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GRI Test Method GS10*

Standard Test Method for

Accelerated Tensile Creep and Creep-Rupture of Geosynthetic Materials Based on Time-Temperature Superposition Using the Stepped Isothermal Method

1. Scope

1.1 This test method covers accelerated testing for tensile creep, and tensile creep-rupture properties using the Stepped Isothermal Method (SIM).

1.2 The test method is currently focused on geosynthetic reinforcement materials such as yarns , strips and ribs of geogrids, or narrow geotextile specimens.

1.3 The SIM tests are laterally unconfined tests based on time-temperature superposition procedures.

1.4 Rapid Load Tensile (RLT) tests are to be completed before SIM tests and the results are used to determine the stress levels for subsequent SIM tests defined in terms of the percentage of Ultimate Tensile Strength (UTS). Additionally, the RLT test can be designed to provide estimates of the initial elastic strain distributions appropriate for the SIM results.

1.5 Ramp and Hold (R+H) tests may be completed in conjunction with SIM tests. They are designed to provide additional estimates of the initial elastic and initial rapid creep strain levels appropriate for the SIM results.

1.6 Values stated in SI units are to be regarded as standard. The common units given in parentheses are for information only.

1.7 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of the regulatory limitations prior to use.

1.8 This method can be used to establish the sustained load creep characteristics of a geosynthetics described in GRI-GG4 and GT7 Section 8.2.2. Results of this method are to be used in addition to the requirements of Section 8.2 of GRI GG4 and GT7, and may not be used as the sole basis for determination of long term creep rupture behavior of geosynthetic material.

*This GRI standard is developed by the Geosynthetic Research Institute through consultation and review by the member organizations. This test method will be reviewed on a periodic, as-required, basis. In this regard it is subject to change at any time. The most recent revision date is the effective version.

2. Referenced Documents

2.1 ASTM Standards

D2990 Standard Test Methods for Tensile, Compressive, and Flexural Creep and Creep-Rupture of Plastics

D4595 Standard Test Method for Tensile Properties of Geotextiles by the Wide-Width Strip Method

D4439 Terminology for Geosynthetics

D5262 Standard Test Method for Evaluating the Unconfined Creep Behavior of Geosynthetics

2.2 ISO Standards

ISO 13431 Determination of the Tension Creep and Creep Rupture Behavior of Geosynthetics

3. Terminology

3.1 For definitions related to geosynthetics see ASTM D4439.

3.2 For definitions related to creep see ASTM D2990 and ASTM D5262.

3.3 *Descriptions of Terms Specific to This Standard*

3.3.1 *viscoelastic response*—refers to polymeric creep, strain, stress relaxation or a combination thereof.

3.3.2 *tensile creep*—time dependent deformation that occurs when a specimen is subjected to a constant tensile load.

3.3.3 *tensile creep-rupture*—time dependent rupture that terminates a creep test at high stress levels.

3.3.4 *time-temperature superposition*—the practice of shifting viscoelastic response curves obtained at different temperatures along a horizontal log time axis so as to achieve a master curve covering an extended range of time.

3.3.5 *shift factor*—The displacement along the log time axis by which a section of the creep or creep modulus curve is moved to create the master curve at the reference temperature. Shift factors are denoted by the symbol a_T when the displacements are generally to shorter times (attenuation) or the symbol A_T when the displacements are generally to longer times (acceleration).

3.3.6 *stepped isothermal method (SIM)* —a method of exposure that uses temperature steps and dwell times to accelerate creep response of a material being tested under load.

3.3.7 *mean test temperature*—The arithmetic average of all temperature readings of the atmosphere surrounding the test specimen for a particular temperature step, starting at a time not later than two minutes after the temperature has been reset and finishing at a time just prior to the subsequent temperature reset.

3.3.8 *ultimate tensile strength (UTS)* —short term strength value used to normalize creep rupture strengths.

3.3.9 *offset modulus method or pointing*—data analysis method used to normalize any prestrain in the samples by shifting the origin of a stress vs strain curve to an axis origin of coordinates, i.e., to coordinates (0,0).

3.3.10 *rapid loading tensile (RLT) test*—a short duration test that is used to determine the stress vs strain curve and the ultimate tensile strength of a material.

3.3.11 *ramp and hold (R+H) test*—a creep test of very short duration, e.g., 100-1000 seconds.

3.3.12 *dwell time*—time during which conditions (particular load) are held constant between temperature steps.

4. Summary of Test Methods

4.1 *SIM* – A procedure whereby specified temperature steps and dwell times are used to accelerate viscoelastic creep characteristics during which strain and load are monitored as a function of time.

4.1.1 *tensile creep* – Constant tensile load in conjunction with specified temperature steps and dwell times are used to accelerate creep strain response characteristics while strain and load are monitored as a function of time.

4.1.2 *tensile creep-rupture* – A tensile creep test where high stress levels are achieved during testing to ensure rupture, while specified temperature steps and dwell times are used to accelerate creep strain response characteristics. Strain and load are monitored as a function of time.

4.2 *RLT* – Test specimens are rapidly loaded over a short period to achieve rupture. RLT tests used to support creep and creep-rupture tests are performed under the same control of loading or strain rate as used to load or strain the creep or creep rupture tests.

4.3 *R+H* – Test specimens are ramp loaded at a predetermined loading rate to a predetermined load and held under constant load (short term creep test).

