93	7.02	6.97	7.05	**7.00**	0.05
Mass/unit area (g/sq.meter)	238	235	238	236	239	**237**	2
Aperature Size (Calipers)							
MD - Aperature Size (in)	0.846	0.814	0.778	0.814	0.823	**0.815**	0.024
MD - Aperature Size (mm)	21.5	20.7	19.8	20.7	20.9	**20.7**	0.6
TD - Aperature Size (in)	1.019	1.033	1.006	1.020	1.018	**1.019**	0.010
TD - Aperature Size (mm)	25.9	26.2	25.6	25.9	25.9	**25.9**	0.2
Rib Width (Calipers)							
MD - Width (in)	0.096	0.093	0.095	0.092	0.091	**0.093**	0.002
MD - Width (mm)	2.44	2.36	2.41	2.34	2.31	**2.37**	0.05
TD - Width (in)	0.107	0.104	0.106	0.105	0.113	**0.107**	0.004
TD - Width (mm)	2.72	2.64	2.69	2.67	2.87	**2.72**	0.09
Rib Thickness (Calipers)							
MD - Thickness (in)	0.05	0.05	0.054	0.056	0.051	**0.052**	0.003
MD - Thickness (mm)	1.27	1.27	1.37	1.42	1.30	**1.33**	0.07
TD - Thickness (in)	0.05	0.053	0.054	0.05	0.047	**0.051**	0.003
TD - Thickness (mm)	1.27	1.35	1.37	1.27	1.19	**1.29**	0.07
Node/Junction Thickness (Calipers)							
Thickness (in)	0.052	0.054	0.057	0.055	0.052	**0.054**	0.002
Thickness (mm)	1.32	1.37	1.45	1.40	1.32	**1.37**	0.05

MD - Machine Direction   TD - Transverse/Cross Machine Direction   NP - Not Provided

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table B-6. Geogrid geometric measurements for 8XT

TRI Log #: E2378-12-06

PARAMETER	TEST REPLICATE NUMBER					MEAN	STD. DEV.
	1	2	3	4	5		
Mass/Unit Area (ASTM D 5261)							
Specimen Width (in) 8.8							
Specimen Length (in) 9.3							
Mass(g)	20.08	19.67	19.88	19.79	20.38		
Mass/unit area (oz/sq.yd)	11.21	10.98	11.09	11.04	11.37	**11.14**	0.16
Mass/unit area (g/sq.meter)	380	372	376	374	386	**378**	5
Aperature Size (Calipers)							
MD - Aperature Size (in)	1.659	1.536	1.398	1.235	1.744	**1.514**	0.204
MD - Aperature Size (mm)	42.1	39.0	35.5	31.4	44.3	**38.5**	5.2
TD - Aperature Size (in)	0.848	0.835	0.762	0.762	0.827	**0.807**	0.042
TD - Aperature Size (mm)	21.5	21.2	19.4	19.4	21.0	**20.5**	1.1
Rib Width (Calipers)							
MD - Width (in)	0.253	0.266	0.270	0.266	0.271	**0.265**	0.007
MD - Width (mm)	6.43	6.76	6.86	6.76	6.88	**6.74**	0.18
TD - Width (in)	0.116	0.104	0.106	0.110	0.099	**0.107**	0.006
TD - Width (mm)	2.95	2.64	2.69	2.79	2.51	**2.72**	0.16
Rib Thickness (Calipers)							
MD - Thickness (in)	0.050	0.052	0.054	0.055	0.053	**0.053**	0.002
MD - Thickness (mm)	1.27	1.32	1.37	1.40	1.35	**1.34**	0.05
TD - Thickness (in)	0.084	0.060	0.051	0.065	0.081	**0.068**	0.014
TD - Thickness (mm)	2.13	1.52	1.30	1.65	2.06	**1.73**	0.36
Node/Junction Thickness (Calipers)							
Thickness (in)	0.066	0.065	0.064	0.067	0.061	**0.065**	0.002
Thickness (mm)	1.68	1.65	1.63	1.70	1.55	**1.64**	0.06

MD - Machine Direction TD - Transverse/Cross Machine Direction NP - Not Provided

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table B-7. Geogrid geometric measurements for 24XT

TRI Log #: E2378-12-06

PARAMETER	TEST REPLICATE NUMBER 1	2	3	4	5	MEAN	STD. DEV.
Mass/Unit Area (ASTM D 5261)							
Specimen Width (in) 8.9							
Specimen Length (in) 6							
Mass(g)	36.35	35.97	36.22	37.19	36.98		
Mass/unit area (oz/sq.yd)	31.09	30.77	30.98	31.81	31.63	**31.26**	0.44
Mass/unit area (g/sq.meter)	1054	1043	1050	1078	1072	**1060**	15
Aperature Size (Calipers)							
MD - Aperature Size (in)	5.655	5.742	5.735	5.690	5.739	**5.712**	0.038
MD - Aperature Size (mm)	143.6	145.8	145.7	144.5	145.8	**145.1**	1.0
TD - Aperature Size (in)	0.493	0.564	0.410	0.452	0.483	**0.480**	0.057
TD - Aperature Size (mm)	12.5	14.3	10.4	11.5	12.3	**12.2**	1.4
Rib Width (Calipers)							
MD - Width (in)	0.488	0.515	0.476	0.497	0.483	**0.492**	0.015
MD - Width (mm)	12.40	13.08	12.09	12.62	12.27	**12.49**	0.38
TD - Width (in)	0.224	0.227	0.230	0.221	0.220	**0.224**	0.004
TD - Width (mm)	5.69	5.77	5.84	5.61	5.59	**5.70**	0.11
Rib Thickness (Calipers)							
MD - Thickness (in)	0.094	0.101	0.103	0.103	0.104	**0.101**	0.004
MD - Thickness (mm)	2.39	2.57	2.62	2.62	2.64	**2.57**	0.10
TD - Thickness (in)	0.066	0.058	0.066	0.068	0.062	**0.064**	0.004
TD - Thickness (mm)	1.68	1.47	1.68	1.73	1.57	**1.63**	0.10
Node/Junction Thickness (Calipers)							
Thickness (in)	0.124	0.128	0.136	0.126	0.132	**0.129**	0.005
Thickness (mm)	3.15	3.25	3.45	3.20	3.35	**3.28**	0.12

MD - Machine Direction TD - Transverse/Cross Machine Direction NP - Not Provided

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Appendix C: Tensile Strength Detailed Test Results

