Chapter 6

Review of Long-Term Durable Creep Performance of Geosynthetics by Constitutive Equations of Reduction Factors

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Additional information is available at the end of the chapter

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Abstract

In an elastic solid the strain stays constant with time and is constant and the stress decays slowly with time. The increase in strain is not linear, and the curve becomes steeper with time and also as the stress-rate is increased. The slope of the curve tends to decrease with time, but it is steeper for higher strain rates. The variation of both strain and stress with time is linear for constant stress- and strain-rate tests upon elastic materials. The final comment about the compressive creep test and data interpretation is as follows: (1) Description of the creep mechanism of the geosynthetics (exactly not compression but perpendicular compression) is very important because the creep mechanism of tension and compression is quite deferent. (2) To reduce the specimen-to-specimen, many ramp-and-hold (in the case of tension creep: 1 h) tests are recommended. (3) Loading rate is also important because it make initial strain value. To check the nonaffected loading rate, prior to the main creep test, some kind of short-term test is needed. (4) The method to assess the reduction factor by creep also will be reviewed because the value will be changed according to the applied load.

Keywords: time dependence, creep loading, stress- and strain-rate tests, creep mechanism, geosynthetics, ramp-and-hold, reinforcements, reduction factor by creep

1. General time-dependent behavior

The exact nature of the time dependence of the mechanical properties of a polymer sample depends upon the type of stress or straining cycle employed. The variation of the stress and strain with time t is illustrated schematically in **Figure 1** for a simple polymer tensile specimen subjected to four different deformation histories [1, 2]. In each case, the behavior of an elastic material is also given as a dashed line for comparison. During creep loading, a constant stress is applied to the specimen at t = 0 and the strain increases rapidly at first, slowing down over longer time periods. In an elastic solid, the strain stays constant with time. The behavior of an elastic material during stress relaxation is shown in **Figure 1(b)**. In this case, the strain is held constant, and the stress decays slowly with time, whereas in an elastic material at a constant stress-rate is shown in **Figure 1(c)**. The increase in strain is not linear, and the curve becomes steeper with time and also as the stress-rate is increased. If different constant strain rates are used, the variation of stress with time is not linear. The slope of the curve tends to decrease with time, but it is steeper for higher strain rates. The variation of both strain and stress with time is linear for constant stress- and strain-rate tests upon elastic materials.