5. Significance and Use

5.1 Use of the Stepped Isothermal Method accelerates the time required for creep to occur and the obtaining of the associated data.

5.2 The statements set forth in Section 1.8 are very important in the context of significance and use, as well as scope of the standard.

5.3 Creep test data are used to calculate the creep modulus of materials as a function of time. These data are then used to predict the long-term creep deformation expected of geosynthetics used in reinforcement applications.

Note 1: Currently, SIM testing has focused mainly on geogrids and geotextiles made from polyester and polypropylene yarns, ribs or narrow strips. Additional testing on other materials is ongoing.

5.4 Creep rupture test data are used to develop a regression line relating creep stress to rupture time. These results predict the long term rupture strength expected for geosynthetics used in reinforcement application.

5.5 Rapid loading tensile (RLT) testing is used to establish the ultimate tensile strength (UTS) of a material and to determine elastic stress, strain and variations thereof for SIM tests.

5.6 Ramp and Hold (R+H) testing is done to establish the range of creep strains experienced in the brief period of very rapid response following the peak of the load ramp.

6. Apparatus

6.1 *Grips* – grips for SIM and R+H tests should be the same as the grips for RLT tests. Neither slippage nor excessive stress should be allowed to occur.

6.2 *Testing machine* – A universal testing machine with the following capabilities and accessories shall be used for testing.

6.2.1 load measurement and control
6.2.2 extension/strain measurement and control
6.2.3 time measurement
6.2.4 environmental temperature chamber to facilitate control of test conditions

6.2.4.1 temperature measurement and control facilities

6.2.5 other environmental measurement and control
6.2.6 computer data acquisition and control

7. Sampling

7.1 The specimens used for RLT, R+H and SIM tests should all be taken from the same sample.

7.2 Remove six (6) test specimens from the sample for RLT tests.

7.3 Remove one (1) test specimen from the sample for each SIM test.

7.4 Remove one (1) test specimen from the sample for each R+H test.

8. Test Specimens

8.1 Geogrid specimens should be single ribs, unless otherwise agreed upon.

8.2 Yarn specimens of geogrids or geotextiles should be single ply or multiple ply strands, unless otherwise agreed upon.

8.3 Geotextile specimens should be 50 mm wide strips, unless otherwise agreed upon.

Note 2: Narrow specimens are preferred to determine the effect of applied load on the tensile creep properties of the material separate from the effect of sample width on the tensile properties of the material.

8.4 Length of the test specimen is determined by the type of grips that are used; typically 900 to 1100 mm (35 to 43 inches).

8.5 *Number of tests*

8.5.1 At least six (6) RLT tests are used to define the UTS.

8.5.2 A single specimen is usually sufficient to define a master creep or relaxation curve using the SIM. However, if only a single SIM test is to be performed, the location of the strain or modulus curve should be confirmed using at least two short term creep (R+H) tests.

8.5.3 Generally 12 to 18 specimens are needed to define a creep-rupture curve. Fewer specimens would be needed to define a specific region of the curve, for example the percent UTS at 1×10^6 hrs (= 110 year) rupture life.

9. Conditioning

9.1 RLT and SIM testing shall be conducted at 20±1°C as the reference or temperature standard. If the laboratory is not within this range, perform RLT tests in a suitable environmental chamber capable of controlled cooling and heating. The environmental chamber should have a programmable or set-point controller so as to maintain temperature to 20±1°C. When agreed to, a reference temperature other than 20°C can be utilized. Also, when agreed to, the results of testing under this standard can be shifted from one reference temperature to another.

9.2 Allow the specimen adequate time to come to temperature equilibrium in the laboratory or environmental chamber. Generally this can be accomplished within a few hours.

9.3 Record the relative humidity in the laboratory or environmental chamber for all tests.

9.4 Unless otherwise agreed upon, specimens will be tested in the as-received condition.

10. Selection of Test Conditions

10.1 The standard environment for testing is dry, since the effect of elevated temperature is to reduce the humidity of ambient air without special controls.

10.2 The standard reference temperature is 20°C unless otherwise agreed to. The individual reference temperature for each SIM test is the average achieved temperature of the first isothermal dwell.

10.3 Testing temperatures are to be within ± 2°C of the target test temperatures. It is critically important that the test specimen has equilibrated throughout its thickness so as to avoid nonisothermal conditions. Initial trials are necessary to establish this minimum equilibrium time.

10.4 Test temperatures are to be maintained within ± 1.0°C of the mean achieved temperature

10.5 Selection of test temperature and times

10.5.1 Temperature steps and dwell times must be such that the steady state creep rate at the beginning of a new step is not so different from that of the previous that it cannot be established within two minutes.

10.6 A constant temperature to within ± 1.0°C in the environmental chamber is to be achieved within two minutes for a temperature step.

11. Procedures

11.1 The same or similar load or strain control shall be applied to the RLT tests and the load ramp portion of R+H and SIM (creep and creep-rupture) tests. The load rate control (in units of kN per min.) that is applied shall achieve a narrow range of strain rates expressed in percent per minute, as agreed upon. Generally 10% ± 3% per minute (or 20% ± 3% per minute for European practice) will be satisfactory.

Note 3: A linear ramp of load vs time will not generally result in a linear strain vs time relationship because stress vs strain curves are not linear for most geosynthetic materials.