Table C-1. Geogrid wide width tensile test results for 2XT

TRI Log #: E2387-12-06

PARAMETER	TEST REPLICATE NUMBER					MEAN	STD. DEV.	MARV
	1	**2**	**3**	**4**	**5**			
Wide Width Tensile Properties (ASTM D 6637, Method B)								
MD Number of Ribs per Specimen:	8							
MD Number of Ribs per foot:	10.71							
MD Ultimate Strength (lbs)	2045	2087	2090	2019	2050	**2058**	30	
MD Ultimate Strength (lbs/ft)	2739	2795	2799	2704	2745	**2756**	40	2,000
MD Ultimate Strength (kN/m)	40.0	40.8	40.9	39.5	40.1	**40.2**	0.6	
MD Strength @ 2% Strain (lbs)	365	375	511	422	358	**406**	64	
MD Strength @ 2% Strain (lbs/ft)	489	502	684	565	479	**544**	85	
MD Strength @ 2% Strain (kN/m)	7.1	7.3	10.0	8.3	7.0	**7.9**	1.2	
MD Strength @ 5% Strain (lbs)	904	949	1044	952	886	**947**	61	
MD Strength @ 5% Strain (lbs/ft)	1211	1271	1398	1275	1186	**1268**	82	
MD Strength @ 5% Strain (kN/m)	17.7	18.6	20.4	18.6	17.3	**18.5**	1.2	
MD Strength @ 10% Strain (lbs)	2010	2067	2077	1983	1817	**1991**	105	
MD Strength @ 10% Strain (lbs/ft)	2692	2768	2781	2655	2433	**2666**	140	
MD Strength @ 10% Strain (kN/m)	39.3	40.4	40.6	38.8	35.5	**38.9**	2.0	
MD Break Elongation (%)	10.4	10.3	10.3	10.4	9.7	**10.2**	0.3	

MD - Machine Direction TD - Transverse/Cross Machine Direction NP - Not Provided

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table C-2. Geogrid wide width tensile test results for 8XT

TRI Log #: E2387-12-06

PARAMETER	TEST REPLICATE NUMBER 1	2	3	4	5	MEAN	STD. DEV.	MARV
Wide Width Tensile Properties (ASTM D 6637, Method B)								
MD Number of Ribs per Specimen:	8							
MD Number of Ribs per foot:	10.90							
MD Ultimate Strength (lbs)	6027	5943	6035	6267	5996	**6054**	125	
MD Ultimate Strength (lbs/ft)	8212	8097	8223	8539	8170	**8248**	170	7,400
MD Ultimate Strength (kN/m)	119.9	118.2	120.1	124.7	119.3	**120.4**	2.5	
MD Strength @ 2% Strain (lbs)	1194	1141	1134	1341	1277	**1217**	90	
MD Strength @ 2% Strain (lbs/ft)	1627	1555	1545	1827	1740	**1659**	122	
MD Strength @ 2% Strain (kN/m)	23.8	22.7	22.6	26.7	25.4	**24.2**	1.8	
MD Strength @ 5% Strain (lbs)	2221	2132	2241	2324	2242	**2232**	68	
MD Strength @ 5% Strain (lbs/ft)	3026	2905	3053	3166	3055	**3041**	93	
MD Strength @ 5% Strain (kN/m)	44.2	42.4	44.6	46.2	44.6	**44.4**	1.4	
MD Strength @ 10% Strain (lbs)	5463	5648	5523	5897	5733	**5653**	172	
MD Strength @ 10% Strain (lbs/ft)	7443	7695	7525	8035	7811	**7702**	235	
MD Strength @ 10% Strain (kN/m)	108.7	112.4	109.9	117.3	114.0	**112.4**	3.4	
MD Break Elongation (%)	11.0	10.6	11.7	11.2	10.6	**11.0**	0.5	

MD - Machine Direction TD - Transverse/Cross Machine Direction NP - Not Provided

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table C-3. Geogrid wide width tensile test results for 24XT

TRI Log #: E2387-12-06

PARAMETER	TEST REPLICATE NUMBER 1	2	3	4	5	MEAN	STD. DEV.	MARV
Wide Width Tensile Properties (ASTM D 6637, Method B)								
MD Number of Ribs per Specimen:	9							
MD Number of Ribs per foot:	12.15							
MD Ultimate Strength (lbs)	21204	20619	21311	21455	21392	**21196**	336	
MD Ultimate Strength (lbs/ft)	28625	27836	28770	28964	28879	**28615**	454	27,415
MD Ultimate Strength (kN/m)	417.9	406.4	420.0	422.9	421.6	**417.8**	6.6	
MD Strength @ 2% Strain (lbs)	3263	3201	3041	3495	3637	**3327**	238	
MD Strength @ 2% Strain (lbs/ft)	4405	4321	4105	4718	4910	**4492**	321	
MD Strength @ 2% Strain (kN/m)	64.3	63.1	59.9	68.9	71.7	**65.6**	4.7	
MD Strength @ 5% Strain (lbs)	5082	4943	4912	5204	5287	**5086**	162	
MD Strength @ 5% Strain (lbs/ft)	6861	6673	6631	7025	7137	**6866**	219	
MD Strength @ 5% Strain (kN/m)	100.2	97.4	96.8	102.6	104.2	**100.2**	3.2	
MD Strength @ 10% Strain (lbs)	10208	8982	9266	10692	11409	**10111**	1003	
MD Strength @ 10% Strain (lbs/ft)	13781	12126	12509	14434	15402	**13650**	1353	
MD Strength @ 10% Strain (kN/m)	201.2	177.0	182.6	210.7	224.9	**199.3**	19.8	
MD Break Elongation (%)	16.3	15.9	17.3	16.4	15.7	**16.3**	0.6	

MD - Machine Direction TD - Transverse/Cross Machine Direction NP - Not Provided

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Appendix D: Installation Damage Detailed Test Results

Table D-1. Laboratory installation damage (ISO/EN 10722) tensile test results for 2XT

TRI Log #: E2387-12-06

PARAMETER	TEST REPLICATE NUMBER					MEAN	STD. DEV.	COEF. VARI.	PERCENT RETAINED
	1	**2**	**3**	**4**	**5**				
Laboratory Installation Damage (ISO/EN 10722)									
Strength Retained measured via wide width tensile (ISO/EN 10319)									
MD Number of Ribs per Specimen:	8								
MD Number of Ribs per foot:	10.71								
MD - Tensile Strength (lbs) - B	2001	2116	2116	2078	2100	**2082**	48	2	
MD Tensile Strength (lbs/ft) - B	2680	2834	2834	2783	2812	**2788**	64	2	
MD Tensile Strength (kN/m) - B	39.1	41.4	41.4	40.6	41.1	**40.7**	0.9	2.3	
MD - Tensile Strength (lbs) - E	1992	1997	2027	2019	2006	**2008**	15	1	
MD Tensile Strength (lbs/ft) - E	2668	2674	2714	2704	2686	**2689**	20	1	**96**
MD Tensile Strength (kN/m) - E	38.9	39.0	39.6	39.5	39.2	**39.3**	0.3	0.7	
MD - Elong. @ Max. Load (%) - B	9.87	10.8	10.3	11.2	9.90	**10.4**	0.6	5.5	
MD - Elong. @ Max. Load (%) - E	11.3	9.69	8.83	9.79	9.83	**9.89**	0.9	9.0	**95**
B - Baseline Unexposed									
E - Exposed									

