Creep-Rupture Behavior of 1100/192DTEX, 1000 Denier High Tenacity PET Yarn

March 2011

Submitted to:

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Project Manager

CONTENTS

INTRODUCTION AND SUMMARY

Objective
The objective of this effort is to obtain creep performance data on SRF Ltd, TTBT's **1100/192DTEX, 1000 Denier** polyester (PET) yarn. Featured herein is the stepped isothermal method (SIM) of time-temperature superposition (TTS).

Scope
Rapid loading tensile (RLT) tests were conducted on the yarns. The purpose of RLT tests was to determine the ultimate tensile strengths (UTS) of the product that were used to establish the baselines for the SIM tests. The RLT tests were also used to establish additional rupture points.

Four SIM tests at stresses ranging from 70% to 80% UTS were performed on the submitted yarn.

Summary
The RLT and creep results are summarized in the figures in the appendix.

Creep-rupture reduction factors are presented in Table 1. The creep-rupture reduction factor is 100 divided by the % of UTS at the lifetime and temperature of the intended service.

$$RF_{CR} \text{ @114 years} = 100/72.15\% = 1.39$$

Table 1. Summary of *ESTIMATED* Creep-Rupture Results for 1100/192DTEX, 1000 Denier Polyester (PET) Yarn at 20C

Yarn	75-Yr % of UTS / RF_{CR}	114-Yr % of UTS / RF_{CR}
1100/192DTEX, 1000 Denier	72.65 / 1.38	72.15 / 1.39

MATERIALS AND METHODS

Materials
The yarn tested is high-tenacity, 1100/192 DTEX, 1000 denier, multifilament, PET.

Equipment
Test equipment used is listed below:

- Testing platforms: Instron Model 5583 load frame under computer control
- Environmental chamber: TRI Model SIWL – stepped isothermal, wide chamber.
- Grips: Instron Model 2111 horn grips.
- Extensometer: Cross-head displacement
- Temperature controller: Watlow Series 982 programmable temperature controller.
- Heating/cooling- Electrical/liquid $C0_2$
- Data acquisition: HP-3852A data acquisition and control unit & Instron Merlin software.

Procedures

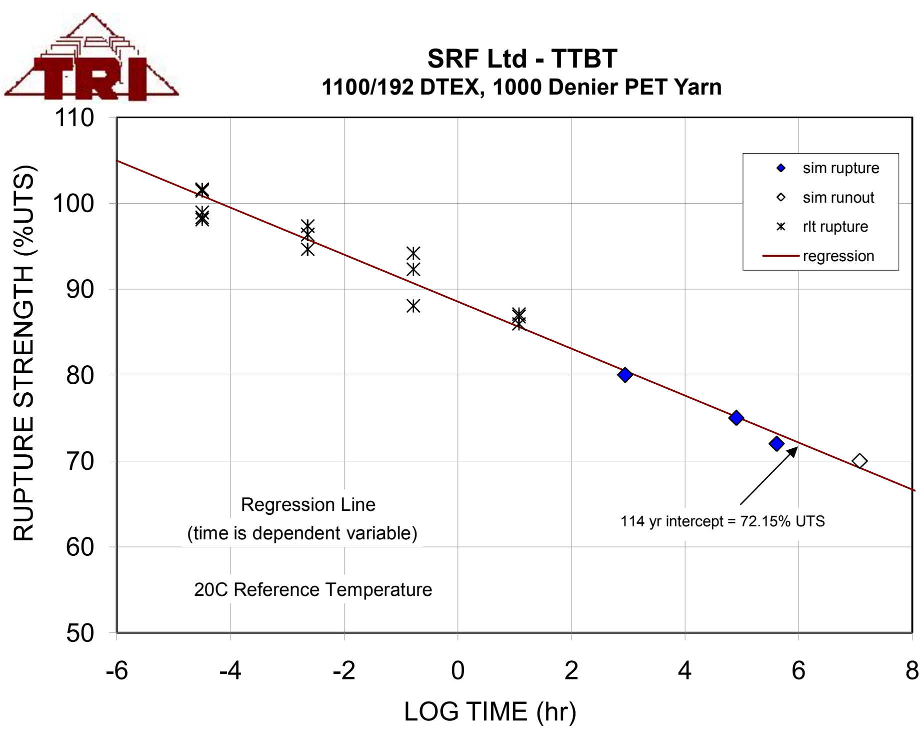
RLT: RLT tests on single yarns were run at a cross-head displacement rate of 10 percent per minute to establish the baseline tensile strength of the specific product being tested

SIM: Testing was conducted in accordance with ASTM D 6992 on single yarn specimens. Each specimen was allowed to reach equilibrium at 20C prior to test initiation. Specimens were then ramped to the specified percentage of UTS at a rate of 1.13 in/min then held at that load. Specimens were held at this load until failure or 60k seconds. Temperature was stepped 14C every 10k seconds starting at 20C and ending at 90C. Strain was measured via cross-head displacement using a 10-inch grip separation, producing an effective gauge length of 11.3 inches.

RESULTS

RLT Results - Tensile results are presented in a figure in the appendix.

Creep-Rupture - Three of four SIM tests were taken to rupture. The creep rupture data along with the RLT data was plotted and evaluated as shown in the following figure.



CONCLUSIONS AND RECOMMENDATIONS

The 75- and 114-year creep rupture-based reduction factors presented in Table 1 have been estimated from the limited creep testing reported herein. These reduction factors are reasonably consistent with previously reported rupture-based reduction factors for yarns used in polyester (PET) geosynthetics. A more extensive testing program would be necessary to confirm the accuracy of these results.

APPENDIX
Backup Tables and Graphs for Creep

Creep Rupture Data

Client: SRF Ltd, TTBT

Product: 1100/192 DTEX
1000 Denier PET Yarn

Stress, % of UTS

SIM DATA: sim file numbers	average $A_T/^oC$	loghrs	data for regression loghrs	data for regression %UTS	sim rupture	rlt rupture	conv'l rupture	sim runout*	conv'l runout*
…1000d-70-11f11.xls	0.0943	7.0737	7.0737	69.99				69.99	
…1000d-75-14f11.xls	0.0950	4.9004	4.9004	75.00	75				
…1000d-80-12f11.xls	0.0900	2.9430	2.9430	80.01	80.01				
…1000d-72-16f11.xls	0.0925	5.6106	5.6106	71.98	71.98				

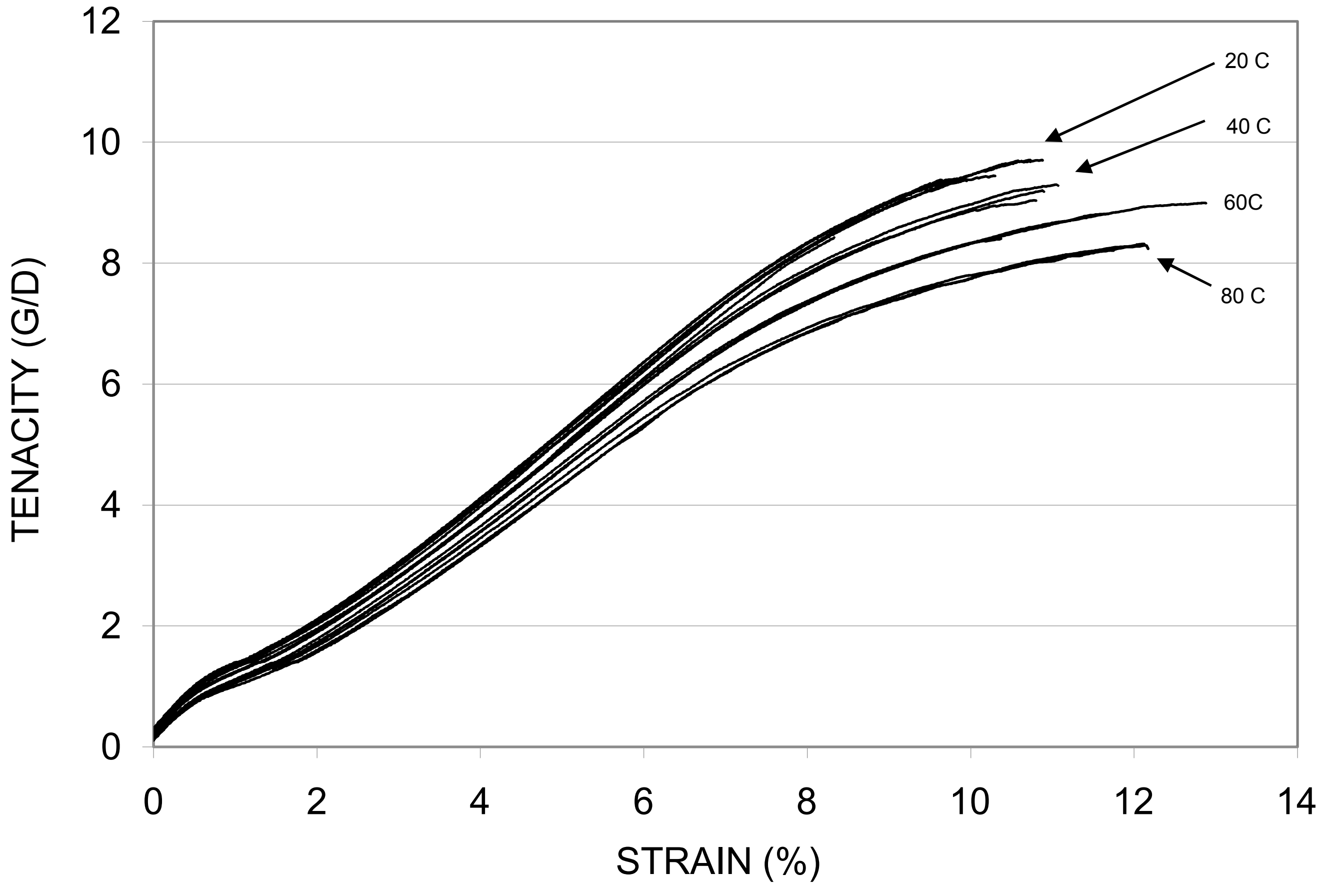
Yarn SIM + RLT
time is dependent variable:

	if time were the y axis	but time is the x axis
slope	-0.36556	-2.73557
intercept	32.37542	88.56507
R^2	0.972942	0.972942
	-6	104.9785
	10	61.20942
6	72.15168	= 114 Year intercept
5.81786	72.64993	= 75 Year intercept

NOTE: Don't include runouts in the regression calculation unless the points lie above the line

RLT DATA:	Temp, C	UTS, lb	rel time	loghrs	%UTS	rlt rupture
shift	20	21.36	0	-4.5	101.43	101.43
-4.5	20	20.71	0	-4.5	98.35	98.35
UTS@20C	20	20.66	0	-4.5	98.11	98.11
21.06	20	20.83	0	-4.5	98.92	98.92
$A_T/^oC$	20	21.4	0	-4.5	101.62	101.62
0.09295	20	21.39	0	-4.5	101.57	101.57
	40	20.5	1.859	-2.641	97.35	97.35
	40	19.93	1.859	-2.641	94.64	94.64
	40	20.29	1.859	-2.641	96.35	96.35
	60	18.54	3.718	-0.782	88.04	88.04
	60	19.83	3.718	-0.782	94.17	94.17
	60	19.44	3.718	-0.782	92.31	92.31
	80	18.34	5.577	1.077	87.09	87.09
	80	18.28	5.577	1.077	86.81	86.81
	80	18.1	5.577	1.077	85.95	85.95

SRF Ltd - TTBT
RAPID LOADING TENSILE TEST RESULTS
1100/192 DTEX, 1000 Denier PET Yarn



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SUMMARY CREEP PARAMETERS: SRF Ltd - TTBT

1100/192 DTEX, 1000 Denier PET Yarn

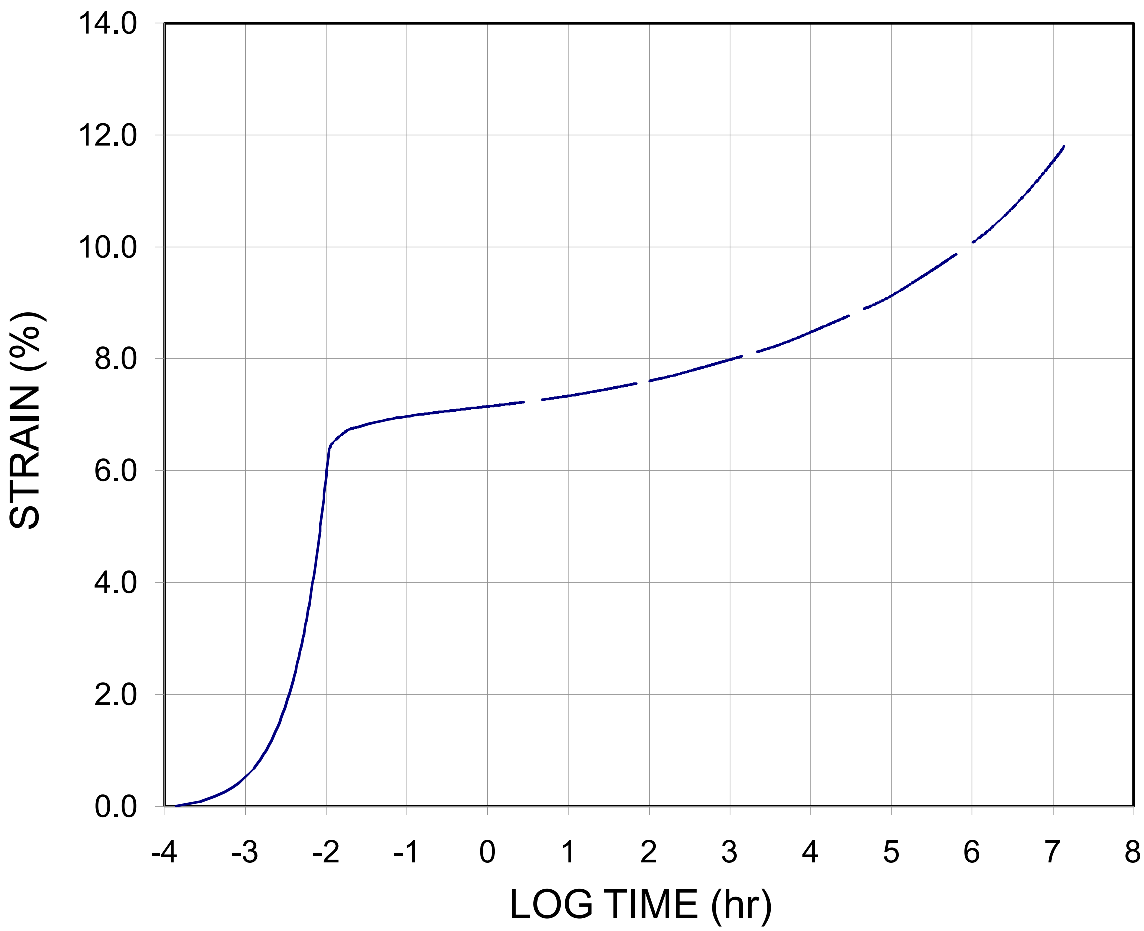
Specimen: 498-s10-1100D-sim70 | Test Date: 11-Feb-11 | Method: SIM (10^4s, 14C), yarn