11.2 Achieve the test loads for R+H and SIM tests within ±2% of the target loads, and maintain any achieved load within ±0.5% of its values for the duration of the test. A brief overshoot of the target load that is within 2% of the target load and limited to a 1 to 2 second time duration is acceptable for load control systems.

11.3 Replicate test loads for R+H and SIM tests should be within ± 0.5% of the average of the achieved loads for a test set.

11.4 Pretensioning up to 2% of the maximum load to be applied is acceptable. The method used to define zero strain is to be identified.

11.5 The same or similar grips shall be used for RLT, R+H and SIM tests. Very effective grips are needed at stress levels which may produce rupture (for example, at loads greater than 55% of UTS for polyester). This requirement may be relaxed for R+H or SIM tests at stress levels below those which may cause rupture.

11.6 Inspect grips to insure loading surfaces are clean and that padding, if used, is free of defects and is secured properly.

11.7 Inspect the specimen installation to be sure the material is properly aligned with the grips and with the loading axis.

11.8 Insure that the load cell used is calibrated properly such that it will accurately measure the range of tensile loads anticipated.

11.9 Insure that the extensometer used (if any) is calibrated properly such that it will accurately measure the range of tensile strains anticipated. If rupture is anticipated, take precautions to insure that the rupture event will not damage the extensometer or create a hazard for the machine operator.

11.10 Unless otherwise agreed, a 100 mm gage length shall be used for geosynthetic products and a 250-300 mm gage length shall be used for precursor yarn products.

11.11 Time, load and extension data shall be collected at a minimum rate of two readings per second during the initial loading ramp portions of tests and a minimum rate of two readings per minute during constant load portions of tests. If load is applied by means of dead weights, with or without a lever, regular measurement of load after the ramp is not necessary.

11.12 The environmental chamber and temperature cooler shall be capable of maintaining the specimen temperature within ± 1°C in range of 0 to 100°C, and of changing the specimen temperature by up to 15°C within two minutes.

11.13 Unless otherwise agreed upon, the temperature steps for SIM applied to polyester geosynthetics shall not exceed 14°C. The temperature steps for polyolefin geosynthetics shall not exceed 7°C.

Note 4: Examples that have been successful are a 14°C step with a 10,000 second dwell for PET, and a 7°C step with a 10,000 second dwell for HDPE.

11.14 Unless otherwise agreed upon, the isothermal dwell time for all SIM tests shall not be less than 10,000 seconds. Unless otherwise agreed upon, the total time for SIM tests not terminated in rupture shall not be less than 60,000 sec.

11.15 The temperature data acquisition rate during SIM shall be contemporaneous and compatible with the stress and strain data acquisition during constant load or constant strain portions of the tests so that thermal events can be correlated readily with stress and strain events using simple spreadsheet manipulations.

11.16 If desired, accelerated tensile property tests can be conducted in liquid, vapor, or gaseous mixtures to simulate unique environmental exposures.

12. Calculation

12.1 *Rapid Loading Tensile (RLT) Results*

12.1.1 Calculate the ultimate tensile strength (UTS) and elongation of the sample.

12.1.2 Plot stress and secant modulus vs strain. It is recommended that the offset modulus method be used to "point" the curves. See Figures 1 and 2 for an illustration of this technique on a set of stress vs strain curves.

Note 5: The offset modulus method is described in ASTM D4595, Appendix X2 and has been used in a number of examples in Thornton, J. S., Sprague, C. J., Kloupmaker, J. and Wedding, D. B., "The Relationship of Creep Curves to Rapid Loading Stress-Strain Curves for Polyester Geogrids," Geosynthetics '99, Vol. 2, Industrial Fabrics Association International, April 28-30, 1999, pp. 735-744.