MD - Machine Direction   TD - Transverse/Cross Machine Direction

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Appendix E: Creep Rupture Detailed Test Results

Table E-1. Explanation/Key for Individual Creep Test Data Tables/Figures

Accelerated Creep Rupture via SIM - ASTM D 6992

Spreadsheet Filename   SUMMARY CREEP PARAMETERS: NTPEP - Manufacturer Product

Specimen: Test Filename   Test Date: 01-Jan-07   Method: SIM (10^4s, 14C),single rib, machine dir.

Average Creep Stress: 65.0 kN/m   %UTS: 66.00

Ultimate Tensile Strength: 100.0 kN/m   Rupture: YES

Dwell Seq	t'	t	$(t\text{-}t')_i$	Vshift(%)	$logA_T$	Temp	$logA_T/T$
1	0	0.5	0.5	-	-	20.00	-
2	9500	10000	500	0.1	1.2600	34.00	0.0900
3	19500	20000	500	0.1	1.2600	48.00	0.0900
4	29500	30000	500	0.1	1.2600	62.00	0.0900
5	39500	40000	500	0.1	1.2600	76.00	0.0900
6	49500	50000	500	0.1	1.2600	90.00	0.0900

Summary	Initial	Final	Units	@20C refT
lab time	90	60000	sec	-
$logA_T(t\text{-}t')$	1.9542	4.7782	log hours	6.0000
$A_T(t\text{-}t')$	-	17.25	years	114.00
Strain	9.500	12.500	%	-
Modulus	800.0	600.0	kN/m	-

AVG 0.0900

$logA_{T/}T$ = Horizontal shift factor for each temperature step expressed per degree C

Average temperature for each step

$logA_T$ = Horizontal shift factor for each temperature step

Vshift(%) = Vertical shift to offset system temperature expansion

Rupture Time expressed in log hours and years

% Strain and Creep Modulus at end of test

% Strain and Creep Modulus at onset of creep

t = The actual start time of each temperature step

t' = The theoritical start time of each temperature step

Accelerated Creep Rupture via SIM - ASTM D 6992

SUMMARY CREEP PARAMETERS: NTPEP - Mirafi Construction Products
8XT

Specimen: 126-n2m-8XT-sim71 Test Date: 29-Sep-15 Method: SIM (10^4s, 14C),single rib, machine dir.

Average Creep Stress: 6119 lb/ft %UTS: 70.40

Ultimate Tensile Strength: 8691 lb/ft Rupture: YES

Dwell Seq	t'	t	$(t-t')_i$	Vshift(%)	$logA_T$	Temp	$logA_T/T$
1	0	0.5	0.5	-	-	19.67	-
2	9600	10020	420	0.12	1.3760	33.66	0.0983
3	19500	20010	510	0.115	1.3084	47.75	0.0929
4	29600	30001	401	0.08	1.4173	61.90	0.1002
5	39200	39990	790	0.12	1.1176	76.33	0.0774
6							
						AVG	0.0921

Summary	Initial	Final	Units	@20C refT
lab time	44.6	42331	sec	-
$logA_T(t-t')$	1.6488	8.7150	log hours	5.1258
$A_T(t-t')$	-	16.44	years	15.24
Strain	8.82	11.675	%	-
Modulus	71337.7	52468.6	lb/ft	-

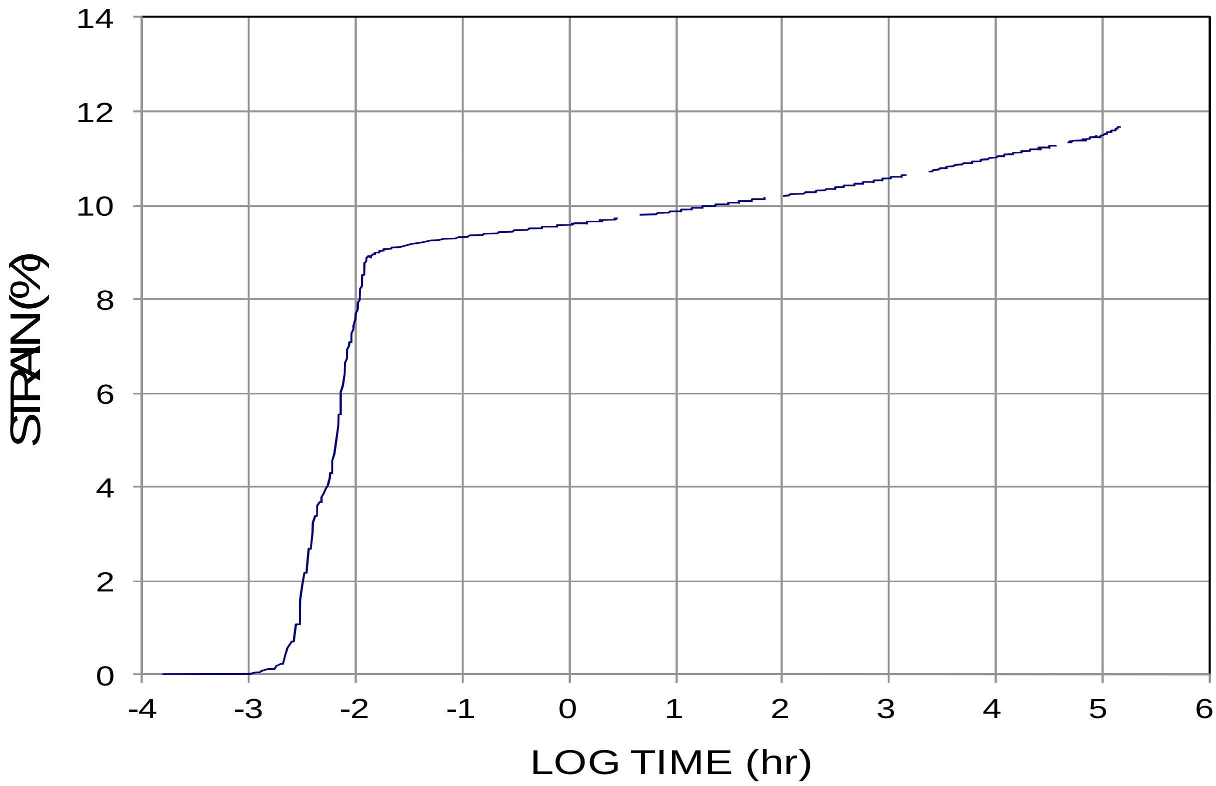

Figure E-1. SIM/Creep data/curve for 8XT at load level of 70.40% UTS.