Average Creep Stress: 6.7 g/d | %UTS: 69.99

Ultimate Tensile Strength: 9.6 g/d | Rupture: NO

Dwell Seq	t'	t	$(t-t')_i$	Vshift(%)	$logA_T$	Temp	$logA_T/T$
1	0	0.5	0.5	-	-	19.33	-
2	9600	10019	419	-0.02	1.3770	33.59	0.0966
3	19500	20009	509	-0.03	1.3092	47.65	0.0931
4	29500	29999	499	-0.03	1.3215	61.84	0.0931
5	39500	39989	489	-0.03	1.3299	75.91	0.0945
6	49500	49979	479	-0.03	1.3384	89.87	0.0959
						AVG	0.0943

Summary	Initial	Final	Units	@20C refT
lab time	38.25	59939	sec	-
$logA_T(t-t')$	1.5826	10.6946	log hours	7.0737
$A_T(t-t')$	-	1568.54	years	1351.91
Strain	6.288	11.797	%	-
Modulus	106.4	56.7	g/d	-



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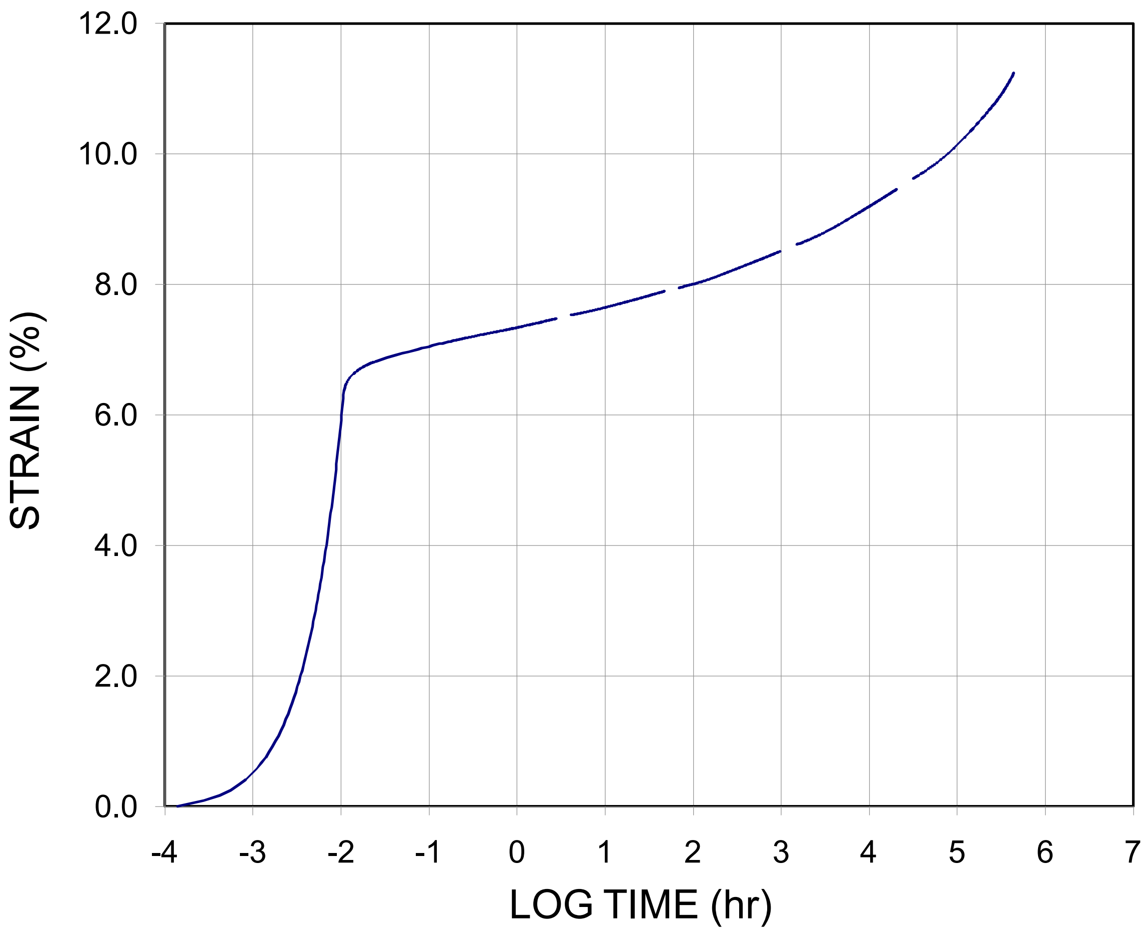
SUMMARY CREEP PARAMETERS: SRF Ltd - TTBT

1100/192 DTEX, 1000 Denier PET Yarn

Specimen: 498-s10-1100D-sim72		Test Date: 16-Feb-11		Method:	SIM (10^4s, 14C), yarn		
	Average Creep Stress:	6.9	g/d			%UTS:	71.98
	Ultimate Tensile Strength:	9.6	g/d			Rupture:	YES

Dwell Seq	t'	t	$(t-t')_i$	Vshift(%)	$logA_T$	Temp	$logA_T/T$
1	0	0.5	0.5	-	-	19.68	-
2	9400	10020	620	-0.02	1.2075	33.60	0.0867
3	19500	20010	510	-0.03	1.3173	47.81	0.0927
4	29500	30000	500	-0.03	1.3214	61.69	0.0952
5	39500	39990	490	-0.03	1.3297	75.60	0.0956
6							
						AVG	0.0925

Summary	Initial	Final	Units	@20C refT
lab time	38.39	49950	sec	-
$logA_T(t-t')$	1.5842	9.1950	log hours	5.6106
$A_T(t-t')$	-	49.65	years	46.54
Strain	6.310	11.238	%	-
Modulus	109.1	61.2	g/d	-



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SUMMARY CREEP PARAMETERS: SRF Ltd - TTBT
1100/192 DTEX, 1000 Denier PET Yarn

Specimen: 498-s10-1100D-sim75 Test Date: 14-Feb-11 Method: SIM (10^4s, 14C), yarn

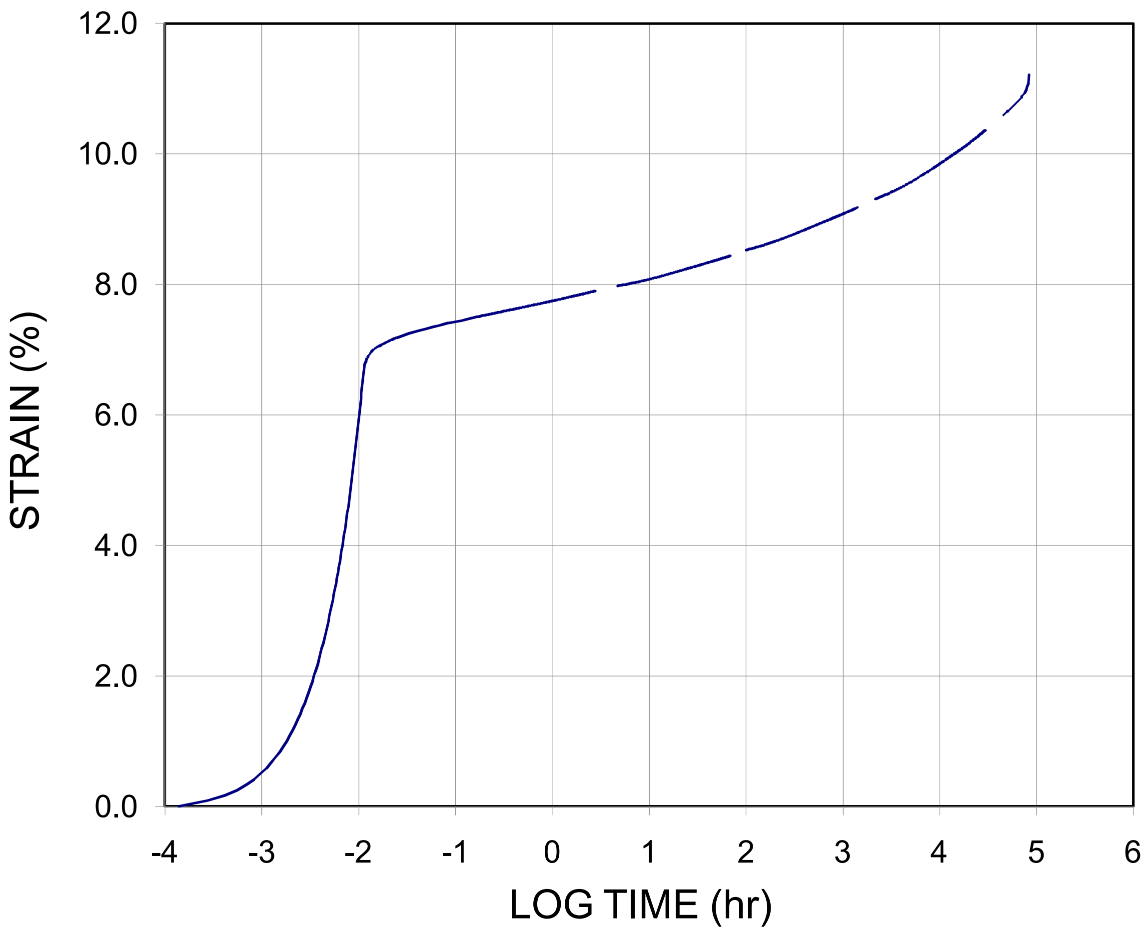
Average Creep Stress: 7.2 g/d %UTS: 75.00

Ultimate Tensile Strength: 9.6 g/d Rupture: YES

Dwell Seq	t'	t	$(t\text{-}t')_i$	Vshift(%)	$logA_T$	Temp	$logA_T/T$
1	0	0.5	0.5	-	-	19.77	-
2	9600	10020	420	-0.02	1.3767	33.61	0.0995
3	19500	20010	510	-0.03	1.3089	47.68	0.0930
4	29500	30000	500	-0.03	1.3213	61.71	0.0942
5	39500	39990	490	-0.09	1.3296	75.97	0.0932
6							

Summary	Initial	Final	Units	@20C refT
lab time	40.48	40890	sec	-
$logA_T(t\text{-}t')$	1.6072	8.4794	log hours	4.9004
$A_T(t\text{-}t')$	-	9.56	years	9.07
Strain	6.658	11.212	%	-
Modulus	107.7	64.0	g/d	-

AVG 0.0950



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SUMMARY CREEP PARAMETERS: SRF Ltd - TTBT

1100/192 DTEX, 1000 Denier PET Yarn

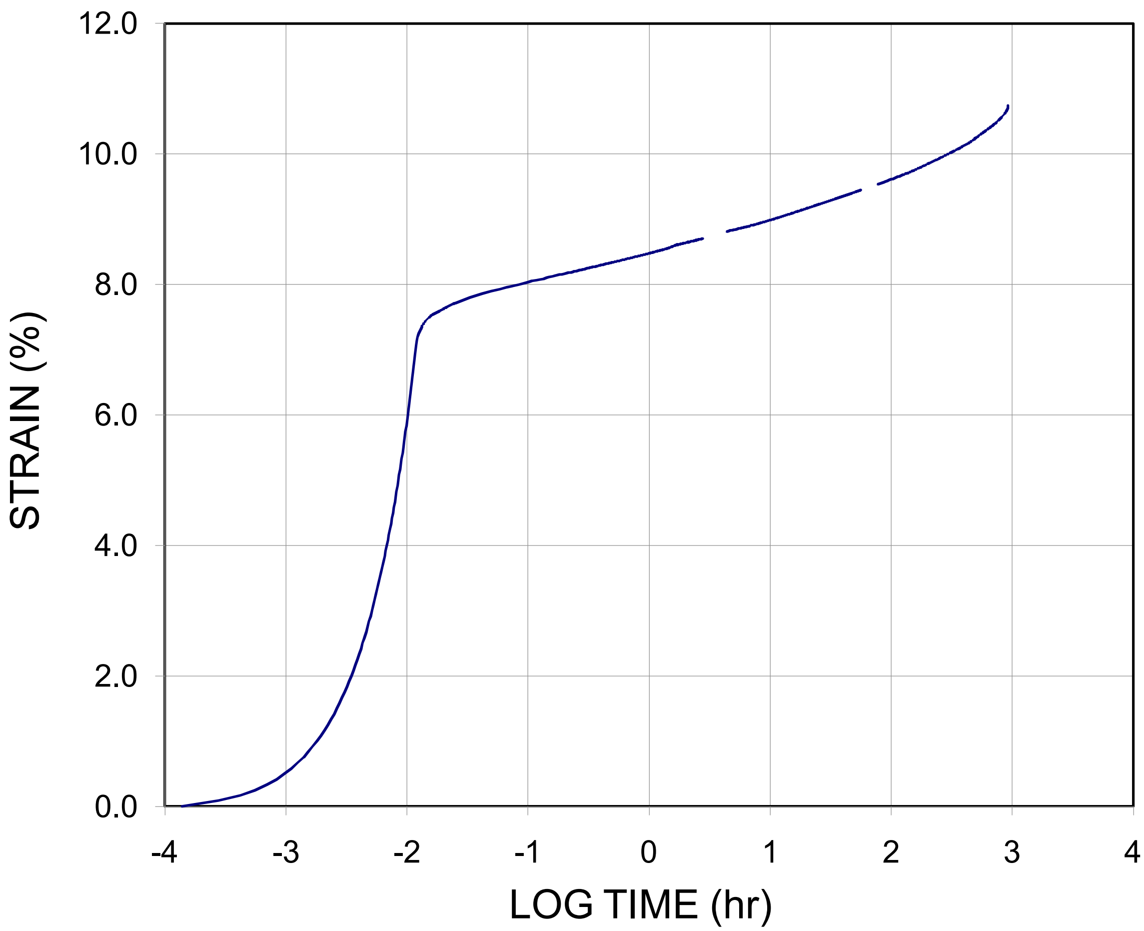
Specimen: 498-s10-1100D-sim80 Test Date: 12-Feb-11 Method: SIM (10^4s, 14C), yarn

Average Creep Stress: 7.6 g/d %UTS: 80.01

Ultimate Tensile Strength: 9.6 g/d Rupture: YES

Dwell Seq	t'	t	$(t-t')_i$	Vshift(%)	$logA_T$	Temp	$logA_T/T$
1	0	0.5	0.5	-	-	19.77	-
2	9500	10020	520	-0.02	1.2838	33.62	0.0927
3	19400	20010	610	-0.07	1.2353	47.75	0.0874
4							
5							
6							
						AVG	0.0900

Summary	Initial	Final	Units	@20C refT
lab time	42.99	29430	sec	-
$logA_T(t-t')$	1.6334	6.5204	log hours	2.9430
$A_T(t-t')$	-	0.11	years	0.10
Strain	7.077	10.740	%	-
Modulus	108.1	71.3	g/d	-



March 11, 2013

Mail To:

Mr. Amit Agarwal
CTM Technical Textiles
205 New Cloth Market
Ahmedabad
India

Email: amit@ctmtechtextile.com

Bill To:

<= Same

Dear Mr. Agarwal:

Thank you for consulting TRI/Environmental, Inc. (TRI) for your geosynthetics testing needs. TRI is pleased to submit this final report for laboratory testing.