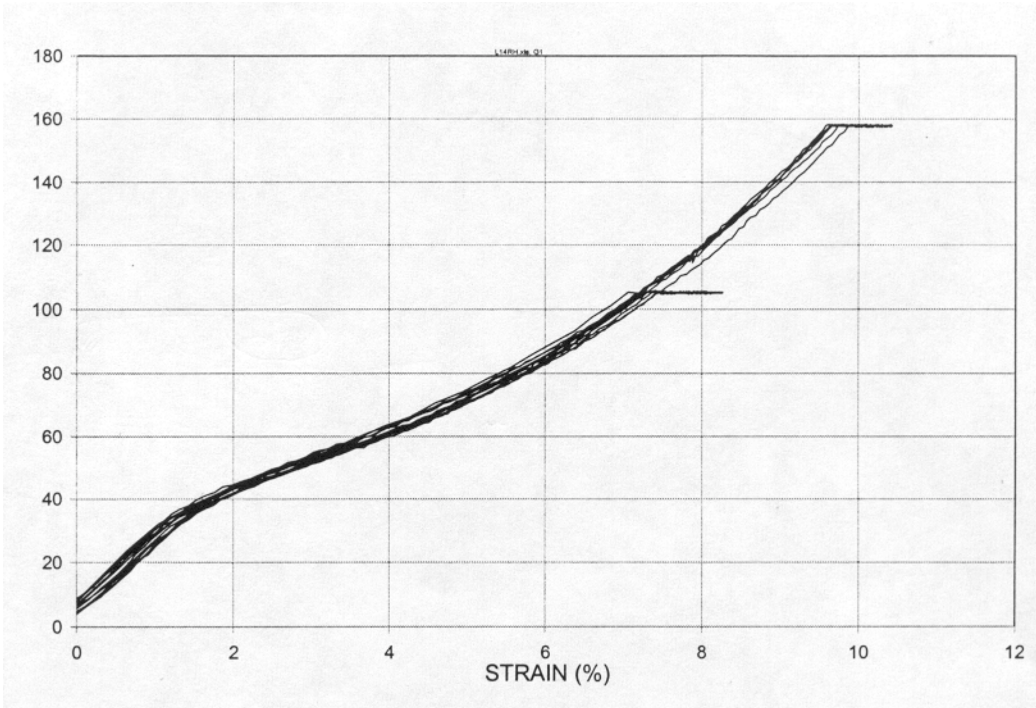

Figure 1 – Stress vs Strain for R H Tests Prior to Pointing

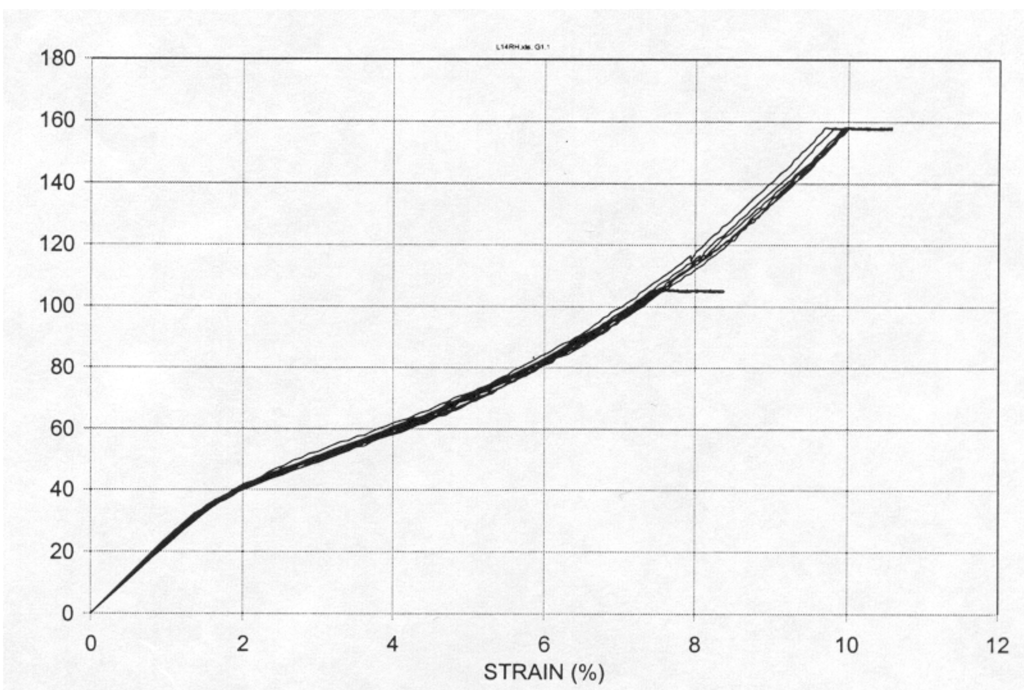

Figure 2 – Stress vs. Strain for R+H Tests After Pointing

12.1.3 Compute the stress levels to be achieved in R+H and creep and creep rupture tests in percent of UTS.

12.1.4 When specified, identify the range of elastic strains that correspond with the stress levels to be achieved in R+H, creep and creep-rupture tests.

12.2 *Ramp and Hold (R+H) Results*

12.2.1 Plot stress and secant (creep) modulus vs strain, and strain and secant (creep) modulus vs linear and log time. Use the offset modulus method to point the curves as described in Section 12.1.2.

12.2.2 Identify the elastic strains at the ramp peaks and the initial rapid creep strain levels for comparison to the ramp and initial creep portions of the SIM results.

12.3 SIM Test Results (See Appendix for Examples)

12.3.1 Compute and plot stress and secant (creep) modulus vs. strain for each specimen, using the offset modulus method to point the curve. Then plot creep strain, creep modulus, stress and temperature as a function of linear time. Inspect these plots to identify that the stated procedures were achieved.

12.3.2 Plot creep modulus (or strain) vs log time after rescaling the elevated temperature segments to achieve slope matching as follows: The semi-logarithmic slopes of a modulus (or strain) curve at the beginning of a higher temperature dwell step should be adjusted to match the slope of the end of the preceding lower temperature by subtracting a time "t" from each of the dwell times of higher temperature steps.

12.3.3 Re-plot the creep modulus (or strain) vs log time after rescaling as above and after employing vertical shifts of the modulus (or strain) data for each elevated temperature to account for system thermal expansion.

12.3.4 Replot the creep modulus and strain vs log time curves as rescaled and vertically shifted above and after employing horizontal shifts of the elevated temperature dwell segments to the right of the initial reference temperature dwell segment. The result of this final manipulation should be a smooth master curve for each specimen subjected to SIM. Identify ruptures, if any, with a symbol at the termination of the master curve.

12.3.5 The rescaling, vertical shifting and horizontal shifting steps generally require some iteration to achieve smooth master curves.

