TRI/ENVIRONMENTAL, INC.
A Texas Research International Company

Creep Rupture Behavior of Reinforcement Geosynthetic:

80 kN/m Geogrid

January 2013

Submitted to:
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January 17, 2013

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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 $C0_2$;
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.

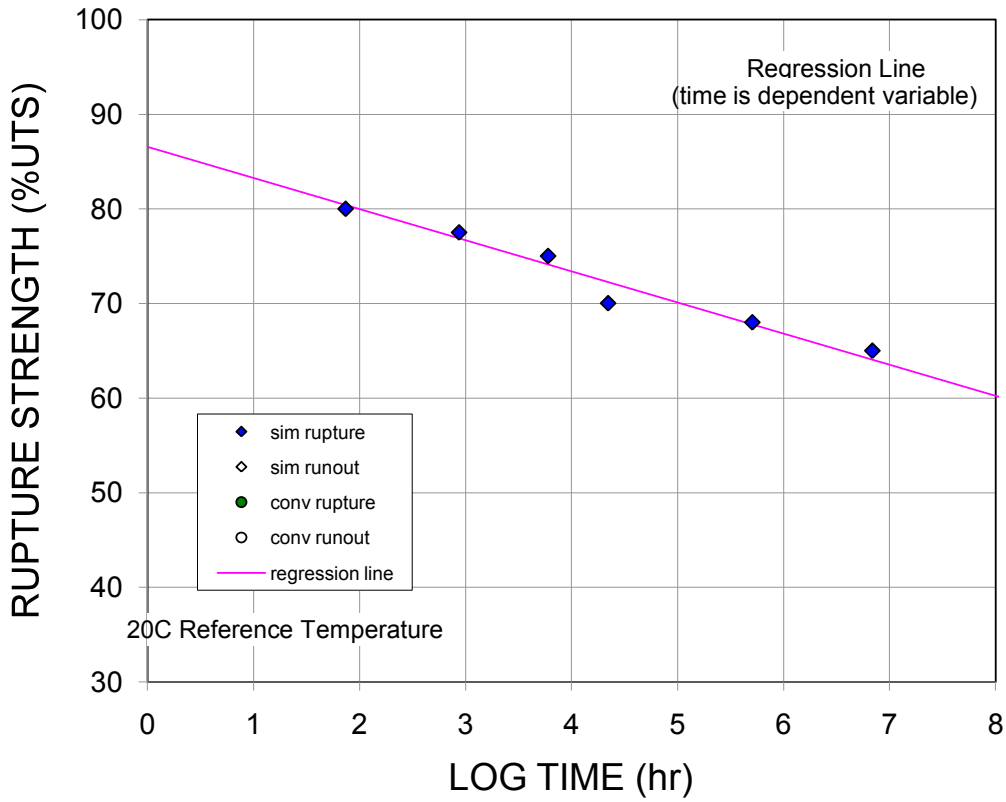


Figure 1. Creep Rupture Curve – 80 kN/m Geogrid (Machine Direction)

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.