TRI Job Reference Number:	E2280-80-10
Material(s) Tested:	1 PET Yarn
Test(s) Requested:	Carboxyl End Group (CEG) Count (ASTM D 7409, GRI-GG7) Molecular Weight by Viscosity (ASTM D 4603, GRI-GG8)

If you have any questions or require any additional information, please call us at 1-800-880-8378.

Sincerely,

Jarrett A. Nelson

Jarrett A. Nelson
Special Projects Manager
Geosynthetic Services Division
www.GeosyntheticTesting.com

LABORATORY TEST RESULTS

TRI Client: CTM Technical Textiles

Material: PET Yarn
Sample Identification: PET Yarn used to manufacture 40 kN/m & 80 kN/m Geogrid
TRI Log #: E2280-80-10

PARAMETER	TEST REPLICATE NUMBER 1	2	3	MEAN	STD. DEV.
Carboxyl End Group (CEG) Count (ASTM D 7409, GRI-GG7)					
mmol/Kg	12.1	11.9	12.2	**12.1**	0.2
Molecular Weight by Viscosity (ASTM D4603, GRI-GG8)					
Relative Viscosity	1.56	1.57	1.57	**1.57**	0.01
Intrinsic Viscosity (dL/g)	0.978	0.980	0.976	**0.978**	0.002
Molecular Weight (g/mol)	37,116	37,239	36,963	**37,106**	138

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. TRI neither accepts responsibility for nor makes claim as to the final use and purpose of the material. TRI observes and maintains client confidentiality. TRI limits reproduction of this report, except in full, without prior approval of TRI.

GeosyntheticTesting.com
9063 Bee Caves Road / Austin, TX 78733 / 512 263 2101 / fax: 512 263 2558

March 11, 2013

Mail To:

Mr. Amit Agarwal
CTM Technical Textiles
205 New Cloth Market
Ahmedabad
India

Email: amit@ctmtechtextile.com

Bill To:

<= Same

Dear Mr. Agarwal:

Thank you for consulting TRI/Environmental, Inc. (TRI) for your geosynthetics testing needs. TRI is pleased to submit this final report for laboratory testing.

TRI Job Reference Number:	E2280-79-08
Material(s) Tested:	1 PET Geogrid(s)
Test(s) Requested:	UV Resistance (EN ISO 12224)

If you have any questions or require any additional information, please call us at 1-800-880-8378.

Sincerely,

Jarrett A. Nelson

Jarrett A. Nelson
Special Projects Manager
Geosynthetic Services Division
www.GeosyntheticTesting.com

GEOGRID TEST RESULTS

TRI Client: CTM Technical Textiles

Material: Coated PET Geogrid
Sample Identification: 40 kN/m
TRI Log #: E2280-79-08

PARAMETER	TEST REPLICATE NUMBER 1	2	3	4	5	MEAN	STD. DEV.	Percent Retained
UV Resistance (EN ISO 10319)								
Strength Retained measured via single rib tensile (ISO 10319, mod.)								
MD Number of Ribs per foot:	10.2							
MD - Tensile Strength (lbs) - B	338	336	333	329	333	**334**	3	
MD - Tensile Strength (lb/ft) - B	3448	3427	3397	3356	3397	**3405**	35	
MD - Tensile Strength (kN/m) - B	50.3	50.0	49.6	49.0	49.6	**49.7**	0.5	
MD - Tensile Strength (lbs) - E	259	259	252	245	253	**254**	6	
MD - Tensile Strength (lb/ft) - E	2642	2642	2570	2499	2581	**2587**	59	
MD - Tensile Strength (kN/m) - E	38.6	38.6	37.5	36.5	37.7	**37.8**	0.9	**76**
MD - Elong. @ Max. Load (%) - B	13.6	13.5	13.0	13.0	14.0	**13.4**	0.4	
MD - Elong. @ Max. Load (%) - E	11.4	11.5	10.9	11.2	11.4	**11.3**	0.2	**84**

B - Baseline Unexposed
E - UV Exposed

Type of Light Source: UVA-340 lamps
Irradiance Set Point: 0.95
Total Radiant Exposure: 50 MJ/m2
Cyclic Conditions: 5 hours dry interval / light exposure at a black standard temperature of 50 +/- 3C
1 hour water spray at a black standard temperature of 25 +/- 3C

MD - Machine Direction TD - Transverse/Cross Machine Direction

GeosyntheticTesting.com
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Installation Damage Testing of Coated PET Geogrid: 40 kN/m In Silty Sand

March 2013

<u>Submitted to:</u>
Mr. Mr. Amit Agarwal
CTM Technical Textiles Ltd.
205 New Cloth Market
Ahmedabad
India

Email: amit@ctmgeosynthetics.com

<u>Submitted by:</u>
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9063 Bee Caves Road
Austin, TX 78733

C. Joel Sprague
Project Manager

March 20, 2013

Mr. Mr. Amit Agarwal
CTM Technical Textiles Ltd.
205 New Cloth Market
Ahmedabad
India

Email: amit@ctmgeosynthetics.com

SUBJECT: **Installation Damage Testing of 40 kN/m Coated PET Geogrid In Silty Sand**

Dear Mr. Agarwal:

TRI/Environmental, Inc. (TRI) is pleased to present this final report for installation damage testing of soil reinforcement geosynthetics. 40 kN/m coated PET geogrid was submitted for exposure to silty sand (Type 3). Testing was performed in the machine direction.

Technical Approach

A convenient method for applying installation damage to geosynthetics that allows for exhumation of the test samples while avoiding unintended damage was initially developed by Watts and Brady of the Transport Research Laboratory (TRL) in the United Kingdom. The BBA has developed a standard laboratory simulation of installation damage based on this procedure. The procedure generally conforms to ASTM D 5818 requirements. TRI used this procedure along with available TRI soils/aggregates to obtain the results reported herein. A short review is provided below.

Exposure Procedure

Since compaction typically occurs parallel to the face of retaining walls and the contour lines of slopes, TRI placed the machine direction perpendicular to the running direction of the compaction equipment. To initiate the exposure procedure, four steel plates each measuring 42-inches x 52-inches (1.07 m x 1.32 m), equipped with lifting chains, were placed on a flat clean surface of hardened limestone rock. The longer side of the plates is parallel to the running direction of the compaction equipment. A layer of soil/aggregate was then placed over the adjacent plates to an approximate compacted thickness of 8 inches (0.20 m). Next, each of four coupons of the tested geosynthetic sample was placed on the compacted soil over an area corresponding to an underlying steel plate. To complete the installation, the second layer of soil was placed and compacted over the coupons to a thickness of 8 inches (0.20 m) using a vibratory compactor. To guide and contain the compaction process, braced railroad ties defined the long (208+ in. / 5.28 m) edges of the installation.

Compaction was accomplished using a 4550 kg (10,000 lb) ride-on steel-wheeled roller with vibratory capability. All compaction and exhumation procedures, as well as laboratory soil classification and field thickness measurements, were performed under the supervision of TRI's Lead Geotechnical Technician. Density measurements were made by a qualified geotechnical technician.

The following construction quality control measures are typically followed during exposure.

- Proctor and sieve analyses were performed on each soil/aggregate, when possible. (Proctors could not be performed on Types 1 and 2)
- Lift thickness measurements were made after soil/aggregate compaction.
- When possible, moisture and density measurements were made on each lift using a nuclear density gage to confirm that densities >90% of modified Proctor (per ASTM D 1557) were being achieved.

In addition to the above, the number of compaction equipment loadings (i.e. passes) was recorded for each exposure and corresponding soil compaction effort.

To exhume the geosynthetic, railroad ties were removed and one end of each plate was raised with lifting chains. After raising the plate to about 45°, soil located near the bottom of the leaning plate was removed and, if necessary, the plate was struck with a sledgehammer to loosen the fill. The covering soil/aggregate was then carefully removed from the surface while "rolling" the geosynthetic away from the underlying soil/aggregate. This procedure assured a minimum of exhumation stress.

Photographs representative of the procedures are included in the Appendix of this report.

Gradation of backfill material

Each geosynthetic was exposed to soils/aggregates chosen by the client from a range of available stockpiles having different gradations. The soil/aggregate used in this testing was silty sand (Type 3). Soil gradation curves may be found in the Appendix of this report.

Specimen Preparation and Wide Width Tensile Testing

Upon removal from the exposure site, exposure coupons were allowed to dry. Coupons were then cleaned by removing surface soil via light hand sweeping. Soil trapped within the geosynthetic structure was not removed by washing or otherwise stressing the geosynthetic. No additional cleaning was performed and specimens were cut and tested in their soiled condition.

The evaluation of RF_{ID} for the geogrid was based on the results of wide width tensile tests per ISO 10319, *Geosynthetics -- Wide-width tensile test*. The multi-rib specimens were tested using an Instron Model 5589 tension/compression machine equipped with Demgen hydraulic grips and Instron Bluehill data acquisition software. Strain was monitored using an Instron non-contacting video extensometer. After exposure was complete, all baseline and exposed wide width tensile tests were performed during the same testing period.

Sampling and Specimen Selection

Each set of tensile tests of an exposed style of geosynthetic were compared with tensile tests of the same style of the geosynthetic in an unexposed, or "baseline" condition. It should be noted that tensile specimens were not representative of the roll width, but instead were specific to a defined region within the roll width. This approach was accomplished by cutting five coupons (four for exposure and one for baseline) measuring approximately 42 inches x 52 inches (1.07 m x 1.32 m) in sequence along the length of the geosynthetic. This technique captured common yarns and/or ribs in the tested specimens to minimize variation.

Tensile tests of the product before exposure to installation conditions: The specific sampling procedure as described above was followed to assure that individual baseline specimen populations were developed from the same region of the roll width as those specimens dedicated to installation damage exposure.

Tensile tests of specimens taken from the damaged material after installation: The coupons and candidate specimens to be exposed to installation stresses were selected prior to exposure and installed in accordance with a defined sampling plan (via ASTM D 5818). Exposure coupons were laid within the exposure lane in consecutive order, each representing five specimens. Thus, the exposure lane was constructed with specimens 1 through 20 as shown below.

Exposure Coupon 1					Exposure Coupon 2					Exposure Coupon 3					Exposure Coupon 4				
1	2	3	4	5	11	12	13	14	15	6	7	8	9	10	16	17	18	19	20

Upon exhumation of the exposed coupons, specimens were cut and tested in numerical order. A minimum of ten exposed specimens from each testing condition was systematically selected for testing from the twenty candidate specimens. The test results were averaged and compared to the average of the baseline specimens.

Tensile test results for both virgin (i.e. baseline) and damaged (i.e. exhumed) specimens: All tensile test results have been tabularized and may be found in the Appendix of this report.

Test Results

Retained strengths for each of the tested geosynthetic styles are presented in Table 1.

Table 1. Retained Strength for Tested Geosynthetics

Style	Gradation Type 3 (Silty Sand)	
	% Retained	RF_{ID}
40 kN/m - MD	92.3	1.08

MD = machine direction;

Conclusion

TRI is very pleased to present this report for installation damage testing of soil reinforcing geosynthetics. If you have any questions or require any additional information, please call me at 1-864-242-2220.

Sincerely,

C. Joel Sprague, P.E.
Senior Engineer

cc: Jarrett Nelson

APPENDIX OF TEST RESULTS

Installation Damage Results

Soil / Aggregate Gradations

Construction Quality Control Summary

Representative Pictures

INSTALLATION DAMAGE
TEST RESULTS

TRI/Environmental, Inc.

A Texas Research International Company

3/11/2013

CTM Technical Textiles

INSTALLATION DAMAGE TESTING - WIDE WIDTH TENSILE (ISO 10319)

40 kN/m

Machine Direction

Sample Identification	Specimen Number	Ribs per Foot Width	Number of Ribs Tested	Maximum Load (lbs)	Maximum Load (lbs/ft)	Maximum Load (kN/m)	Elongation @ Break (%)	Load @ 2% lbs	Load @ 2% (lbs/ft)	Load @ 2% (kN/m)	Load @ 5% lbs	Load @ 5% (lbs/ft)	Load @ 5% (kN/m)	Load @ 10% lbs	Load @ 10% (lbs/ft)	Load @ 10% (kN/m)
40 kN/m Baseline	1	10.2	7	2172	3165	46.2	12.0	384	560	8.2	605	881	12.9	1733	2525	36.9
	2	10.2	7	2297	3348	48.9	12.5	386	562	8.2	612	891	13.0	1763	2569	37.5
	3	10.2	7	2140	3120	45.5	12.3	373	544	7.9	587	856	12.5	1728	2518	36.8
	4	10.2	7	2213	3225	47.1	12.7	377	549	8.0	593	865	12.6	1691	2464	36.0
	5	10.2	7	2244	3271	47.8	12.4	374	545	8.0	596	869	12.7	1746	2545	37.2
Average				2213	3226	47.1	12.4	379	552	8.1	598	872	12.7	1732	2524	36.9
Standard Deviation				61.3	89.3	1.3	0.3	5.8	8.5	0.1	9.7	14.1	0.2	26.8	39.0	0.6
% COV				2.8	2.8	2.8	2.4	1.5	1.5	1.5	1.6	1.6	1.6	1.5	1.5	1.5