12.3.6 Prepare a plot of the logarithm of the cumulative shift factor vs temperature.

12.3.7 For a creep rupture test series, plot rupture stress as a percentage of UTS vs log (accelerated) time to rupture. Perform linear regression analysis on the data set, selecting time as the dependent variable. If specified, compute the 90% or 95% one-sided confidence limits for the creep rupture data.

12.3.8 If specified, determine the instability strain limit (strain and time) as the onset of tertiary creep for each creep-rupture data point and plot this strain value vs log (accelerated) time to instability strain.

12.3.9 Compute the mean temperature and a measure of temperature variation such as standard deviation or extreme values for each temperature step.

13. Report (See Appendix for Examples)

13.1 Report the material type and structure along with the brand name and style nomenclature and the structure (yarn, rib, strip, fabric, etc.) of the geosynthetic product. Report the tensile strength of the product. If the tensile strength value is provided by the manufacturer then this should be so stated.

13.2 Document the tests performed and the electronic data files wherein original data is stored.

13.3 Complete and provide the graphs specified in Section 12, and provide tables for creep-rupture values.

13.4 Results generated under this standard shall be stated as having been measured by SIM testing protocol per this test method.

14. Keywords

14.1 creep, geosynthetics, stepped isothermal method, time-temperature superposition, rapid loading tensile test, ramp and hold test, creep-rupture.

APPENDIX

X1. INTRODUCTION

X.1.1 The following table and graphs are typical of those used in the report section of the SIM test procedure. Figures X.1 through X.8 show the results for a polyester yarn before and after scaling and shifting. Table X.1 shows the values used to scale and shift the data. The reference temperature for this test sequence was 26°C and the total SIM exposure time was 50,000 sec.

Table X.1

Line	**t**	**t**	**t-r**	**Vert. Shift**	**Log A_T**	**Temp**	**Log A_T/T**
5	0	0.5	0.5	0	0	25.90	0
516	9588	10188	600	0	1.22	39.70	0.0884
850	19608	20208	600	0	1.26	53.60	0.0906
1184	29508	30108	600	0	1.22	67.48	0.0879
1518	39528	40128	600	0	1.25	81.48	0.0893
Summary		**Initial**					AVG 0.0891
Time (laboratory)		120	50118				