Accelerated Creep Rupture via SIM - ASTM D 6992

SUMMARY CREEP PARAMETERS: NTPEP - Mirafi Construction Products

8XT

Specimen: 126-n2m-8XT-sim71b   Test Date: 30-Sep-15   Method: SIM (10^4s, 14C),single rib, machine dir.

Average Creep Stress: 6149 lb/ft   %UTS: 70.75

Ultimate Tensile Strength: 8691 lb/ft   Rupture: YES

Dwell Seq	t'	t	$(t-t')_i$	Vshift(%)	$logA_T$	Temp	$logA_T/T$
1	0	0.5	0.5	-	-	19.66	-
2	9600	10020	420	0.13	1.3758	33.70	0.0980
3	19600	20010	410	0.16	1.4029	47.79	0.0996
4	29500	30001	501	0.15	1.3162	61.94	0.0930
5	39200	39991	791	0.12	1.1215	76.62	0.0764
6							
						AVG	0.0916

Summary	Initial	Final	Units	@20C refT
lab time	52.0	40591	sec	-
$logA_T(t-t')$	1.7160	8.3597	log hours	4.7700
$A_T(t-t')$	-	7.25	years	6.72
Strain	8.43	10.560	%	-
Modulus	73266.9	58276.4	lb/ft	-

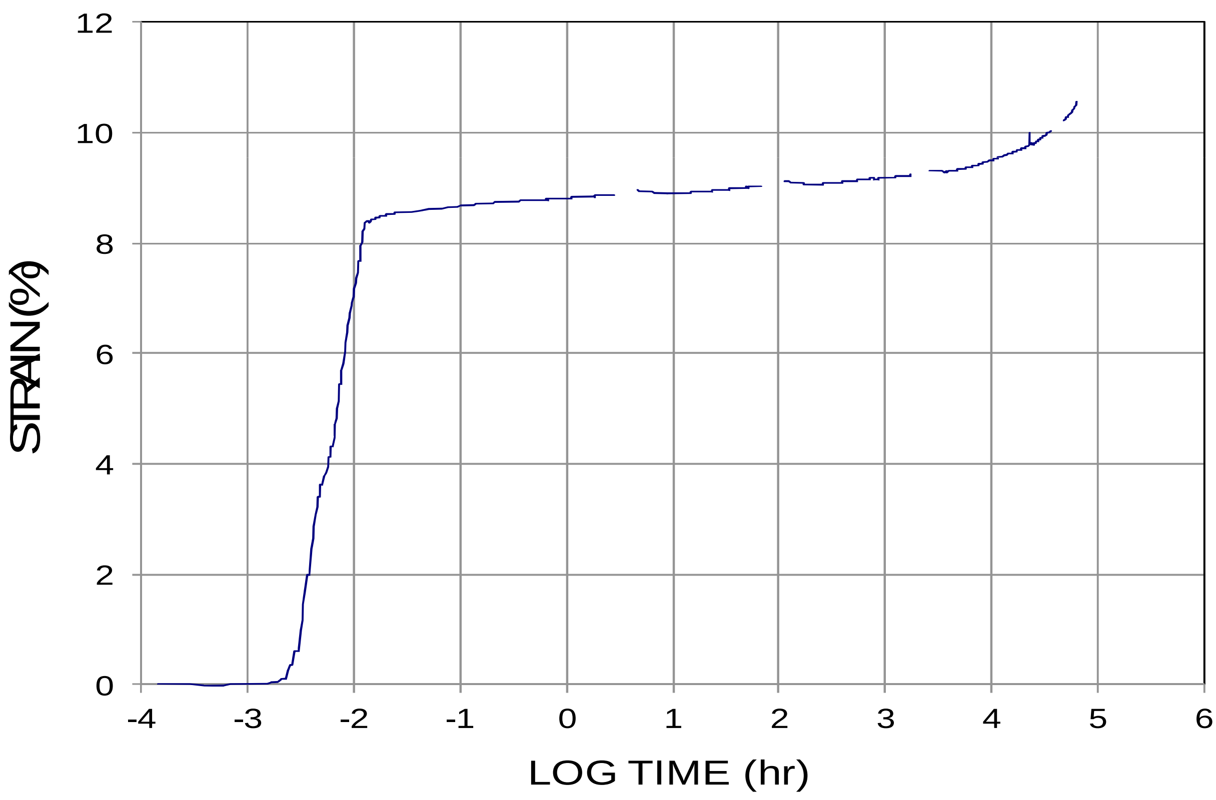

Figure E-2. SIM/Creep data/curve for 8XT at load level of 70.75% UTS.

Accelerated Creep Rupture via SIM - ASTM D 6992

SUMMARY CREEP PARAMETERS: NTPEP - Mirafi Construction Products

8XT

Specimen: 126-n2m-8XT-sim71 Test Date: 02-Oct-15 Method: SIM (10^4s, 14C),single rib, machine dir.

Average Creep Stress: 6165 lb/ft %UTS: 70.93

Ultimate Tensile Strength: 8691 lb/ft Rupture: YES

Dwell Seq	t'	t	$(t-t')_i$	Vshift(%)	$logA_T$	Temp	$logA_T/T$
1	0	0.5	0.5	-	-	19.63	-
2	9500	10021	521	0.095	1.2832	33.62	0.0917
3	19500	20010	510	0.15	1.3126	47.65	0.0936
4	29500	30000	500	0.12	1.3206	61.72	0.0938
5	39300	39991	691	0.13	1.1804	76.06	0.0824
6							
						AVG	0.0903

Summary	Initial	Final	Units	@20C refT
lab time	52.0	42091	sec	-
$logA_T(t-t')$	1.7160	8.5424	log hours	4.9525
$A_T(t-t')$	-	11.05	years	10.23
Strain	8.21	10.268	%	-
Modulus	75401.1	60005.0	lb/ft	-