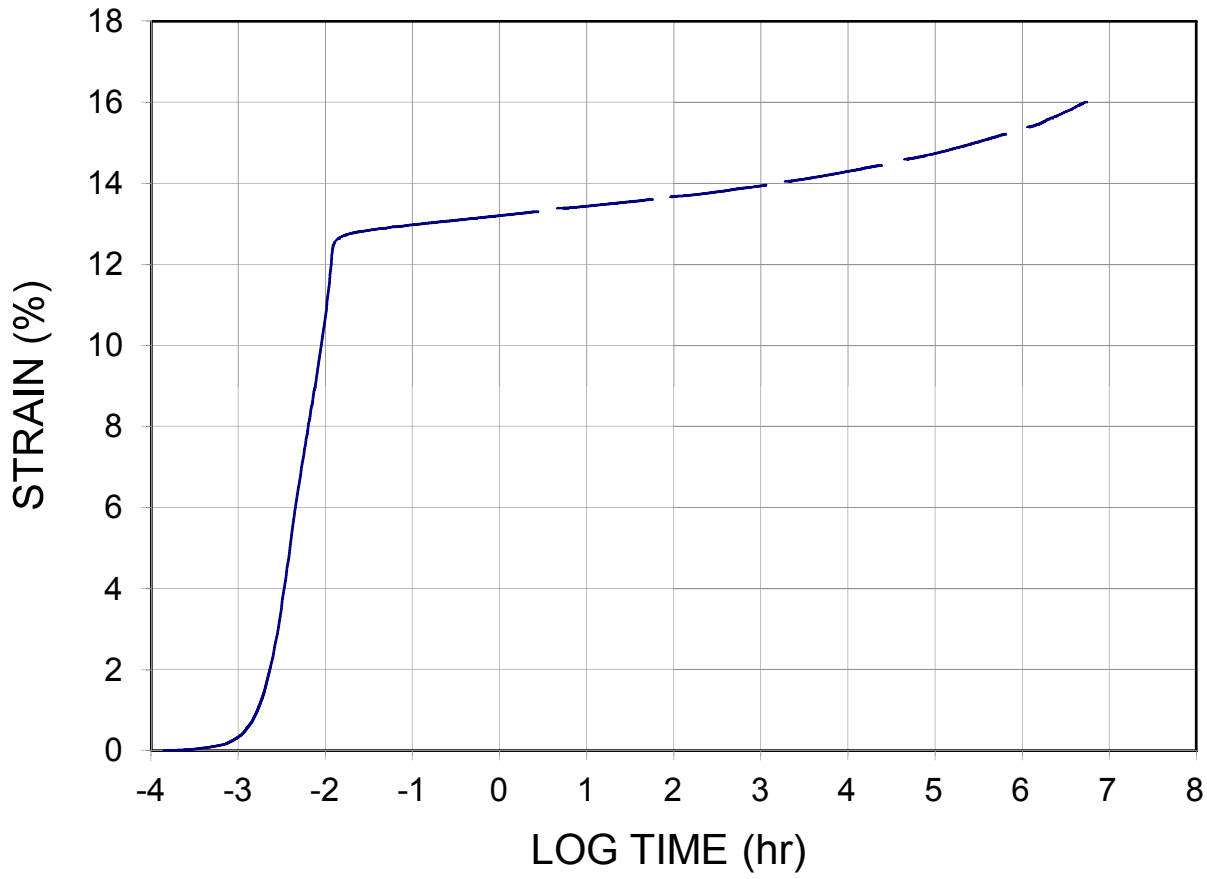
Average Creep Stress: 56.5 kN/m %UTS: 64.98

Ultimate Tensile Strength: 87.0 kN/m Rupture: YES

Dwell Seq	t'	t	$(t-t')_i$	Vshift(%)	$\log A_T$	Temp	$\log A_T/T$
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	-
$\log A_T(t-t')$	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.

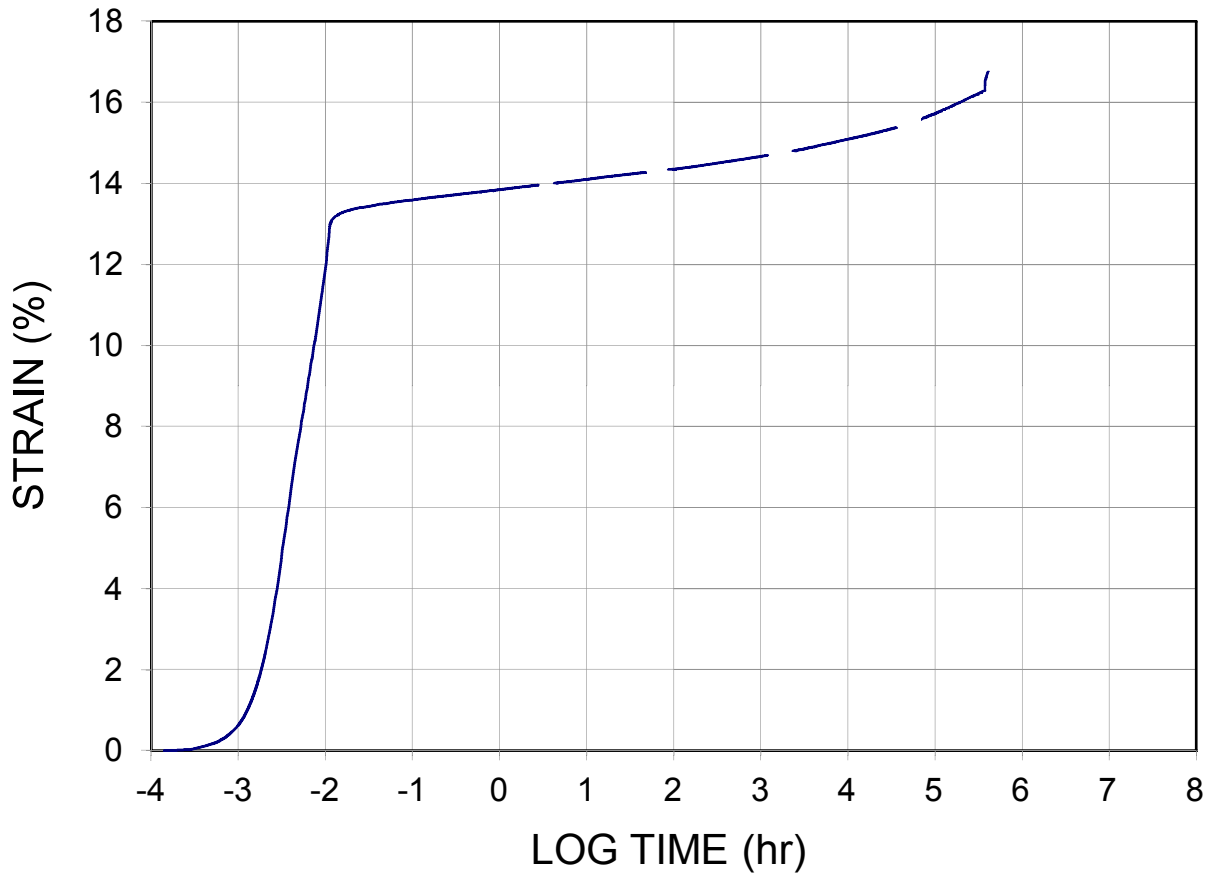
Average Creep Stress: 59.2 kN/m %UTS: 67.99