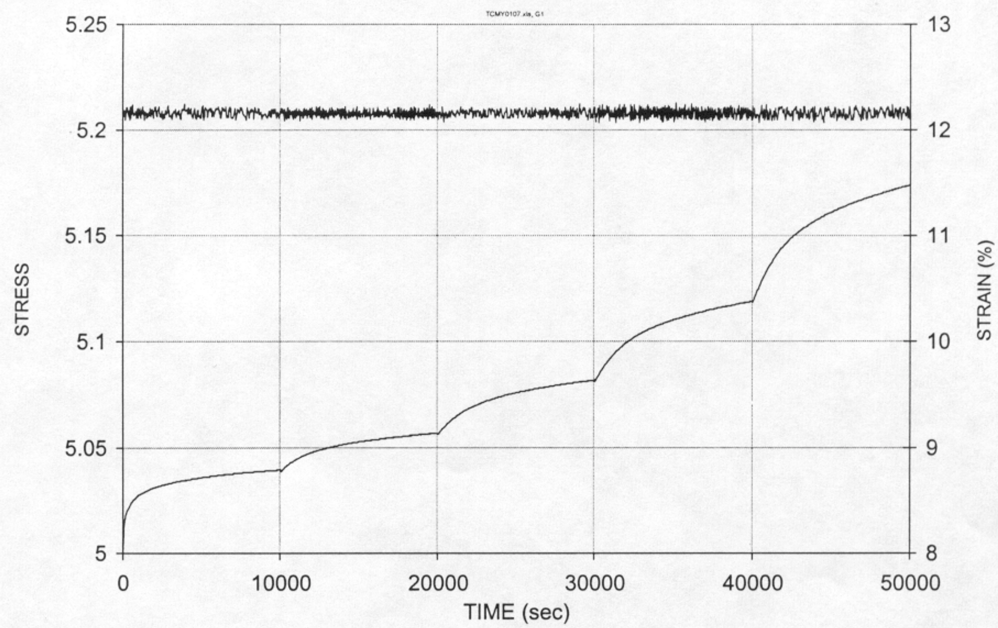

Figure X.1 – Stress and Creep Strain vs. Linear Time

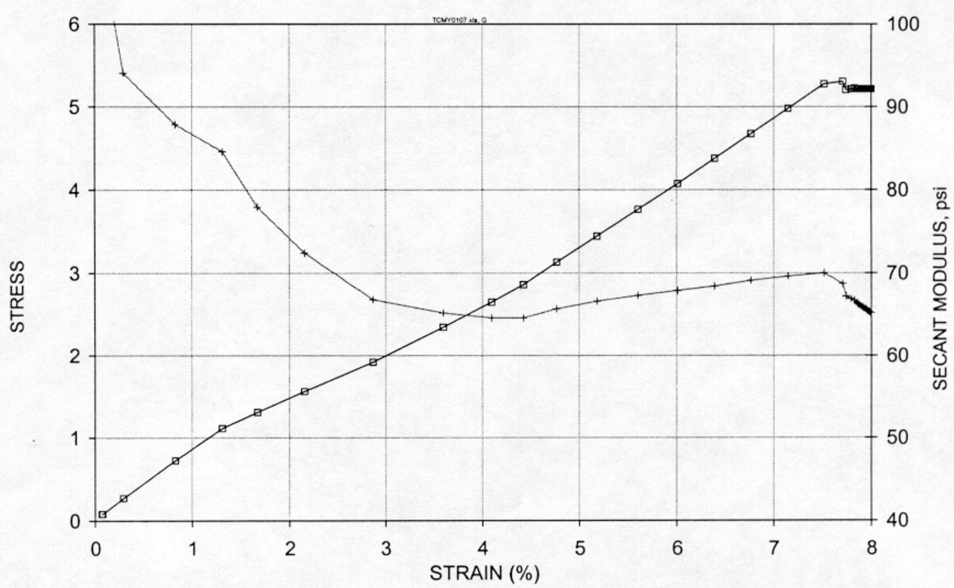

Figure X.2 – Stress and Secant Modulus vs. Linear Time

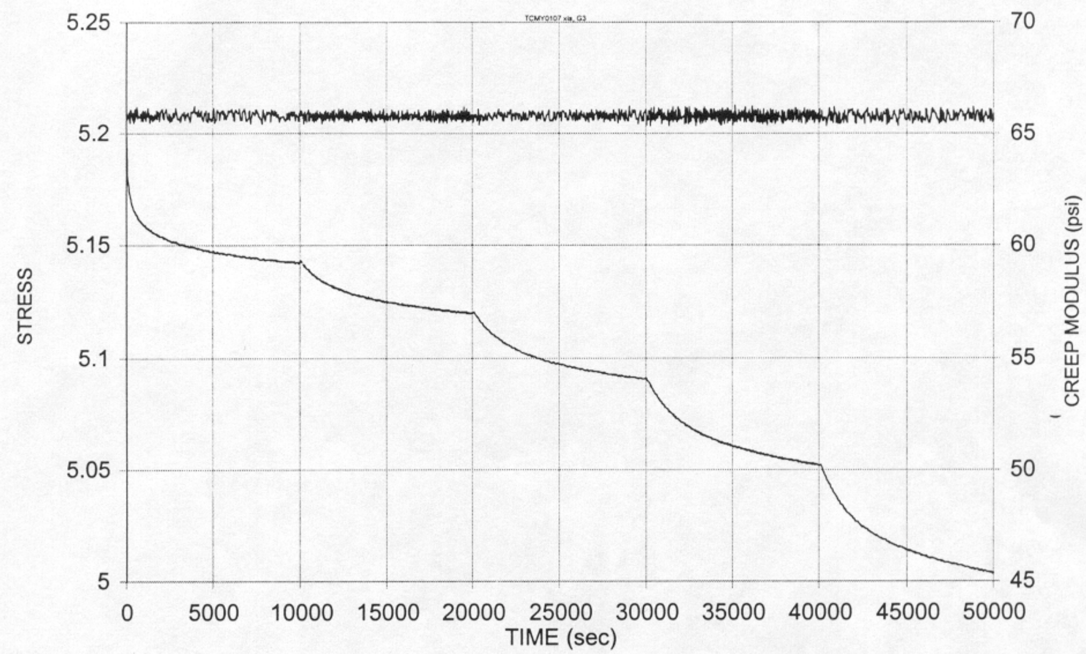

Figure X.3 – Stress and Creep Modulus vs. Linear Time

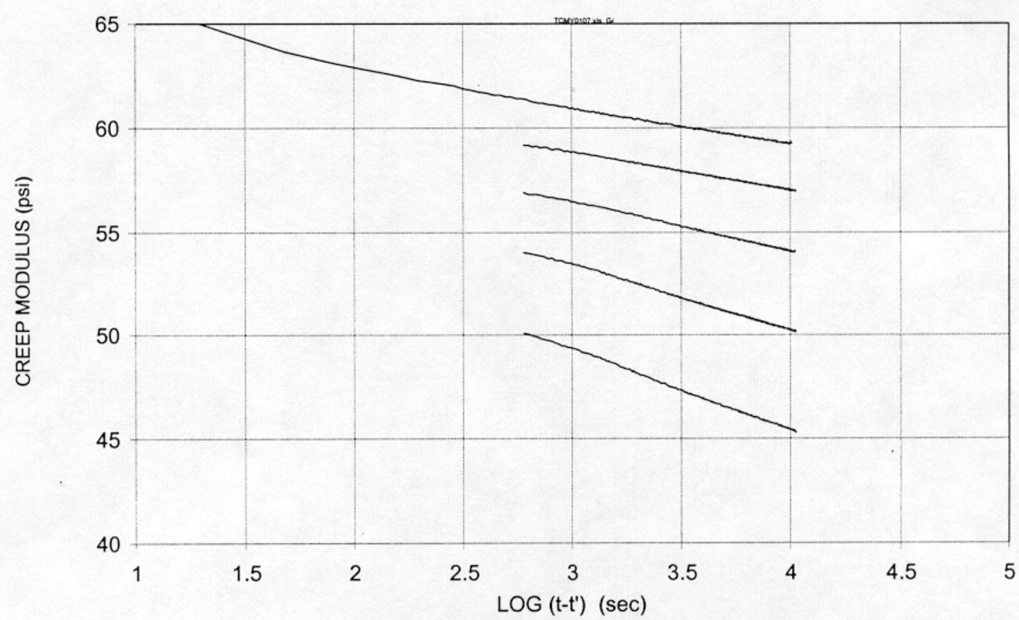