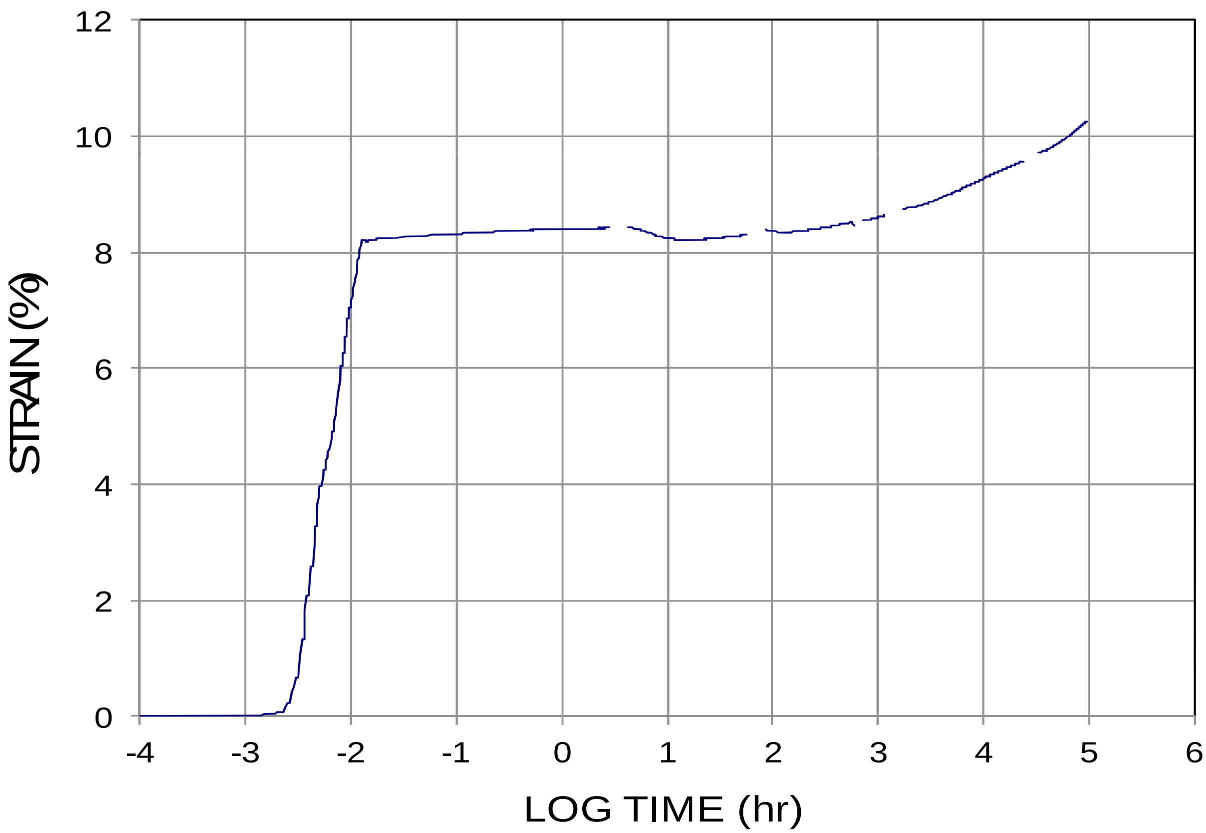

Figure E-3. SIM/Creep data/curve for 8XT at load level of 70.93% UTS.

Accelerated Creep Rupture via SIM - ASTM D 6992

SUMMARY CREEP PARAMETERS: NTPEP - Mirafi Construction Products

8XT

Specimen: 126-n2m-8XT-sim79 Test Date: 07-Oct-15 Method: SIM (10^4s, 14C),single rib, machine dir.

Average Creep Stress: 6855 lb/ft %UTS: 78.88

Ultimate Tensile Strength: 8691 lb/ft Rupture: YES

Dwell Seq	t'	t	$(t\text{-}t')_i$	Vshift(%)	$logA_T$	Temp	$logA_T/T$
1	0	0.5	0.5	-	-	19.58	-
2	8900	10020	1120	0.1	0.9503	33.76	0.0670
3	18100	20011	1911	0.12	0.7634	48.00	0.0536
4	28700	30000	1300	0.1	0.9605	62.49	0.0663
5							
6							

AVG 0.0623

Summary	Initial	Final	Units	@20C refT
lab time	50.1	32640	sec	-
$logA_T(t\text{-}t')$	1.6994	6.2696	log hours	2.6852
$A_T(t\text{-}t')$	-	0.06	years	0.06
Strain	9.23	11.791	%	-
Modulus	76183.5	58149.5	lb/ft	-

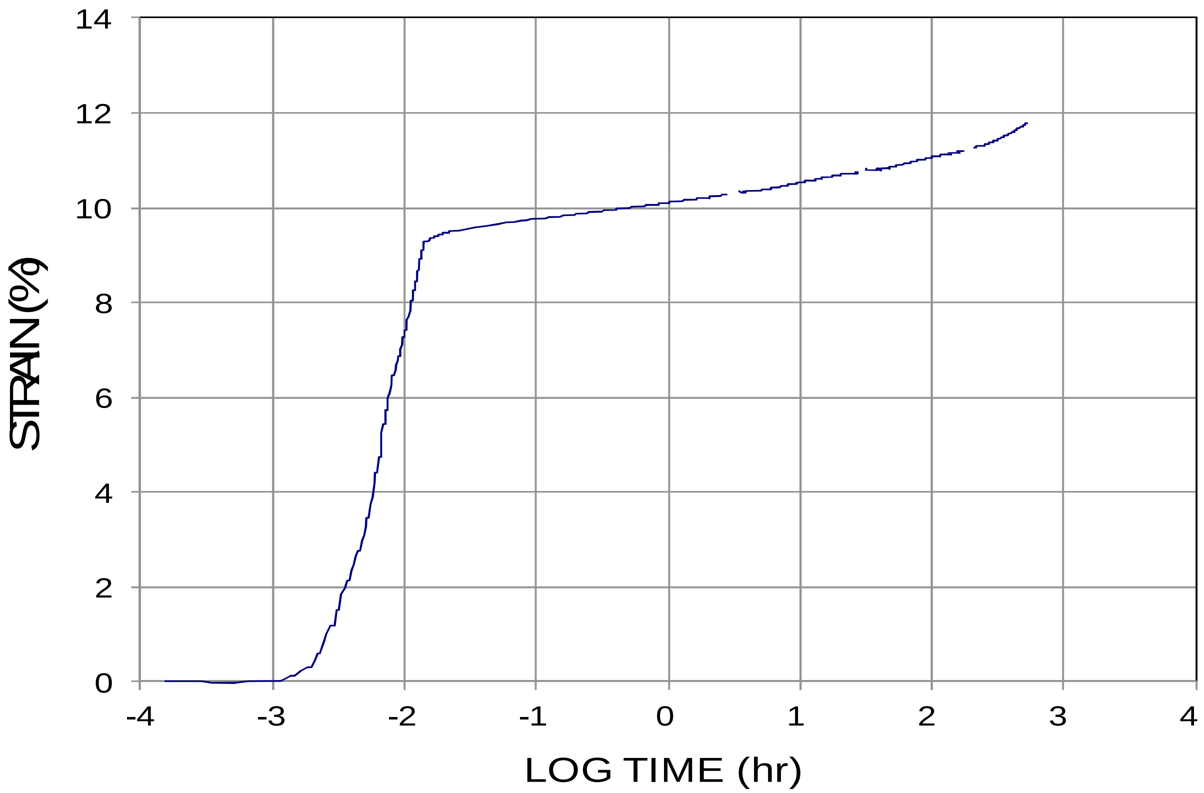

Figure E-4. SIM/Creep data/curve for 8XT at load level of 78.88% UTS.