Ultimate Tensile Strength: 87.0 kN/m Rupture: YES

Dwell Seq	t'	t	$(t-t')_i$	Vshift(%)	$\log A_T$	Temp	$\log A_T/T$
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	-
$\log A_T(t-t')$	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.

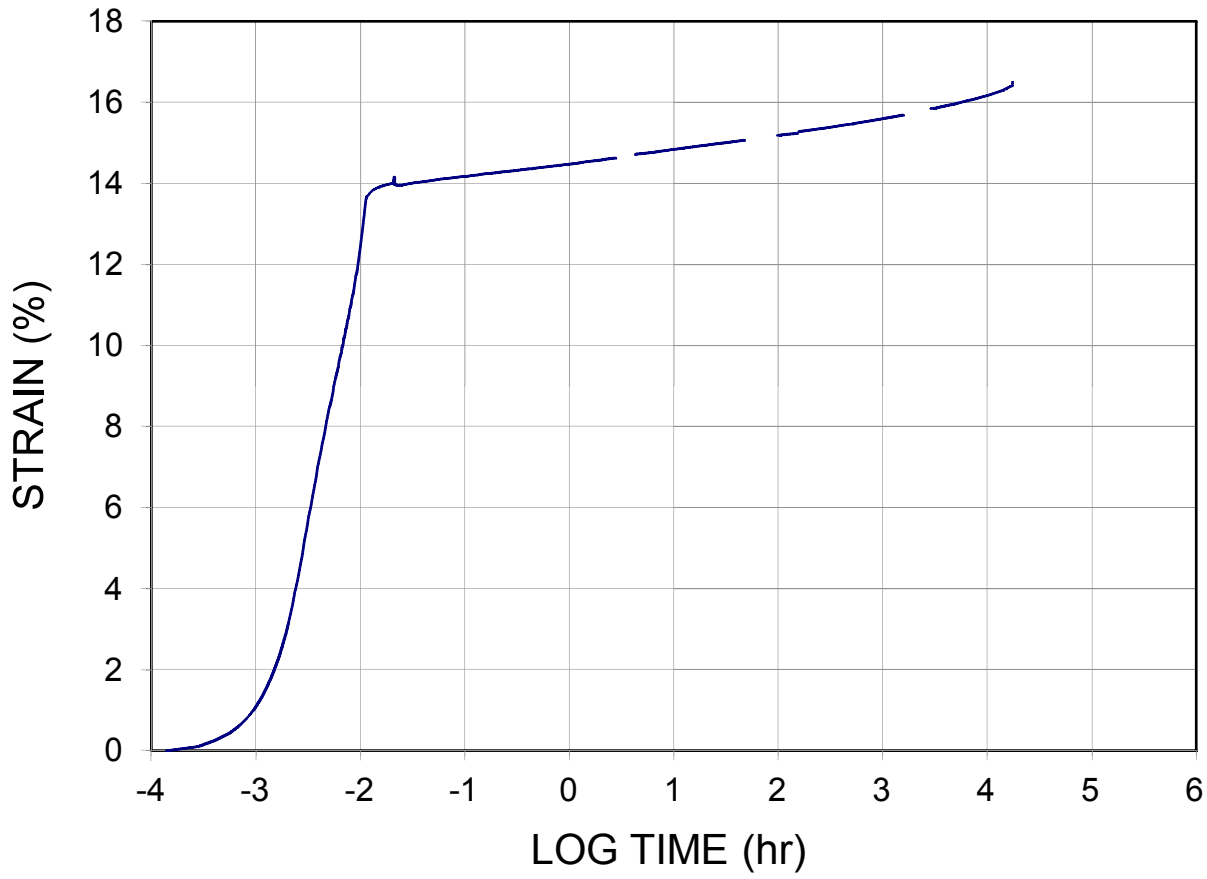
Average Creep Stress: 60.9 kN/m %UTS: 70.01