Machine Direction

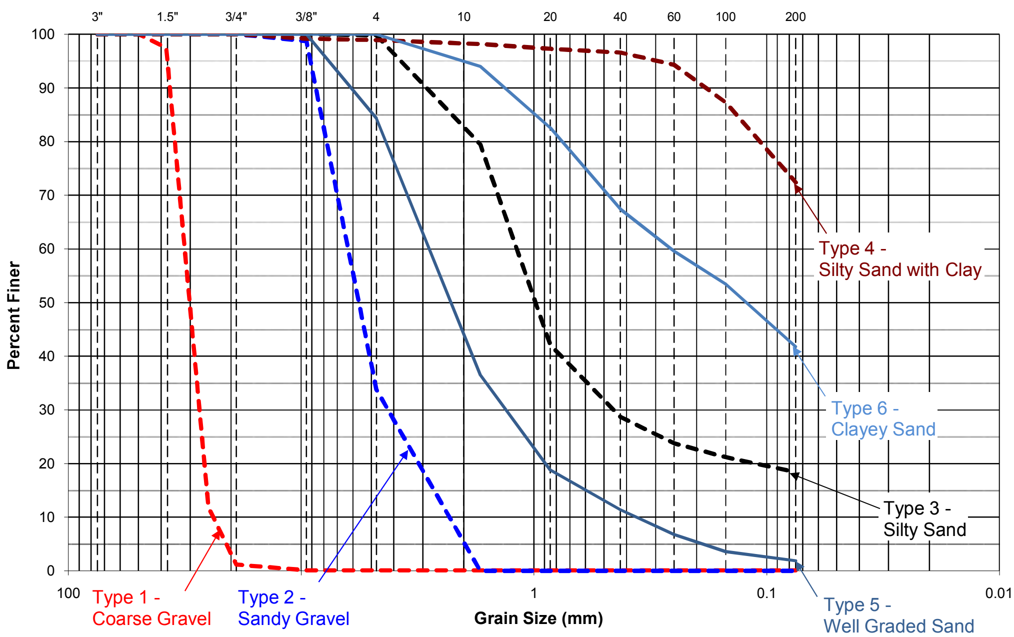
Sample Identification	Specimen Number	Ribs per Foot Width	Number of Ribs Tested	Maximum Load (lbs)	Maximum Load (lbs/ft)	Maximum Load (kN/m)	Elongation @ Break (%)	Load @ 2% lbs	Load @ 2% (lbs/ft)	Load @ 2% (kN/m)	Load @ 5% lbs	Load @ 5% (lbs/ft)	Load @ 5% (kN/m)	Load @ 10% lbs	Load @ 10% (lbs/ft)	Load @ 10% (kN/m)
40 kN/m installed in Gradation 3 (Sand)	1	10.2	7	2048	2984	43.6	11.4	376	548	8.0	590	860	12.6	1695	2471	36.1
	2	10.2	7	2128	3101	45.3	11.8	384	559	8.2	606	883	12.9	1745	2544	37.1
	3	10.2	7	2145	3126	45.6	12.1	380	554	8.1	588	857	12.5	1725	2514	36.7
	4	10.2	7	1953	2847	41.6	10.7	385	562	8.2	617	899	13.1	1800	2624	38.3
	5	10.2	7	2029	2957	43.2	11.0	372	542	7.9	598	872	12.7	1794	2615	38.2
	6	10.2	7	2076	3025	44.2	11.8	374	545	7.9	594	866	12.6	1760	2565	37.4
	7	10.2	7	2040	2973	43.4	11.9	382	557	8.1	602	877	12.8	1744	2542	37.1
	8	10.2	7	1879	2739	40.0	10.3	387	564	8.2	609	887	13.0	1803	2628	38.4
	9	10.2	7	2123	3095	45.2	11.6	377	549	8.0	592	862	12.6	1762	2568	37.5
	10	10.2	7	2014	2935	42.9	11.1	385	561	8.2	606	883	12.9	1750	2551	37.2
Average				2043	2978	43.5	11.4	380	554	8.1	600	875	12.8	1758	2562	37.4
Standard Deviation				82.4	120.1	1.8	0.6	5.2	7.7	0.1	9.2	13.4	0.2	34.3	50.0	0.7
% COV				4.0	4.0	4.0	5.2	1.4	1.4	1.4	1.5	1.5	1.5	2.0	2.0	2.0

Percent Retained			92.3	92.3	92.3	91.7	100.3	100.3	100.3	100.3	100.3	100.3	101.5	101.5	101.5
RFid			**1.08**	**1.08**	**1.08**										

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. TRI neither accepts responsibility for nor makes claim as to the final use and purpose of the material. TRI observes and maintains client confidentiality. TRI limits reproduction of this report, except in full, without prior approval of TRI.

SOIL/AGGREGATE GRADATIONS

Grain Size Distribution - 2012 Standard Soils



INSTALLATION DAMAGE SOILS							
US Sieve No.	Sieve Size (mm)	Percent Passing					
		Type 1 (Coarse Gravel)	Type 2 (Sandy Gravel)	Type 3 (Silty Sand)	Type 4 (Silty Sand with Clay)	Type 5 (Well Graded Sand)	Type 6 (Clayey Sand)
3 - in.	75	100.0	100.0	100.0	100.0	100.0	100.0
2 - in.	50	100.0	100.0	100.0	100.0	100.0	100.0
1.5 - in.	38	97.5	100.0	100.0	100.0	100.0	100.0
1 - in.	25	11.8	100.0	100.0	100.0	100.0	100.0
3/4 - in.	19	1.2	100.0	100.0	100.0	100.0	100.0
3/8 - in.	9.5	0.1	98.7	100.0	99.2	100.0	100.0
No. 4	4.75	0.1	33.8	99.8	98.9	84.3	100.0
No. 10	1.7	0.1	0.0	79.5	98.2	36.5	94.0
No. 20	0.85	0.1	0.0	42.1	97.3	18.8	82.6
No. 40	0.425	0.1	0.0	28.7	96.6	11.4	67.4
No. 60	0.25	0.1	0.0	23.8	94.3	6.8	59.6
No. 100	0.15	0.1	0.0	21.2	87.3	3.6	53.4
No. 200	0.075	0.1	0.0	18.4	72.4	1.9	41.8
Liquid Limit, %		-	-	-	28	-	25
Plasticity Index, %		-	-	-	14	-	9
Angularity		Angular to Subangular	Angular	Angular to Subangular	-	Angular to Subangular	-
USCS Classification		GP	GP	SM	CL-ML	SW	SC
		Poorly Graded Gravel	Poorly Graded Gravel with Sand	Silty Sand	Silty Sand with Clay	Graded Sand	Sand with Clay

CONSTRUCTION QUALITY CONTROL DURING INSTALLATION DAMAGE EXPOSURE

SUMMARY OF OBSERVATIONS AND MEASUREMENTS

				FIRST LIFT				SECOND LIFT			
DATE	CLIENT	MATERIAL	SOIL TYPE	LOCATION	DENSITY	MOISTURE	# PASSES	LOCATION	DENSITY	MOISTURE	# PASSES
06-Mar-13	CTM	40 kN/m	1	NA NA	NA NA	NA NA	4	NA NA	NA NA	NA NA	4
06-Mar-13	CTM	80 kN/m	1	NA NA	NA NA	NA NA	4	NA NA	NA NA	NA NA	4
06-Mar-13	CTM	40 kN/m	3	NA NA	NA NA	NA NA	6	NA NA	NA NA	NA NA	6
06-Mar-13	CTM	80 kN/m	3	NA NA	NA NA	NA NA	6	NA NA	NA NA	NA NA	6

REPRESENTATIVE PICTURES
OF
EXPOSURE PROCEDURE

(Typical Pictures from Testing a Range of Geosynthetics)

LIFTING PLATES POSITIONED BETWEEN TIES AND COVERED WITH FIRST LIFT OF COMPACTED SOIL/AGGREGATE

GEOSYNTHETIC POSITIONED OVER COMPACTED BASE AND COVERED

COVER SOIL/AGGREGATE IS UNIFORMLY SPREAD AND COMPACTED USING FIELD-SCALE EQUIPMENT AND PROCEDURES

THE DENSITY OF COMPACTED SOIL IS MEASURED

THE STEEL PLATES ARE TILTED TO FACILITATE EXHUMATION

Installation Damage Testing of Coated PET Geogrid: 80 kN/m In Silty Sand

March 2013

<u>Submitted to:</u>
Mr. Mr. Amit Agarwal
CTM Technical Textiles Ltd.
205 New Cloth Market
Ahmedabad
India

Email: amit@ctmgeosynthetics.com

<u>Submitted by:</u>
TRI/Environmental, Inc.
9063 Bee Caves Road
Austin, TX 78733

C. Joel Sprague
Project Manager

March 20, 2013

Mr. Mr. Amit Agarwal
CTM Technical Textiles Ltd.
205 New Cloth Market
Ahmedabad
India

Email: amit@ctmgeosynthetics.com

SUBJECT: **Installation Damage Testing of 80 kN/m Coated PET Geogrid In Silty Sand**

Dear Mr. Agarwal:

TRI/Environmental, Inc. (TRI) is pleased to present this final report for installation damage testing of soil reinforcement geosynthetics. 80 kN/m coated PET geogrid was submitted for exposure to silty sand (Type 3). Testing was performed in the machine direction.

Technical Approach

A convenient method for applying installation damage to geosynthetics that allows for exhumation of the test samples while avoiding unintended damage was initially developed by Watts and Brady of the Transport Research Laboratory (TRL) in the United Kingdom. The BBA has developed a standard laboratory simulation of installation damage based on this procedure. The procedure generally conforms to ASTM D 5818 requirements. TRI used this procedure along with available TRI soils/aggregates to obtain the results reported herein. A short review is provided below.

Exposure Procedure

Since compaction typically occurs parallel to the face of retaining walls and the contour lines of slopes, TRI placed the machine direction perpendicular to the running direction of the compaction equipment. To initiate the exposure procedure, four steel plates each measuring 42-inches x 52-inches (1.07 m x 1.32 m), equipped with lifting chains, were placed on a flat clean surface of hardened limestone rock. The longer side of the plates is parallel to the running direction of the compaction equipment. A layer of soil/aggregate was then placed over the adjacent plates to an approximate compacted thickness of 8 inches (0.20 m). Next, each of four coupons of the tested geosynthetic sample was placed on the compacted soil over an area corresponding to an underlying steel plate. To complete the installation, the second layer of soil was placed and compacted over the coupons to a thickness of 8 inches (0.20 m) using a vibratory compactor. To guide and contain the compaction process, braced railroad ties defined the long (208+ in. / 5.28 m) edges of the installation.

Compaction was accomplished using a 4550 kg (10,000 lb) ride-on steel-wheeled roller with vibratory capability. All compaction and exhumation procedures, as well as laboratory soil classification and field thickness measurements, were performed under the supervision of TRI's Lead Geotechnical Technician. Density measurements were made by a qualified geotechnical technician.

The following construction quality control measures are typically followed during exposure.

- Proctor and sieve analyses were performed on each soil/aggregate, when possible. (Proctors could not be performed on Types 1 and 2)
- Lift thickness measurements were made after soil/aggregate compaction.
- When possible, moisture and density measurements were made on each lift using a nuclear density gage to confirm that densities >90% of modified Proctor (per ASTM D 1557) were being achieved.

In addition to the above, the number of compaction equipment loadings (i.e. passes) was recorded for each exposure and corresponding soil compaction effort.

To exhume the geosynthetic, railroad ties were removed and one end of each plate was raised with lifting chains. After raising the plate to about 45°, soil located near the bottom of the leaning plate was removed and, if necessary, the plate was struck with a sledgehammer to loosen the fill. The covering soil/aggregate was then carefully removed from the surface while "rolling" the geosynthetic away from the underlying soil/aggregate. This procedure assured a minimum of exhumation stress.

Photographs representative of the procedures are included in the Appendix of this report.

Gradation of backfill material

Each geosynthetic was exposed to soils/aggregates chosen by the client from a range of available stockpiles having different gradations. The soil/aggregate used in this testing was silty sand (Type 3). Soil gradation curves may be found in the Appendix of this report.

Specimen Preparation and Wide Width Tensile Testing

Upon removal from the exposure site, exposure coupons were allowed to dry. Coupons were then cleaned by removing surface soil via light hand sweeping. Soil trapped within the geosynthetic structure was not removed by washing or otherwise stressing the geosynthetic. No additional cleaning was performed and specimens were cut and tested in their soiled condition.

The evaluation of RF_{ID} for the geogrid was based on the results of wide width tensile tests per ISO 10319, *Geosynthetics -- Wide-width tensile test*. The multi-rib specimens were tested using an Instron Model 5589 tension/compression machine equipped with Demgen hydraulic grips and Instron Bluehill data acquisition software. Strain was monitored using an Instron non-contacting video extensometer. After exposure was complete, all baseline and exposed wide width tensile tests were performed during the same testing period.

Sampling and Specimen Selection

Each set of tensile tests of an exposed style of geosynthetic were compared with tensile tests of the same style of the geosynthetic in an unexposed, or "baseline" condition. It should be noted that tensile specimens were not representative of the roll width, but instead were specific to a defined region within the roll width. This approach was accomplished by cutting five coupons (four for exposure and one for baseline) measuring approximately 42 inches x 52 inches (1.07 m x 1.32 m) in sequence along the length of the geosynthetic. This technique captured common yarns and/or ribs in the tested specimens to minimize variation.

<u>Tensile tests of the product before exposure to installation conditions:</u> The specific sampling procedure as described above was followed to assure that individual baseline specimen populations were developed from the same region of the roll width as those specimens dedicated to installation damage exposure.

<u>Tensile tests of specimens taken from the damaged material after installation:</u> The coupons and candidate specimens to be exposed to installation stresses were selected prior to exposure and installed in accordance with a defined sampling plan (via ASTM D 5818). Exposure coupons were laid within the exposure lane in consecutive order, each representing five specimens. Thus, the exposure lane was constructed with specimens 1 through 20 as shown below.

Exposure Coupon 1					Exposure Coupon 2					Exposure Coupon 3					Exposure Coupon 4				
1	2	3	4	5	11	12	13	14	15	6	7	8	9	10	16	17	18	19	20

Upon exhumation of the exposed coupons, specimens were cut and tested in numerical order. A minimum of ten exposed specimens from each testing condition was systematically selected for testing from the twenty candidate specimens. The test results were averaged and compared to the average of the baseline specimens.

<u>Tensile test results for both virgin (i.e. baseline) and damaged (i.e. exhumed) specimens:</u> All tensile test results have been tabularized and may be found in the Appendix of this report.

Test Results

Retained strengths for each of the tested geosynthetic styles are presented in Table 1.

Table 1. Retained Strength for Tested Geosynthetics

Style	Gradation Type 3 (Silty Sand)	
	% Retained	RF_{ID}
80 kN/m - MD	90.2	1.11

MD = machine direction;

Conclusion

TRI is very pleased to present this report for installation damage testing of soil reinforcing geosynthetics. If you have any questions or require any additional information, please call me at 1-864-242-2220.