Statistical Evaluation of Qualification Creep Data: The 8XT verification creep test results were obtained to perform a check on the qualification data for the primary product (8XT) to confirm the acceptability of using the qualification data to establish the composite creep curve for the product line. The verification check of the 8XT creep rupture data is shown in Figure E-5. This figure illustrates that the 95% single-sided lower confidence limit per R69-15 is met by the test data.

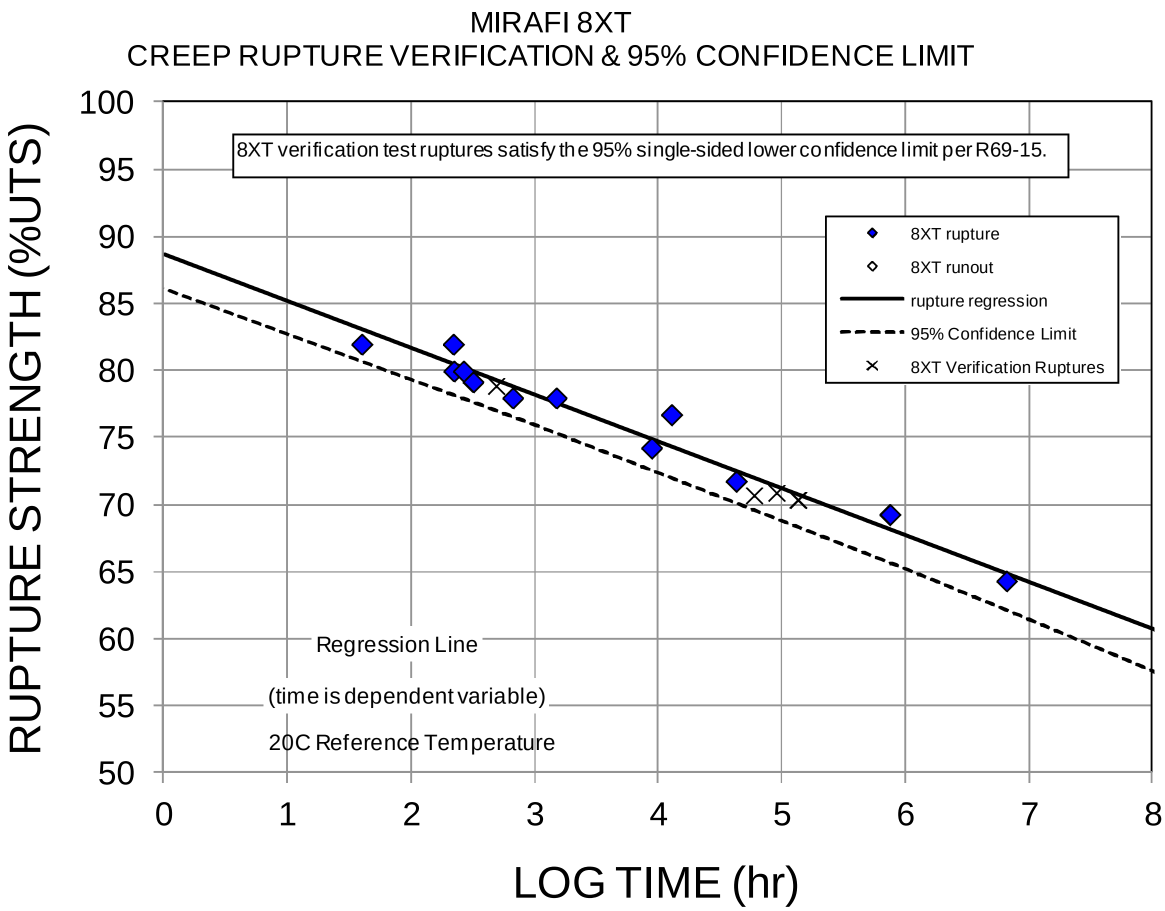

Figure E-5. Comparison of NTPEP verification 8XT creep rupture test results to 95% confidence limit for qualification creep rupture data.

Appendix F: Durability Detailed Test Results

Table F-1. Yarn test results to evaluate susceptibility to hydrolysis

Material: Polyester Yarn
Product Identification: Uncoated 2XT
TRI Log #: E2387-12-06

PARAMETER	TEST REPLICATE NUMBER 1	2	3	MEAN	STD. DEV.
Carboxyl End Group (CEG) Count (Test Method: GRI GG7)					
mmol/Kg	22.0	23.3	21.0	**22.1**	1.2
Molecular Weight (Test Method: GRI GG8)					
Mn (Number average molecular weight)	27,051	31,752	32,907	**30,570**	3,102

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table F-2. UV resistance test results of 2XT geogrid.

TRI Log #: E2387-12-06

PARAMETER	TEST REPLICATE NUMBER 1	2	3	4	5	MEAN	STD. DEV.	PERCENT RETAINED
UV Resistance (ASTM D 4355) Strength Retained measured via single strip tensile (ASTM D 6637, Method A, mod.)								
MD - Number of Ribs per foot:	10.71							
MD - Tensile Strength (lbs) - B	269.4	267.4	275.4	270.9	272.4	**271.1**	3.0	
MD - Tensile Strength (lb/ft) - B	2886	2865	2950	2902	2918	**2904**	32	
MD - Tensile Strength (kN/m) - B	42.1	41.8	43.1	42.4	42.6	**42.4**	0.5	
MD - Tensile Strength (lbs) - E	226.0	218.5	219.3	204.8	242.0	**222.1**	13.5	
MD - Tensile Strength (lb/ft) - E	2421	2341	2349	2194	2593	**2380**	145	**82**
MD - Tensile Strength (kN/m) - E	35.3	34.2	34.3	32.0	37.9	**34.7**	2.1	
MD - Elong. @ Max. Load (%) - B	10.5	10.0	10.9	10.1	10.6	**10.4**	0.4	
MD - Elong. @ Max. Load (%) - E	9.25	9.06	9.66	7.62	10.2	**9.16**	0.96	**88**

B - Baseline Unexposed
E - Exposed for 500 hours of ASTM D 4355 Cycle

MD - Machine Direction TD - Transverse/Cross Machine Direction

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table F-3 Summary of UV resistance test results for Miragid XT geogrid.