Ultimate Tensile Strength: 87.0 kN/m Rupture: YES

Dwell Seq	t'	t	$(t-t')_i$	Vshift(%)	$\log A_T$	Temp	$\log A_T/T$
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	-
$\log A_T(t-t')$	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.

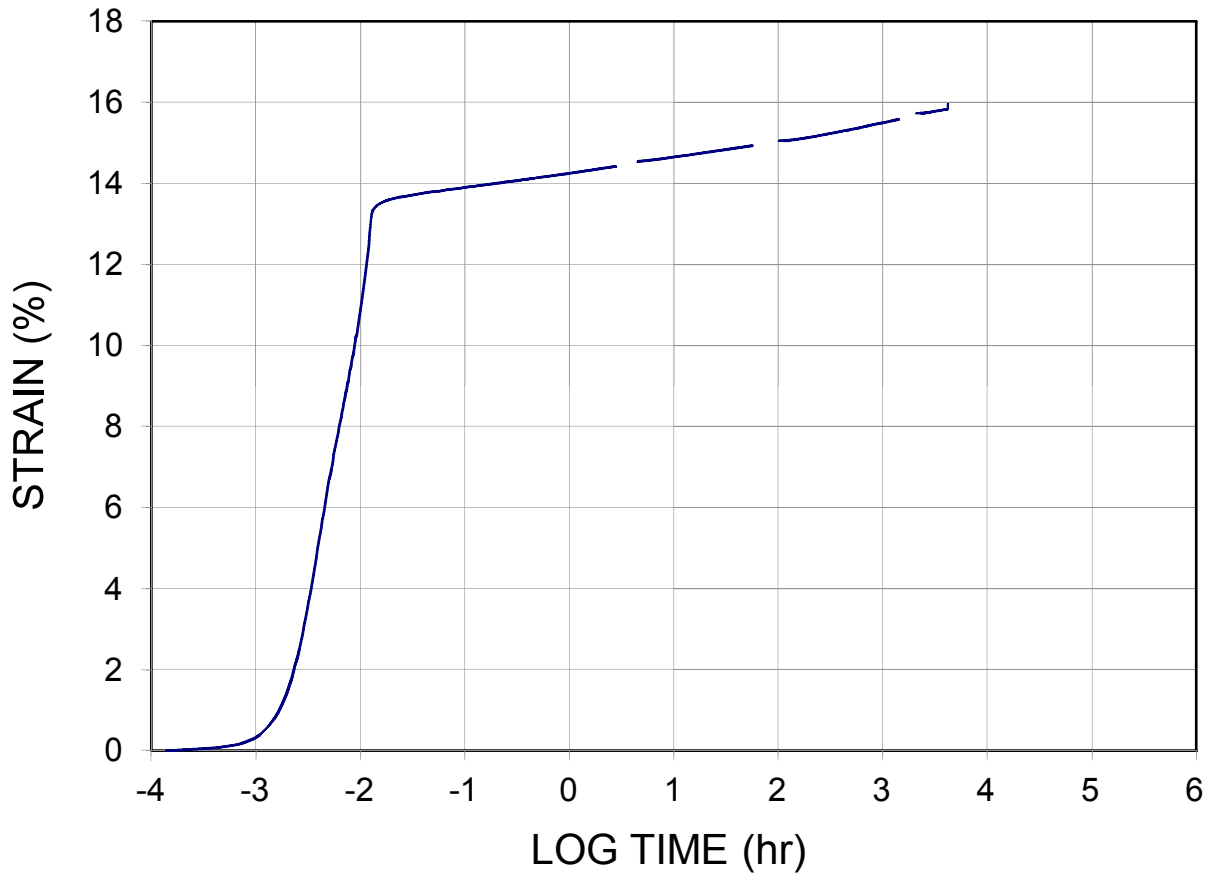
Average Creep Stress: 65.3 kN/m %UTS: 75.00

Ultimate Tensile Strength: 87.0 kN/m Rupture: YES

Dwell Seq	t'	t	$(t-t')_i$	Vshift(%)	$\log A_T$	Temp	$\log A_T/T$
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	-
$\log A_T(t-t')$	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.