Sincerely,

C. Joel Sprague, P.E.
Senior Engineer

cc: Jarrett Nelson

APPENDIX OF TEST RESULTS

Installation Damage Results

Soil / Aggregate Gradations

Construction Quality Control Summary

Representative Pictures

INSTALLATION DAMAGE
TEST RESULTS

CTM Technical Textiles
INSTALLATION DAMAGE TESTING - WIDE WIDTH TENSILE (ISO 10319)
80 kN/m

Machine Direction

Sample Identification	Specimen Number	Ribs per Foot Width	Number of Ribs Tested	Maximum Load (lbs)	Maximum Load (lbs/ft)	Maximum Load (kN/m)	Elongation @ Break (%)	Load @ 2% lbs	Load @ 2% (lbs/ft)	Load @ 2% (kN/m)	Load @ 5% lbs	Load @ 5% (lbs/ft)	Load @ 5% (kN/m)	Load @ 10% lbs	Load @ 10% (lbs/ft)	Load @ 10% (kN/m)
80 kN/m Baseline	1	9.2	7	4140	5442	79.4	13.8	709	932	13.6	952	1251	18.3	2106	2769	40.4
	2	9.2	7	4220	5548	81.0	14.3	686	902	13.2	910	1197	17.5	1981	2605	38.0
	3	9.2	7	4197	5517	80.5	14.4	691	908	13.3	936	1230	18.0	2020	2655	38.8
	4	9.2	7	4224	5552	81.1	14.2	687	902	13.2	913	1200	17.5	1991	2618	38.2
	5	9.2	7	4061	5338	77.9	14.0	690	907	13.2	911	1198	17.5	1912	2514	36.7
Average				4168	5479	80.0	14.1	693	910	13.3	924	1215	17.7	2002	2632	38.4
Standard Deviation				68.8	90.4	1.3	0.2	9.3	12.3	0.2	18.6	24.4	0.4	70.3	92.5	1.4
% COV				1.7	1.7	1.7	1.8	1.3	1.3	1.3	2.0	2.0	2.0	3.5	3.5	3.5

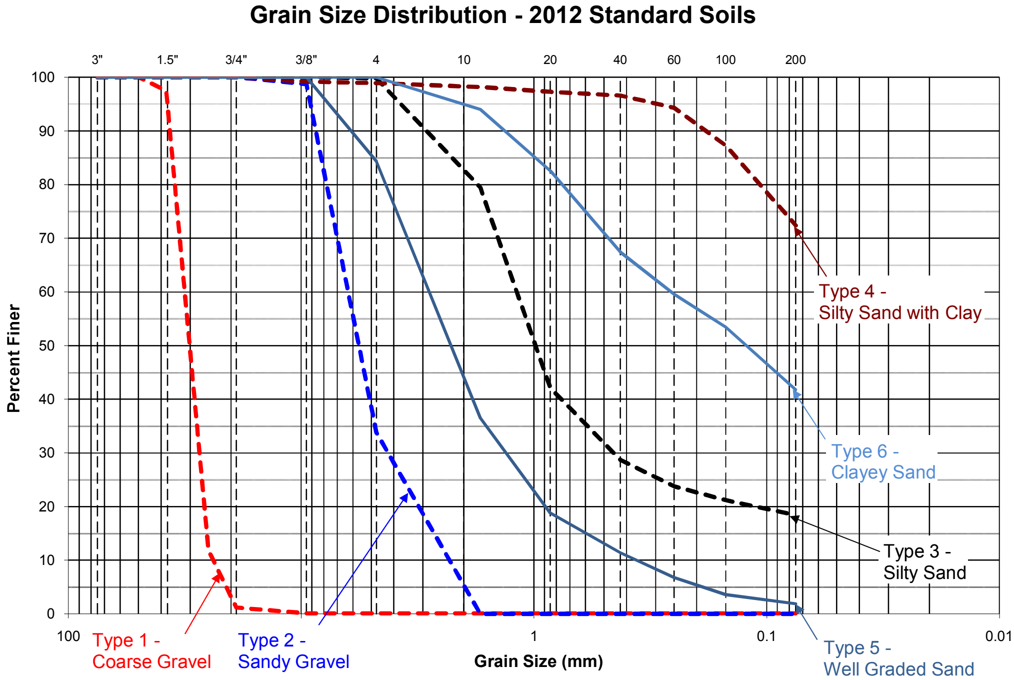
Machine Direction

Sample Identification	Specimen Number	Ribs per Foot Width	Number of Ribs Tested	Maximum Load (lbs)	Maximum Load (lbs/ft)	Maximum Load (kN/m)	Elongation @ Break (%)	Load @ 2% lbs	Load @ 2% (lbs/ft)	Load @ 2% (kN/m)	Load @ 5% lbs	Load @ 5% (lbs/ft)	Load @ 5% (kN/m)	Load @ 10% lbs	Load @ 10% (lbs/ft)	Load @ 10% (kN/m)
80 kN/m installed in Gradation 3 (Sand)	1	9.2	7	3879	5099	74.4	13.1	692	910	13.3	923	1213	17.7	2150	2826	41.3
	2	9.2	7	3825	5028	73.4	13.2	678	891	13.0	914	1202	17.5	2051	2696	39.4
	3	9.2	7	3794	4987	72.8	13.1	697	916	13.4	941	1237	18.1	2094	2752	40.2
	4	9.2	7	3407	4478	65.4	12.4	689	906	13.2	927	1219	17.8	2071	2723	39.8
	5	9.2	7	3639	4784	69.8	12.8	694	912	13.3	950	1249	18.2	2088	2745	40.1
	6	9.2	7	3827	5031	73.5	13.3	697	916	13.4	933	1226	17.9	2033	2673	39.0
	7	9.2	7	3814	5013	73.2	13.1	701	921	13.4	943	1240	18.1	2063	2712	39.6
	8	9.2	7	3725	4897	71.5	13.0	693	912	13.3	927	1219	17.8	2030	2668	39.0
	9	9.2	7	3793	4986	72.8	13.0	698	917	13.4	943	1239	18.1	2099	2759	40.3
	10	9.2	7	3879	5099	74.4	13.1	692	909	13.3	923	1213	17.7	2150	2826	41.3
Average				3758	4940	72.1	13.0	693	911	13.3	932	1226	17.9	2083	2738	40.0
Standard Deviation				142.6	187.4	2.7	0.2	6.3	8.3	0.1	11.4	15.0	0.2	42.5	55.8	0.8
% COV				3.8	3.8	3.8	1.9	0.9	0.9	0.9	1.2	1.2	1.2	2.0	2.0	2.0

Percent Retained			90.2	90.2	90.2	92.1	100.1	100.1	100.1	100.9	100.9	100.9	104.0	104.0	104.0
RFid			**1.11**	**1.11**	**1.11**										

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. TRI neither accepts responsibility for nor makes claim as to the final use and purpose of the material. TRI observes and maintains client confidentiality. TRI limits reproduction of this report, except in full, without prior approval of TRI.

SOIL/AGGREGATE GRADATIONS



INSTALLATION DAMAGE SOILS							
US Sieve No.	Sieve Size (mm)	Percent Passing					
		Type 1 (Coarse Gravel)	Type 2 (Sandy Gravel)	Type 3 (Silty Sand)	Type 4 (Silty Sand with Clay)	Type 5 (Well Graded Sand)	Type 6 (Clayey Sand)
3 - in.	75	100.0	100.0	100.0	100.0	100.0	100.0
2 - in.	50	100.0	100.0	100.0	100.0	100.0	100.0
1.5 - in.	38	97.5	100.0	100.0	100.0	100.0	100.0
1 - in.	25	11.8	100.0	100.0	100.0	100.0	100.0
3/4 - in.	19	1.2	100.0	100.0	100.0	100.0	100.0
3/8 - in.	9.5	0.1	98.7	100.0	99.2	100.0	100.0
No. 4	4.75	0.1	33.8	99.8	98.9	84.3	100.0
No. 10	1.7	0.1	0.0	79.5	98.2	36.5	94.0
No. 20	0.85	0.1	0.0	42.1	97.3	18.8	82.6
No. 40	0.425	0.1	0.0	28.7	96.6	11.4	67.4
No. 60	0.25	0.1	0.0	23.8	94.3	6.8	59.6
No. 100	0.15	0.1	0.0	21.2	87.3	3.6	53.4
No. 200	0.075	0.1	0.0	18.4	72.4	1.9	41.8
Liquid Limit, %		-	-	-	28	-	25
Plasticity Index, %		-	-	-	14	-	9
Angularity		Angular to Subangular	Angular	Angular to Subangular	-	Angular to Subangular	-
USCS Classification		GP	GP	SM	CL-ML	SW	SC
		Poorly Graded Gravel	Poorly Graded Gravel with Sand	Silty Sand	Silty Sand with Clay	Graded Sand	Sand with Clay

CONSTRUCTION QUALITY CONTROL DURING INSTALLATION DAMAGE EXPOSURE

SUMMARY OF OBSERVATIONS AND MEASUREMENTS

REPRESENTATIVE PICTURES
OF
EXPOSURE PROCEDURE

(Typical Pictures from Testing a Range of Geosynthetics)

				FIRST LIFT				SECOND LIFT			
DATE	CLIENT	MATERIAL	SOIL TYPE	LOCATION	DENSITY	MOISTURE	# PASSES	LOCATION	DENSITY	MOISTURE	# PASSES
06-Mar-13	CTM	40 kN/m	1	NA NA	NA NA	NA NA	4	NA NA	NA NA	NA NA	4
06-Mar-13	CTM	80 kN/m	1	NA NA	NA NA	NA NA	4	NA NA	NA NA	NA NA	4
06-Mar-13	CTM	40 kN/m	3	NA NA	NA NA	NA NA	6	NA NA	NA NA	NA NA	6
06-Mar-13	CTM	80 kN/m	3	NA NA	NA NA	NA NA	6	NA NA	NA NA	NA NA	6

LIFTING PLATES POSITIONED BETWEEN TIES AND COVERED WITH FIRST LIFT OF COMPACTED SOIL/AGGREGATE

GEOSYNTHETIC POSITIONED OVER COMPACTED BASE AND COVERED

COVER SOIL/AGGREGATE IS UNIFORMLY SPREAD AND COMPACTED USING FIELD-SCALE EQUIPMENT AND PROCEDURES

THE DENSITY OF COMPACTED SOIL IS MEASURED

THE STEEL PLATES ARE TILTED TO FACILITATE EXHUMATION

Creep Rupture Behavior of Reinforcement Geosynthetic:

80 kN/m Geogrid

January 2013

<u>Submitted to:</u>
CTM Technical Textiles
205 New Cloth Market
Ahmedabad, India

Attn: Mr. Amit Agarwal
amit@ctmtechtextile.com

<u>Submitted by</u>:
TRI/Environmental, Inc.
9063 Bee Caves Rd.
Austin, Texas 78733

C. Joel Sprague
Project Manager

January 17, 2013

Mr. Amit Agarwal
CTM Technical Textiles
205 New Cloth Market
Ahmedabad, India

amit@ctmtechtextile.com

SUBJECT: Creep Testing of Reinforcement Geosynthetic: 80 kN/m Geogrid

Dear Mr. Agarwal:

TRI/Environmental, Inc. (TRI) is pleased to present this final report for creep testing of a reinforcement geosynthetic. The 80 kN/m Geogrid was tested in the machine direction.

INTRODUCTION AND SUMMARY

Objective.
The objective of this effort is to obtain an estimate of the 120-year creep rupture performance of the submitted geosynthetic. Featured herein is accelerated creep testing using the stepped isothermal method (SIM) of time-temperature superposition (TTS) creep-rupture testing. The results apply to the tensile strength in the machine direction.

Scope.
Rapid loading tensile (RLT) and accelerated (SIM) creep tests were conducted. The purpose of RLT tests was to determine the ultimate tensile strength (UTS) of the products in order to establish the baseline for the creep tests. The accelerated creep testing results were used to derive an approximate rupture curve for the product.

Summary.

The creep rupture results are summarized in Table 1.

Table 1. Summary of Creep-Rupture Results for the 80 kN/m Geogrid

Ref. Temp. of Regression Line	Regression Equation	Retained Strength (%)		Reduction Factor	
		75 Years (log 5.8179 hrs)	120 Years (log 6.0220 hrs)	75 Years	120 Years
20°C	%UTS = -3.289 log hrs + 86.545	67.41	66.75	1.48	1.50
30°C	%UTS = -3.289 log hrs + 83.585	64.45	63.78	1.55	1.57
40°C	%UTS = -3.289 log hrs + 80.625	61.49	60.82	1.63	1.64
50°C	%UTS = -3.289 log hrs + 77.665	58.53	57.86	1.71	1.73

MATERIALS AND METHODS

Materials. The product described herein is a reinforcement geosynthetic composed of polyester yarns woven into a grid structure and coated to maintain geometric stability.

Equipment

Testing platforms: Instron Model 5583 load frame under computer control;
Environmental chamber: TRI Model SIW – stepped isothermal, wide chamber;
Grips: TRI Model PM-100, Pacman x 100mm;
Extensometer: Epsilon Model SW3542-0200-050-ST (SIM) with 2.2 GL;
Temperature controller: Watlow Series 982 programmable temperature controller;
Heating/cooling- Electrical/liquid CO_2;
Data acquisition: Instron Bluehill 2 software.

Procedures

SIM: Testing was conducted using narrow strips of geosynthetic. Each specimen was allowed to reach equilibrium at 20°C prior to test initiation. Specimens were then ramped to the specified percentage of UTS and then held at that load until failure or 60000 seconds. Temperature was stepped 14°C every 10000 seconds starting at 20°C and ending at 90°C. Strain was measured with an Epsilon extensometer with a 2.2-inch gauge length.

RESULTS

RLT Results. RLT tests were run in accordance with ISO 10319 using a strain rate of 20%/minute to establish the baseline tensile strength of the specific product being tested and are shown in Table 2.

Table 2. Product Tested Tensile Strengths

Product	**UTS (kN/m)**	**% Strain @ UTS**
80 kN Geogrid	87.0	16.9

Creep Rupture. Table 4 present test data and rupture curve calculations and Figure 1 presents the associated creep rupture curve for the material tested. A creep rupture curve for each SIM test is presented in the appendix.