Miragrid XT Series Style	Mean Baseline Tensile Strength (lb/ft)	Standard Deviation (lb/ft)	Mean Exposed Tensile Strength (lb/ft)	Standard Deviation (lb/ft)	% Strength Retained
2XT	2,678	31	2,280	30	85
2XT Verification	2,904	32	2,380	145	82

(Conversion: 1 lb/ft = 0.0146 kN/m)

Appendix G: Creep Stiffness Detailed Test Results

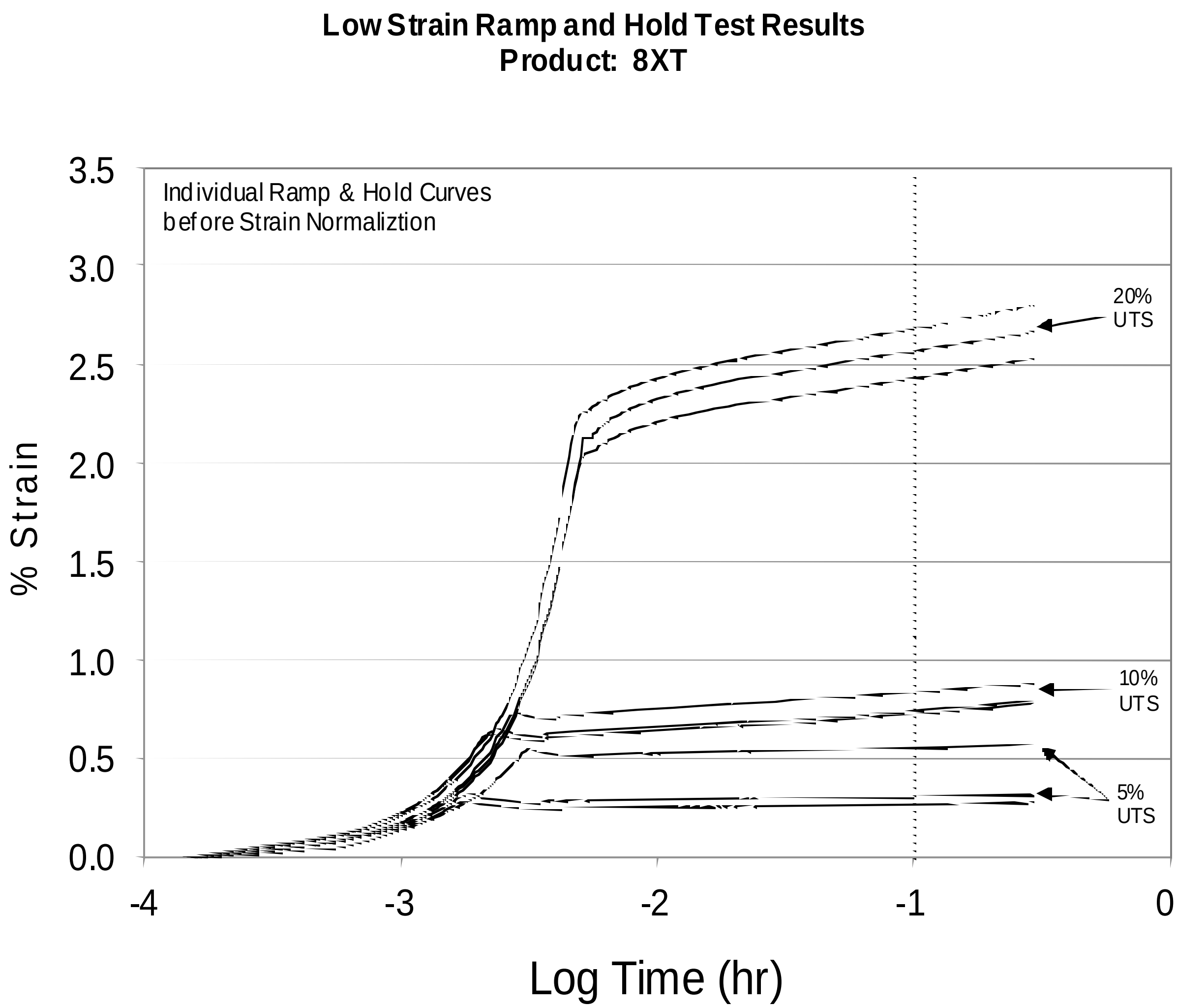

Figure H-4. Low strain ramp and hold tests for 8XT, before strain normalization.