Figure X.4 – Creep Modulus vs. Log Time After Rescaling

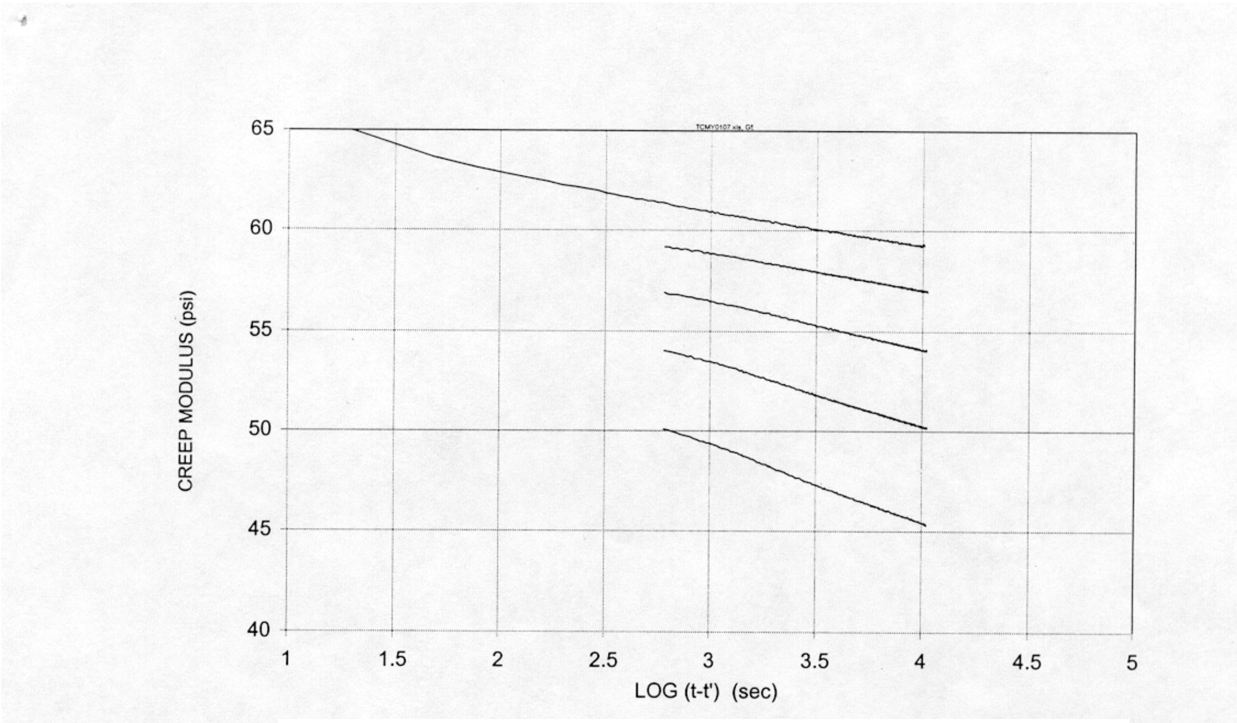

Figure X.5 – Creep Modulus vs. Log Time (Vertical Shifts)

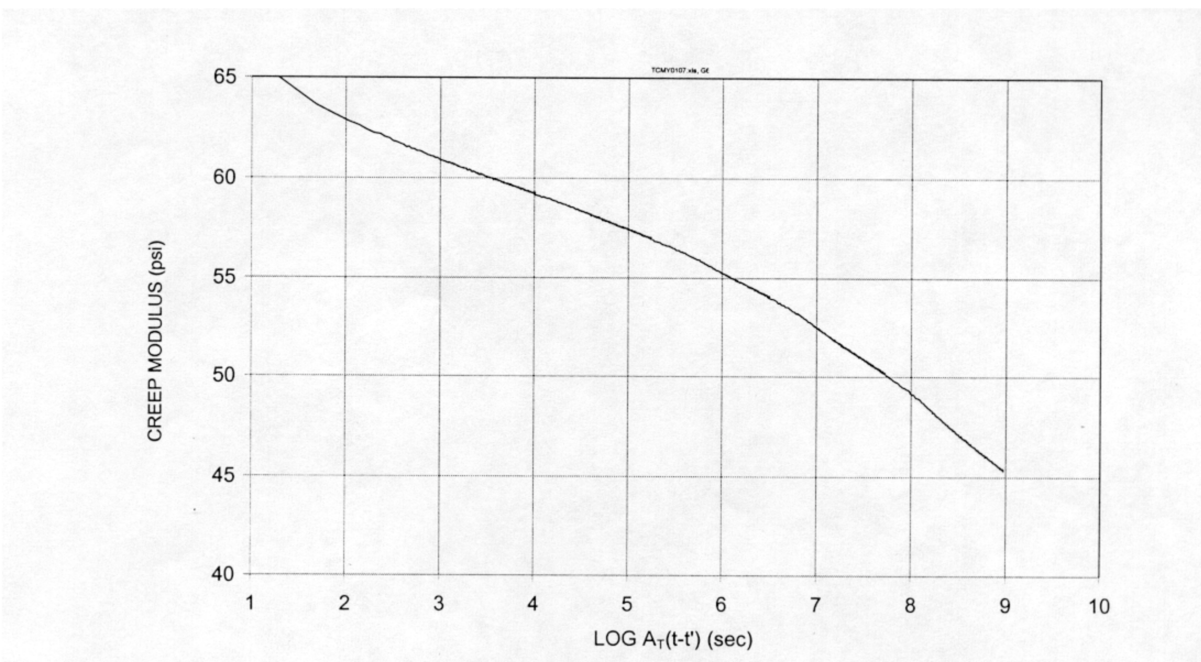

Figure X.6 – Master Creep Modulus vs. Log Time Curve at the Step One Reference Temperature