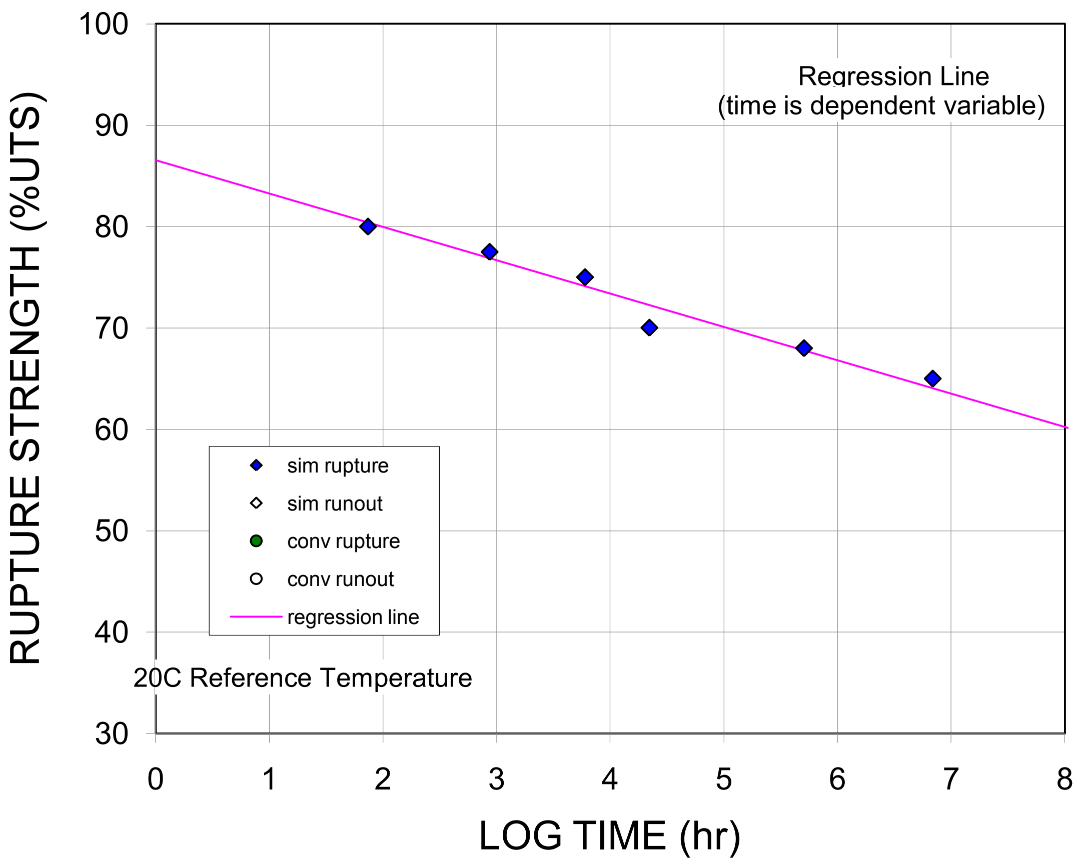


Figure 1. Creep Rupture Curve – 80 kN/m Geogrid (Machine Direction)

Table 4. Creep Rupture Data and Regression/Reduction Factor (in gray) Calculations

product	loghrs	SIM rupture, %UTS		Time on y axis	Time on x axis	
80 kN/m Geogrid	6.8376	64.98	Slope	-0.30405	-3.28895	
	5.7067	67.99	Intercept	26.3139	86.54501	
	4.3454	70.01	R^2	0.95922	0.95922	
	3.7795	75.00	Estimated RFCR	loghrs	%UTS	Intercept
	2.9398	77.49				
	1.8703	80.00	1.50	6.02168	66.75	= 120 Year intercept
			1.48	5.817863	67.41	= 75 Year intercept
			1.36	4	73.39	= 10k hr intercept
			1.30	3	76.68	= 1k hr intercept

CONCLUSIONS AND RECOMMENDATIONS

An estimate of creep reduction factors have been determined for the product tested using accelerated (SIM) creep testing. The estimated creep rupture reduction factor for the 80 kN/m Geogrid reinforcement geosynthetic is 1.48 and 1.50 for 75 and 120 years, respectively.

APPENDIX

795c980kn6512j13.xls SUMMARY CREEP PARAMETERS: CTM Technical

80 kN Geogrid

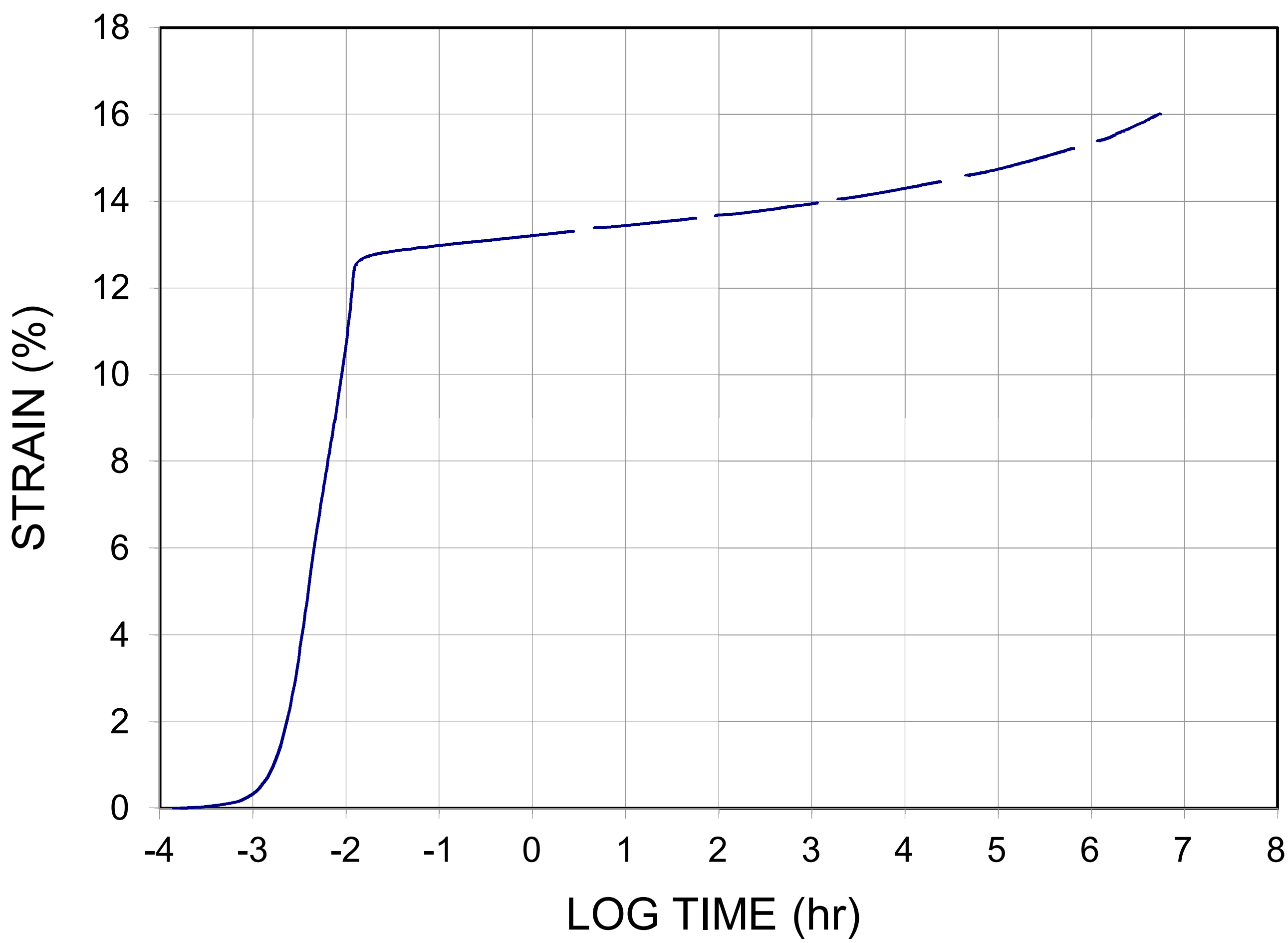
Specimen: 795c8-80kn-sim65 Test Date: 12-Jan-13 Method: SIM (10^4s, 14C),single rib, machine dir.

Average Creep Stress: 56.5 kN/m %UTS: 64.98

Ultimate Tensile Strength: 87.0 kN/m Rupture: YES

Dwell Seq	t'	t	$(t-t')_i$	Vshift(%)	$logA_T$	Temp	$logA_T/T$
1	0	0.5	0.5	-	-	21.12	-
2	9500	10020	520	0.11	1.2838	35.13	0.0916
3	19500	20010	510	0.1	1.3130	49.05	0.0943
4	29500	30000	500	0.1	1.3212	62.84	0.0959
5	39600	39990	390	0.15	1.4288	76.92	0.1015
6	49600	49980	380	0.16	1.4355	90.92	0.1025
						AVG	0.0972

Summary	Initial	Final	Units	@20C refT
lab time	42.99	52830	sec	-
$logA_T(t-t')$	1.6334	10.2915	log hours	6.8376
$A_T(t-t')$	-	620.06	years	784.89
Strain	12.354	16.001	%	-
Modulus	457.8	353.2	kN/m	-



795c980kn6815j13.xls

SUMMARY CREEP PARAMETERS: CTM Technical
80 kN Geogrid

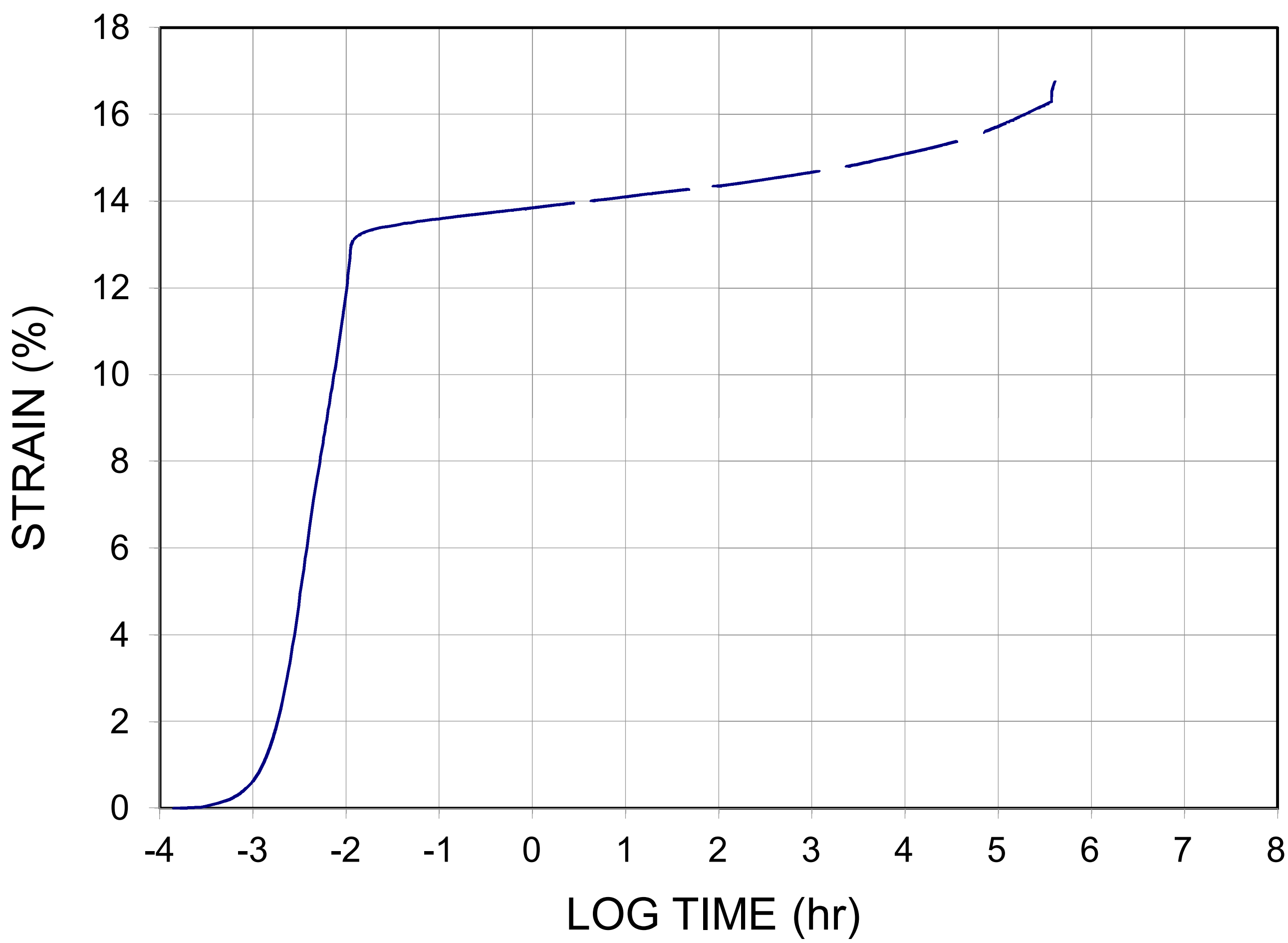
Specimen: 795c8-80kn-sim68 | Test Date: 15-Jan-13 | Method: SIM (10^4s, 14C),single rib, machine dir.

Average Creep Stress: 59.2 kN/m | %UTS: 67.99

Ultimate Tensile Strength: 87.0 kN/m | Rupture: YES

Dwell Seq	t'	t	$(t-t')_i$	Vshift(%)	$logA_T$	Temp	$logA_T/T$
1	0	0.5	0.5	-	-	21.12	-
2	9400	10020	620	0.06	1.2074	34.99	0.0870
3	19600	20010	410	0.07	1.4120	48.88	0.1016
4	29650	30000	350	0.08	1.4721	62.78	0.1059
5	39650	39990	340	0.13	1.4822	76.72	0.1064
6							
						AVG	0.1002

Summary	Initial	Final	Units	@20C refT
lab time	40.42	43560	sec	-
$logA_T(t-t')$	1.6066	9.1659	log hours	5.7067
$A_T(t-t')$	-	46.43	years	58.06
Strain	12.981	16.764	%	-
Modulus	460.6	352.8	kN/m	-



795c980kn7011j13.xls

SUMMARY CREEP PARAMETERS: CTM Technical
80 kN Geogrid

Specimen: 795c8-80kn-sim70 Test Date: 11-Jan-13 Method: SIM (10^4s, 14C),single rib, machine dir.