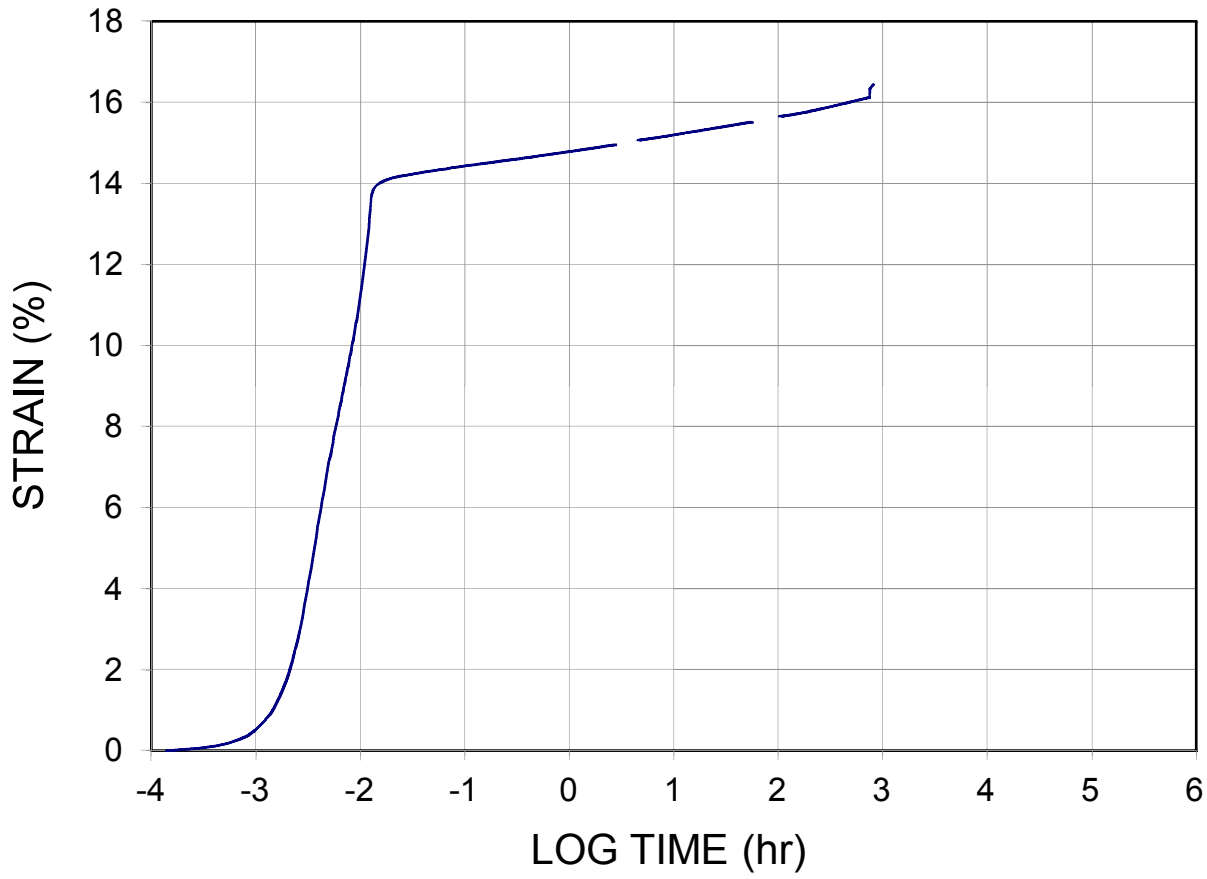
Average Creep Stress: 67.4 kN/m %UTS: 77.49

Ultimate Tensile Strength: 87.0 kN/m Rupture: YES

Dwell Seq	t'	t	$(t-t')_i$	Vshift(%)	$\log A_T$	Temp	$\log A_T/T$
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							

Summary	Initial	Final	Units	@20C refT
lab time	46.17	25559	sec	-
$\log A_T(t-t')$	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	-

AVG 0.0971



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(%)	$\log A_T$	Temp	$\log A_T/T$
1	0	0.5	0.5	-	-	21.27	-
2	9550	10019	469	0.09	1.3280	34.91	0.0974
3							
4							
5							
6							

AVG 0.0974

Summary	Initial	Final	Units	@20C refT
lab time	49.71	18989	sec	-
$\log A_T(t-t')$	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	-