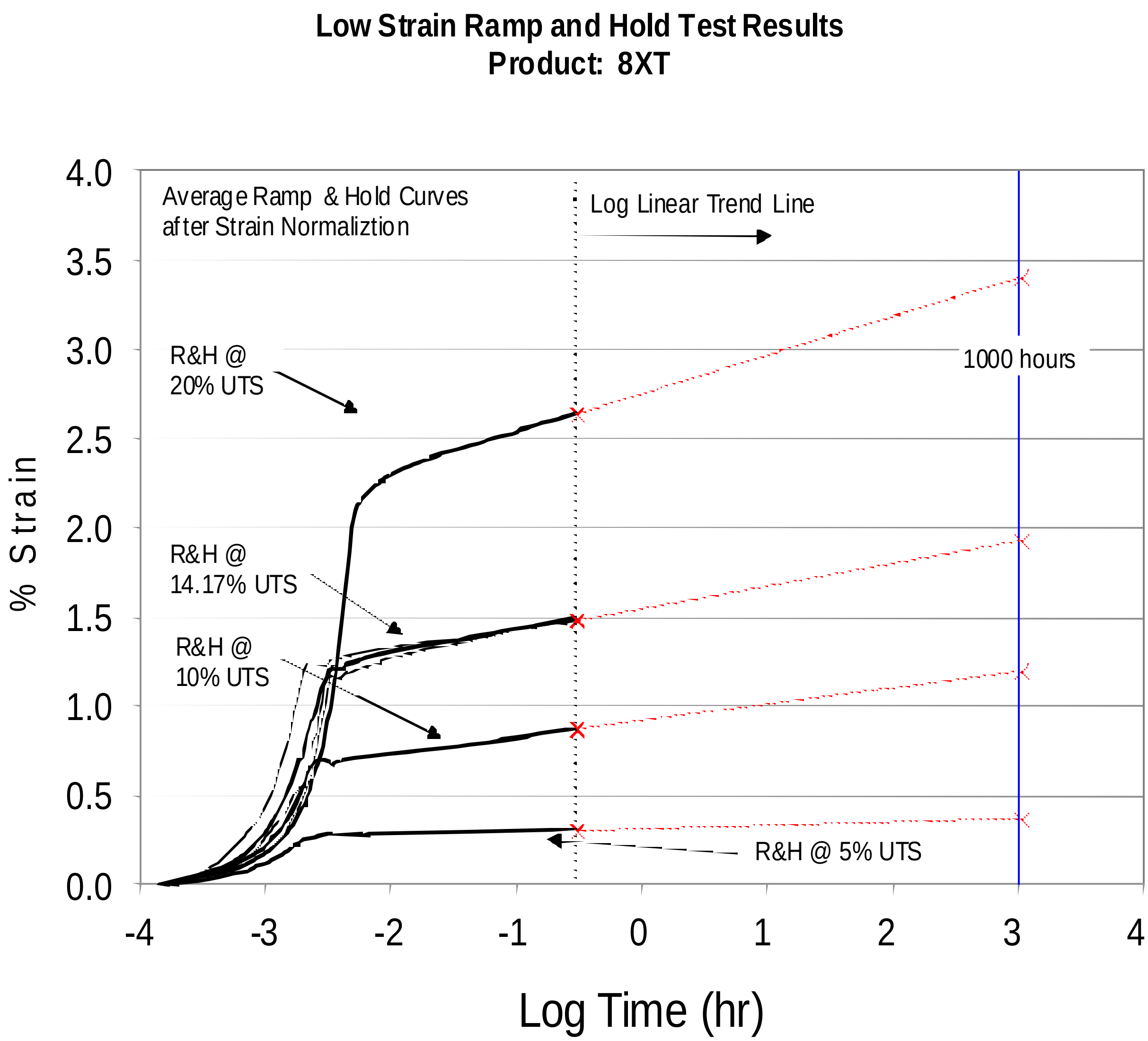

Figure H-5. Low strain ramp and hold tests for 8XT, after strain normalization.

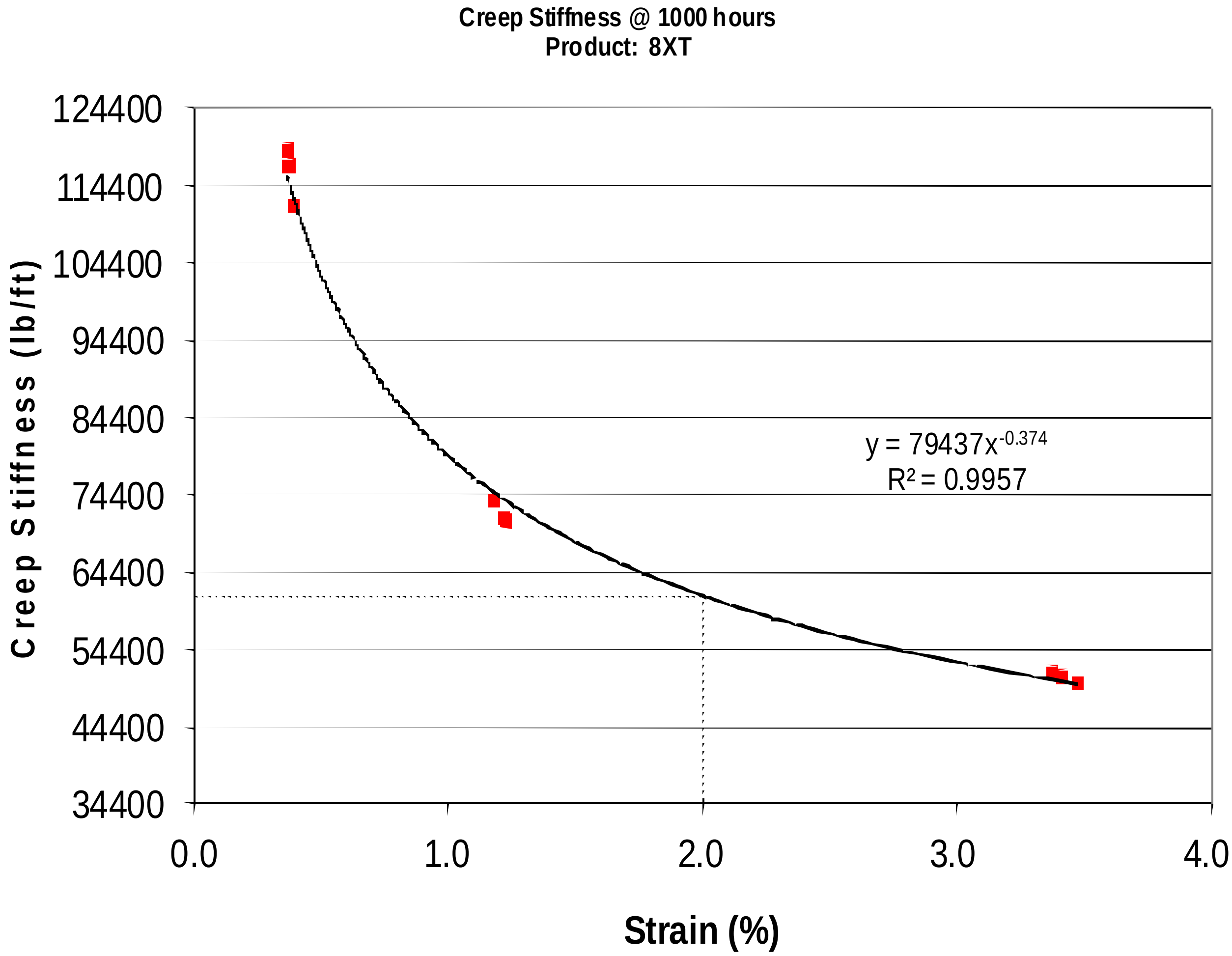

Figure H-6. Creep stiffness versus strain at 1,000 hours for 8XT.

"The National Transportation Product Evaluation Program (NTPEP) was established by the American Association of State Highway and Transportation Officials (AASHTO) in early 1994. The program pools the professional and physical resources of the AASHTO member departments in order to test materials, products and devices of common interest. The primary goals of the program are to provide cost-effective evaluations for the states by eliminating duplication of routine testing by the states; and to reduce duplication of effort by the manufacturers who produce and market commonly used proprietary, engineered products." **NTPEP**

-- Rick Smutzer (IN), former NTPEP Chairman

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