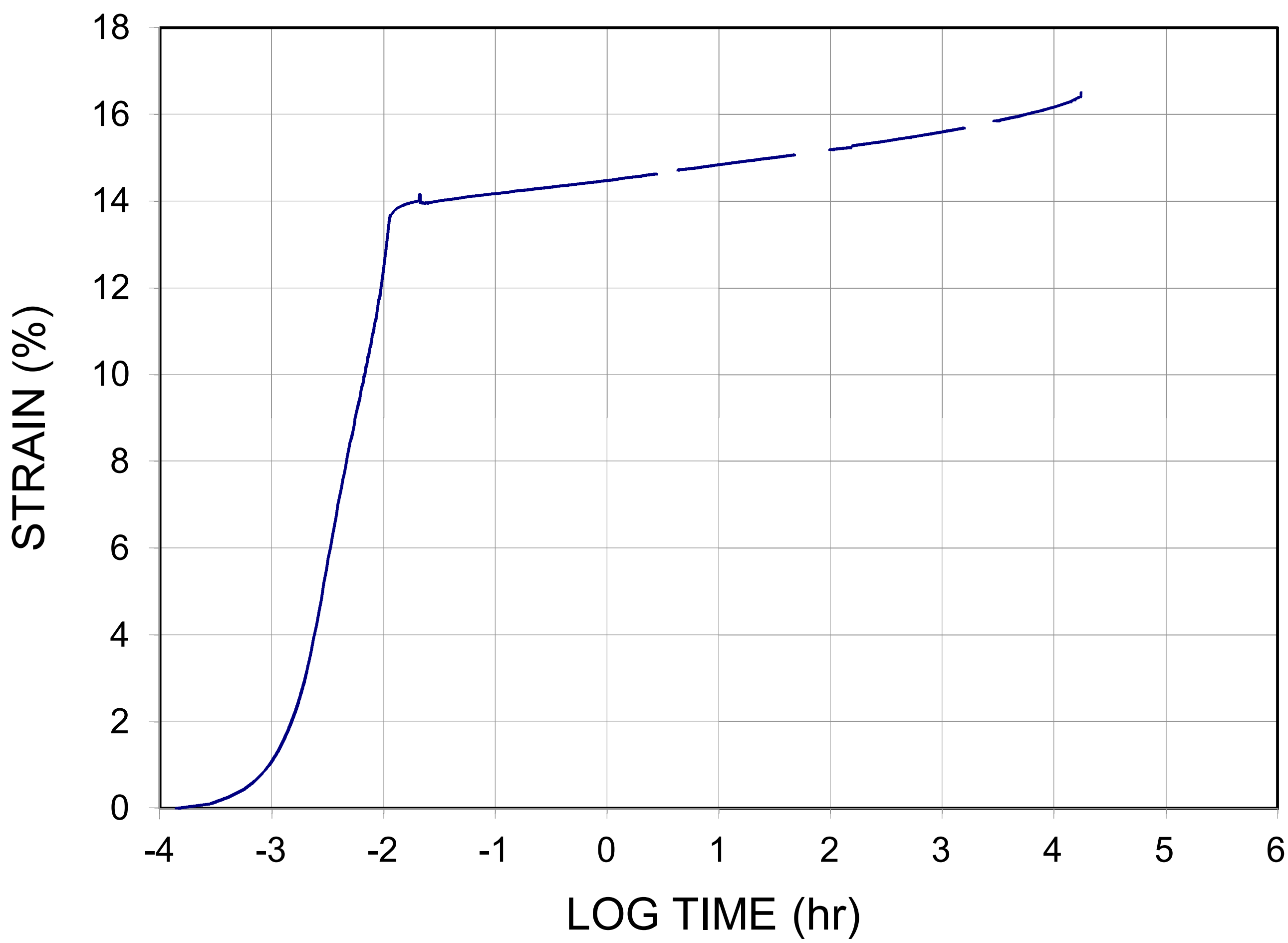
Average Creep Stress: 60.9 kN/m %UTS: 70.01

Ultimate Tensile Strength: 87.0 kN/m Rupture: YES

Dwell Seq	t'	t	$(t-t')_i$	Vshift(%)	$logA_T$	Temp	$logA_T/T$
1	0	0.5	0.5	-	-	21.23	-
2	9400	10019	619	0.07	1.2077	35.08	0.0872
3	19700	20009	309	0.1	1.5342	48.90	0.1111
4	29600	29999	399	0.1	1.4104	62.93	0.1005
5							
6							

AVG 0.0996

Summary	Initial	Final	Units	@20C refT
lab time	41.004	33989	sec	-
$logA_T(t-t')$	1.6128	7.7947	log hours	4.3454
$A_T(t-t')$	-	1.97	years	2.53
Strain	13.657	16.510	%	-
Modulus	453.6	368.9	kN/m	-



795c980kn7513j13.xls SUMMARY CREEP PARAMETERS: CTM Technical 80 kN Geogrid

Specimen: 795c8-80kn-sim75 Test Date: 13-Jan-13 Method: SIM (10^4s, 14C),single rib, machine dir.

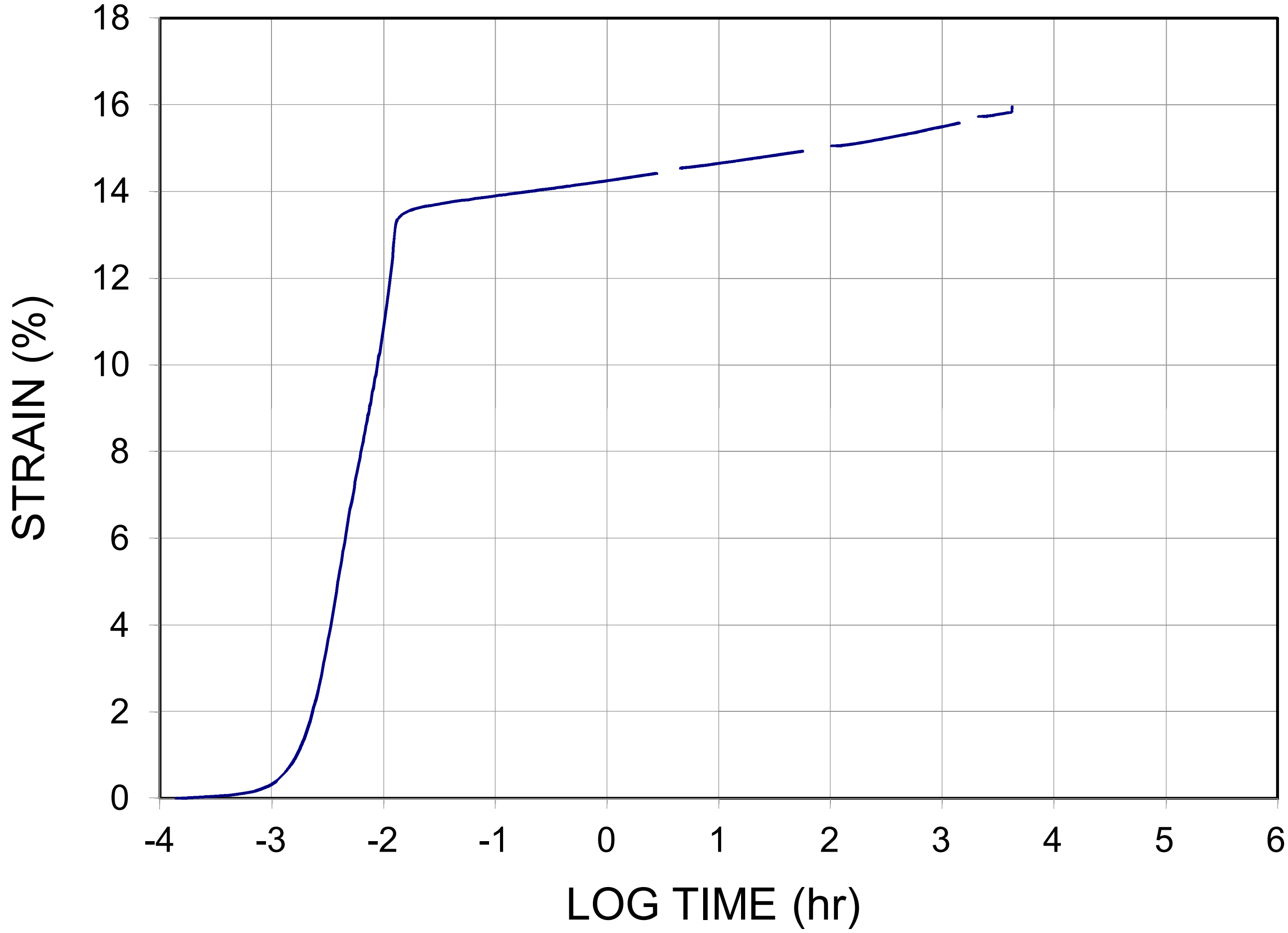
Average Creep Stress: 65.3 kN/m %UTS: 75.00

Ultimate Tensile Strength: 87.0 kN/m Rupture: YES

Dwell Seq	t'	t	$(t-t')_i$	Vshift(%)	$logA_T$	Temp	$logA_T/T$
1	0	0.5	0.5	-	-	21.61	-
2	9500	10019	519	0.1	1.2841	35.01	0.0958
3	19600	20009	409	0.11	1.4083	48.93	0.1012
4	29300	29999	699	0.14	1.1711	63.12	0.0825
5							
6							

Summary	Initial	Final	Units	@20C refT
lab time	46.072	31379	sec	-
$logA_T(t-t')$	1.6634	7.1814	log hours	3.7795
$A_T(t-t')$	-	0.48	years	0.69
Strain	13.234	15.969	%	-
Modulus	498.2	408.7	kN/m	-

AVG 0.0931



795c980kn7716j13.xls

SUMMARY CREEP PARAMETERS: CTM Technical

80 kN Geogrid

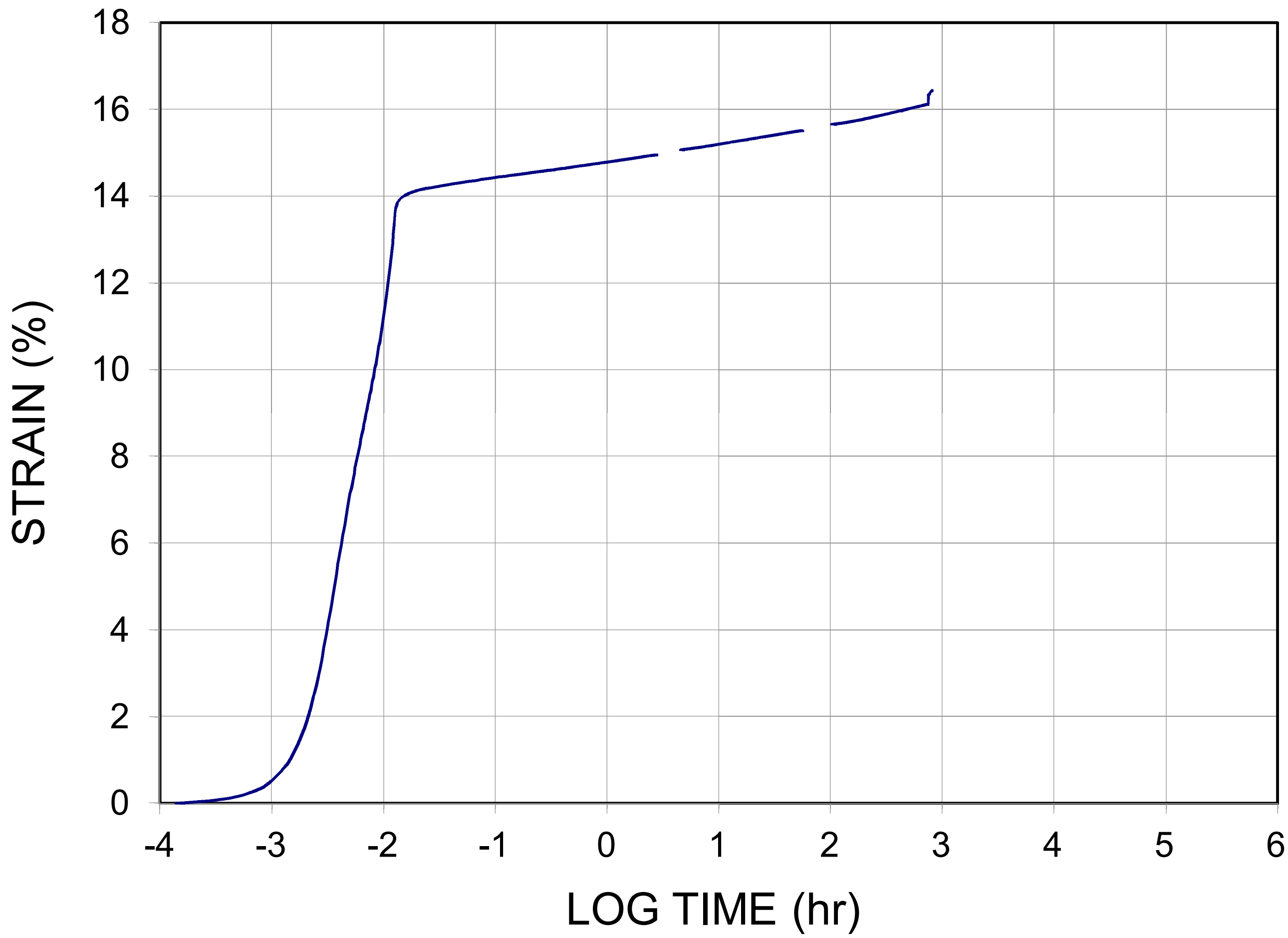
Specimen: 795c8-80kn-sim775 | Test Date: 16-Jan-13 | Method: SIM (10^4s, 14C),single rib, machine dir.

Average Creep Stress: 67.4 kN/m | %UTS: 77.49

Ultimate Tensile Strength: 87.0 kN/m | Rupture: YES

Dwell Seq	t'	t	$(t-t')_i$	Vshift(%)	$logA_T$	Temp	$logA_T/T$
1	0	0.5	0.5	-	-	20.31	-
2	9500	10019	519	0.1	1.2840	34.15	0.0928
3	19600	20009	409	0.1	1.4082	48.03	0.1014
4							
5							
6							
						AVG	0.0971

Summary	Initial	Final	Units	@20C refT
lab time	46.17	25559	sec	-
$logA_T(t-t')$	1.6644	6.4674	log hours	2.9398
$A_T(t-t')$	-	0.09	years	0.10
Strain	13.725	16.429	%	-
Modulus	496.1	410.4	kN/m	-



795c980kn8014j13.xls SUMMARY CREEP PARAMETERS: CTM Technical 80 kN Geogrid

Specimen: 795c8-80kn-sim80 Test Date: 14-Jan-13 Method: SIM (10^4s, 14C),single rib, machine dir.