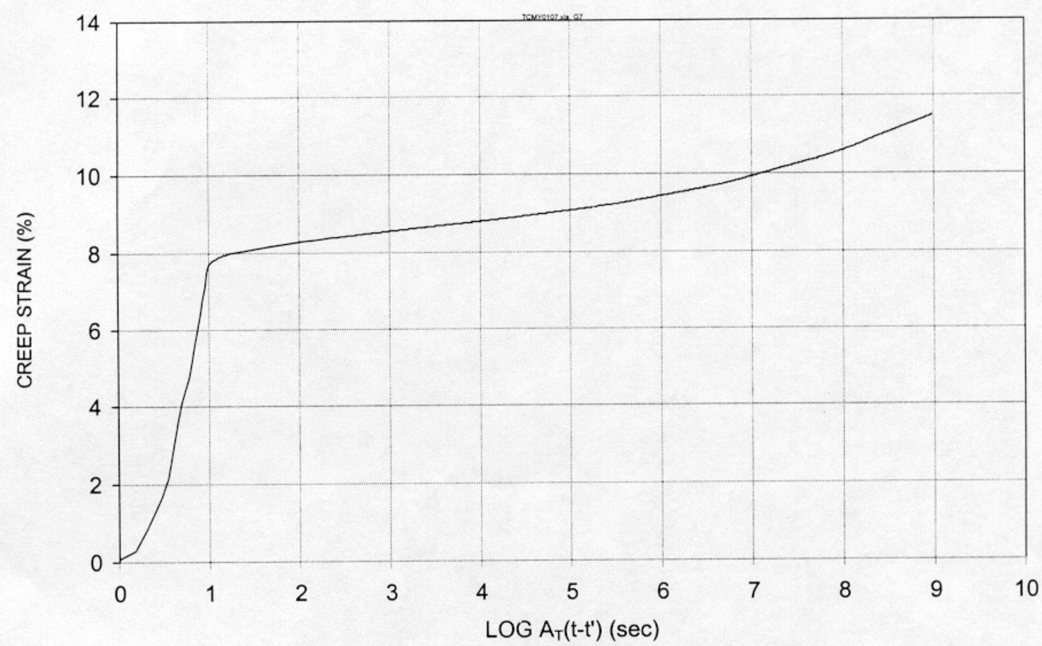

Figure X.7 – Master Creep Strain vs. Log Time at the Step One Reference Temperature

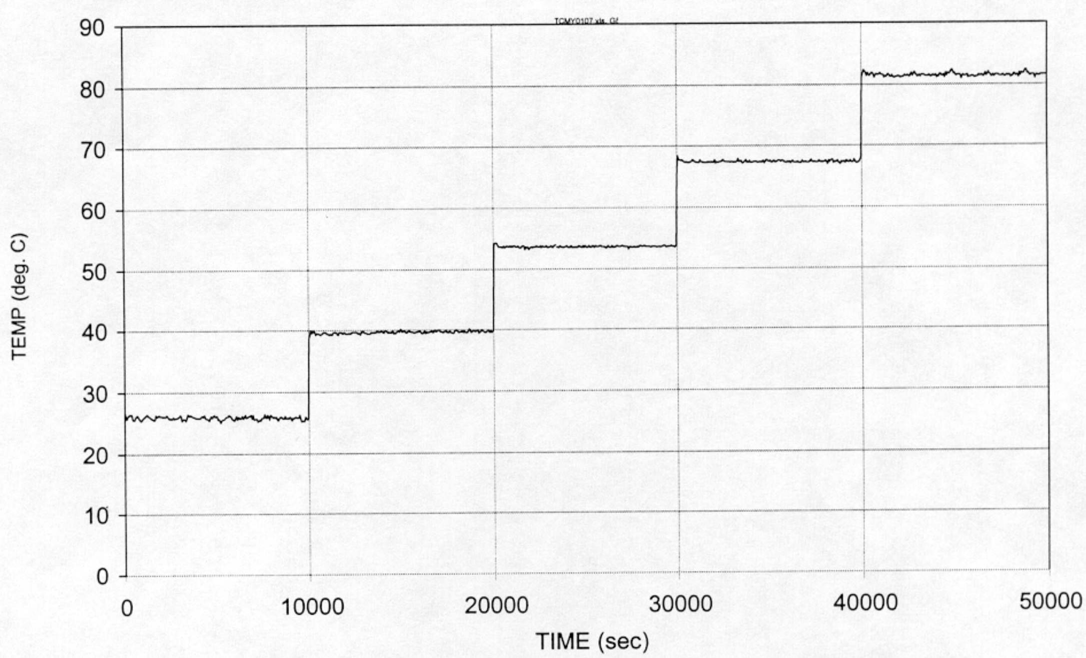

Figure X.8 – SIM Temperature Steps vs. Time Steps