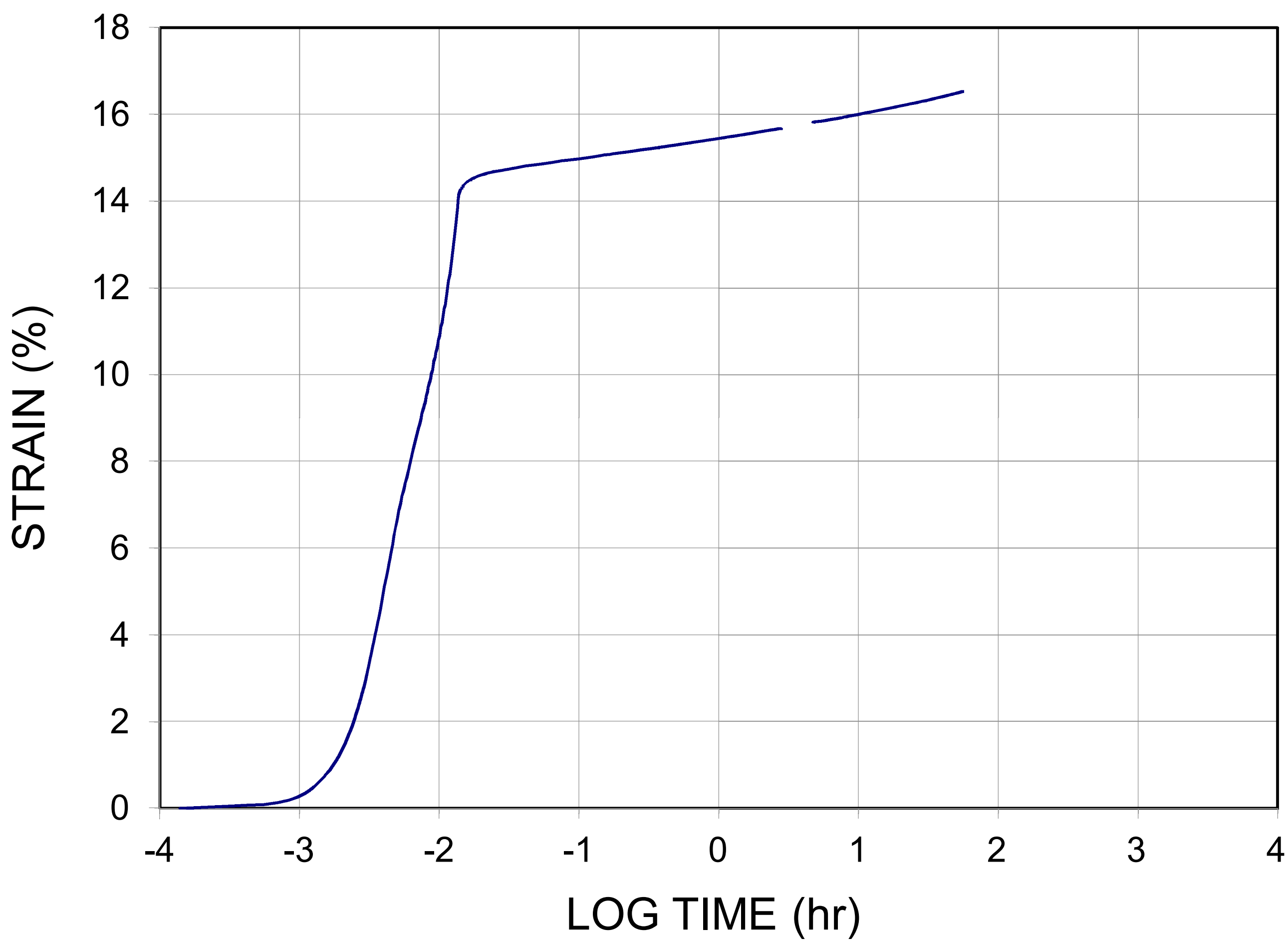
Average Creep Stress: 69.6 kN/m %UTS: 80.00

Ultimate Tensile Strength: 87.0 kN/m Rupture: YES

Dwell Seq	t'	t	$(t-t')_i$	Vshift(%)	$logA_T$	Temp	$logA_T/T$
1	0	0.5	0.5	-	-	21.27	-
2	9550	10019	469	0.09	1.3280	34.91	0.0974
3							
4							
5							
6							

Summary	Initial	Final	Units	@20C refT
lab time	49.71	18989	sec	-
$logA_T(t-t')$	1.6964	5.3029	log hours	1.8703
$A_T(t-t')$	-	0.01	years	0.01
Strain	14.148	16.538	%	-
Modulus	496.7	420.8	kN/m	-

AVG 0.0974



March 11, 2013

Mr. Amit Agarwal
CTM Technical Textiles
205 New Cloth Market
Ahmedabad
India
Email: amit@ctmtechtextile.com

Re: Pullout Testing of CTM Technical Textiles 80 kN/m PET Geogrid in TRI Type II Sandy Gravel (TRI Log #: E2280-79-09)

Dear Mr. Agarwal:

TRI/Environmental is pleased to present the final results for large scale pull-out tests performed on CTM Technical Textiles 40 kN/m PET Geogrid embedded in TRI Type II Sandy Gravel. The pullout box is a custom-made apparatus, 76 cm wide x 61 cm high x 152 cm long (30 in x 24 in x 60 in), nominally. The testing was in general accordance with ASTM D 6706, *Standard Test Method for Measuring Geosynthetic Pullout Resistance in Soil.*

After the soil was remolded into the lower half of the pullout box, the geosynthetic test specimen was placed over the prepared soil layer. Another layer of soil was then placed and compacted above the geosynthetic specimen. A rigid steel platen was then placed upon the soil and the normal load was applied using a large air bladder. The normal stresses applied at 20 kPa, 35 kPa, and 50 kPa (418 psf, 734 psf, and 1051 psf) for this test.

A horizontal force was then applied to the geosynthetic and the force required to pull the geosynthetic out of the soil was recorded. Specimens were pulled out at a constant rate of 1 mm per minute (0.04 in/min). "Tell-tails" mounted to the geosynthetic are used to monitor movement of the geosynthetic at various points along its length during the test. Normal load, tensile load, and geosynthetic displacement at the front of the pullout box and at points along the geosynthetic from the tell-tails were collected during the entire testing. The type of pullout failure (i.e. slippage at the soil-geosynthetic interface or rupture of the geosynthetic or partial geosynthetic rupture/slippage) was identified and recorded.

Pullout resistance is obtained by dividing the maximum load attained by the test specimen width and embedment length. Graphs of pullout resistance versus displacement at various points along the geosynthetic are generated for various applied normal stresses are also presented in the attached figures.

For your convenience a one page summary report is attached with specific testing details and results for all three tests. If you have any questions regarding the data or the testing please feel free to contact me at Jnelson@tri-env.com or telephone to 512 263 2101.

Sincerely,

Jarrett A. Nelson

Jarrett A. Nelson
Special Projects Manager
TRI Geosynthetic Services
www.GeosyntheticTesting.com

[Attachments]

TRI/ENVIRONMENTAL, INC.

A Texas Research International Company

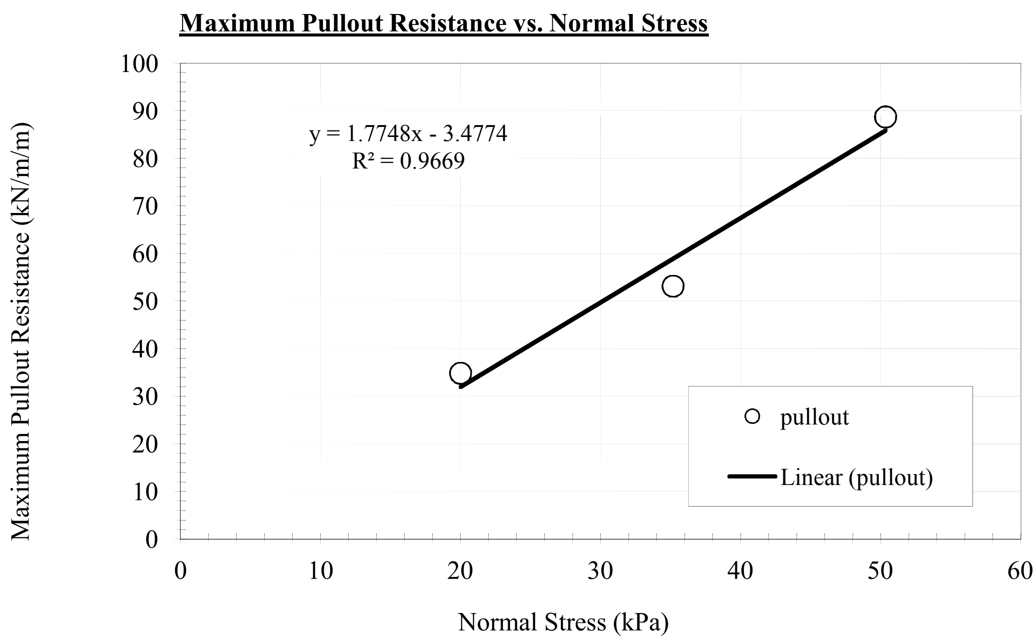
Geosynthetic Pullout Resistant in Soil

Client:	CTM Technical Textiles	TRI Log#:	E2280-79-09
Product:	80 kN/m Geogrid	Test Method:	ASTM D 6706
Backfill Type:	Sandy Gravel	Test Date:	1/23-2/5/2013
	(c' = 0.0 psi, ϕ' = 44.3°)	Pullout Rate (in/min):	0.04

Test No.	Width of Geogrid (m)	Geogrid Embedment Length (m)	Normal Stress (kPa)	Approx. Soil Depth (m)	Max. Pullout Resistance (kN/m width/m length)	Mode of Failure	Pullout Interaction Coefficient, Ci
1	0.61	1.2	20.0	1.06	34.9	Pullout	0.89
2	0.61	0.7	35.2	1.87	53.2	Pullout	0.77
3	0.61	0.5	50.3	2.67	88.7	Pullout	0.90

Note 1: $Ci = P / (C*L_e*(c' + \sigma'_v \tan \phi'))$ where P = pullout resistance per unit width; C = effective unit perimeter (2 for geosynthetics); Le = embedment length, and σ'_v = effective vertical stress.

Note 2: The Mohr-Coulomb strength parameters, c' and ϕ', used in this calculation were determined at normal stresses ranged from 20 kPa to 35 kPa.



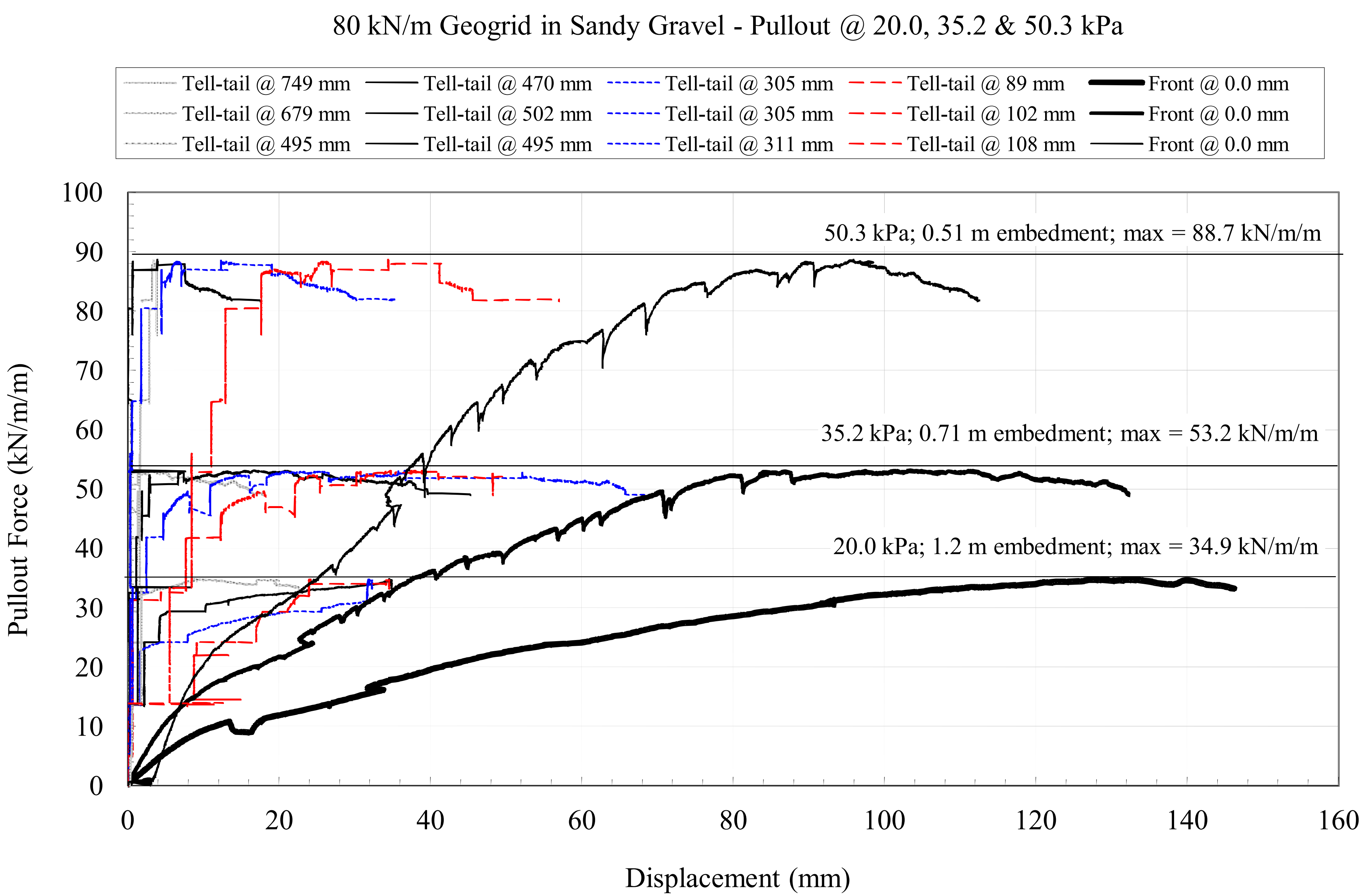
C. Joel Sprague, 03/11/13

Quality Review/Date

Analysis by: Jarrett A. Nelson

Specimens prepared by: Willard White

9063 Bee Caves Road □ Austin, TX 78733-6201 □ (512) 263-2101 □ (512) 263-2558 □ 1-800-880-TEST

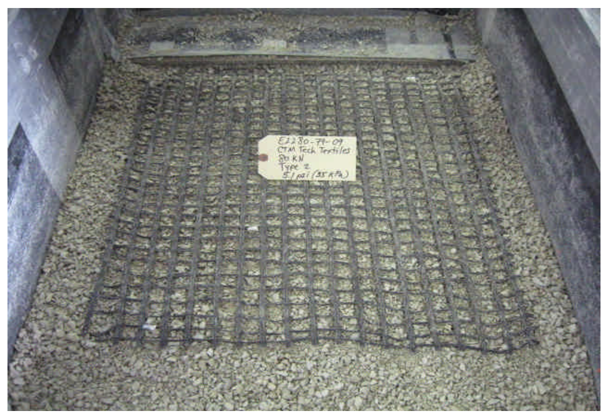

80 kN/m Geogrid in Sandy Gravel - Pullout @ 20.0, 35.2 & 50.3 kPa
Tell-tail @ 749 mm
Tell-tail @ 470 mm
Tell-tail @ 305 mm
Tell-tail @ 89 mm
Front @ 0.0 mm
Tell-tail @ 679 mm
Tell-tail @ 502 mm
Tell-tail @ 305 mm
Tell-tail @ 102 mm
Front @ 0.0 mm
Tell-tail @ 495 mm
Tell-tail @ 495 mm
Tell-tail @ 311 mm
Tell-tail @ 108 mm
Front @ 0.0 mm
50.3 kPa; 0.51 m embedment; max = 88.7 kN/m/m
35.2 kPa; 0.71 m embedment; max = 53.2 kN/m/m
20.0 kPa; 1.2 m embedment; max = 34.9 kN/m/m
Pullout Force (kN/m/m)
Displacement (mm)
0
10
20
30
40
50
60
70
80
90
100
0
20
40
60
80
100
120
140
160

Geosynthetic Pullout Resistant in Soil

80 kN/m Geogrid @ 20 kPa Pre-test

80 kN/m Geogrid @ 20 kPa Post-test

80 kN/m Geogrid @ 35 kPa Post-test



80 kN/m Geogrid @ 35 kPa Pre-test

80 kN/m Geogrid @ 50 kPa Pre-test

80 kN/m Geogrid @ 50 kPa Post-test