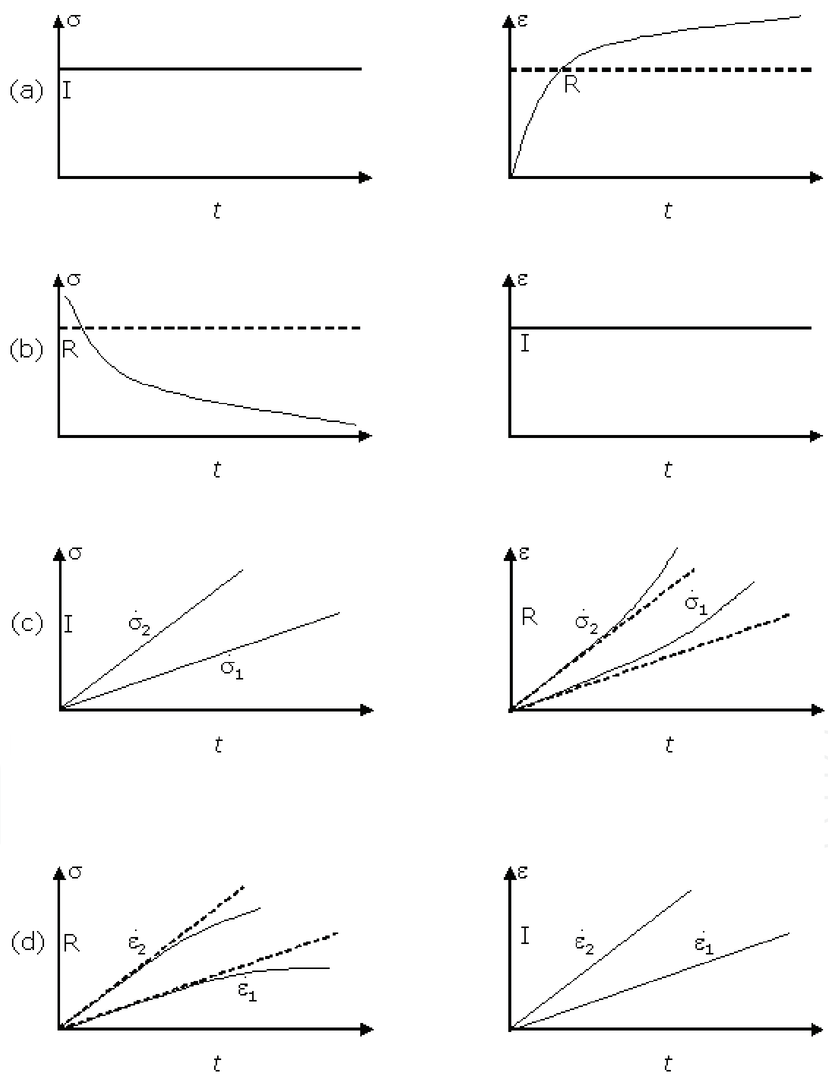

Figure 1. Schematic representation of the variation of stress and strain with time indicating the input (I) and responses (R) for different types of loading: (a) creep, (b) relaxations, (c) constant stressing rate, and (d) constant straining rate.

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2. Creep deformation

Creep behavior is typically time-dependent elongation property for geosynthetics, which are used to reinforce and improve the long-term performance and sustainable durability in the soil-related structure. Also, creep behavior is changed under temperature and service life after installation period

Figure 2 shows a curve of creep strain versus time of the creep test results, and slope of this curve is creep rate [3]. In general, creep phenomena can be divided into three stages.

i. First stage – primary creep, start at a rapid rate and slows with time.

ii. Second stage – secondary creep has a relatively uniform rate.

iii. Third stage – tertiary creep has an accelerating creep rate and terminates by failure of material at time for rupture (**Figure 2**).

Creep analysis in designing with geosynthetic reinforcement is considered, and the tertiary creep is very important because creep fracture can be occurred within this area.

As geosynthetics are generally manufactured from polymer materials, they exhibit a visco-elastic behavior, time, load, and temperature-dependent, under a sustained constant load. The creep behavior of geosynthetics is generally presented as strain versus time or (log time) curves and strain-rate versus time as shown in **Figure 2**. At time t, the total strain ε(t) can be expressed from the following equation:

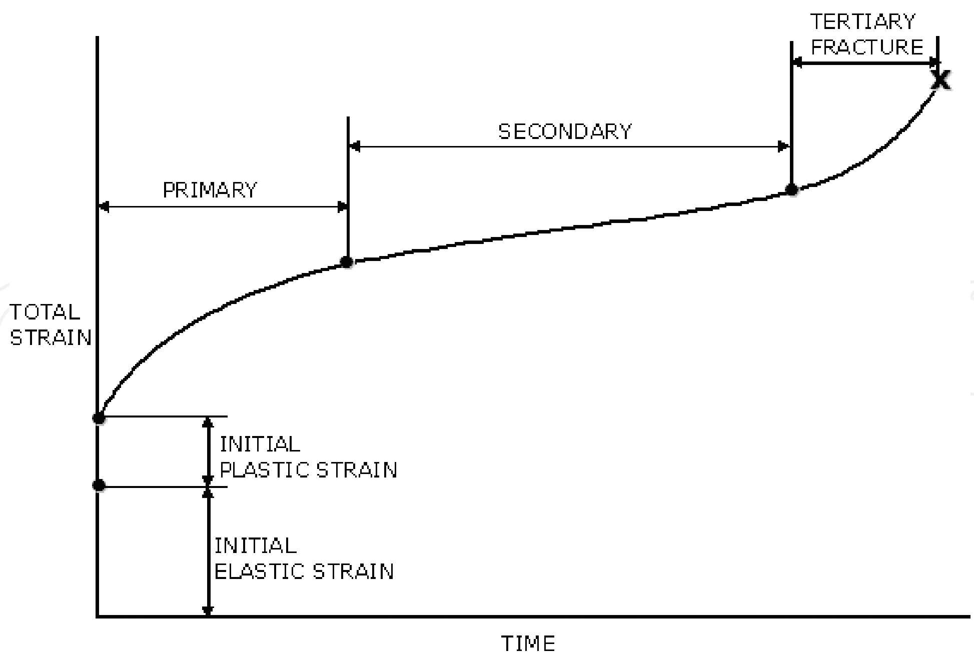

Figure 2. Time-dependent strain curve with primary, secondary, and tertiary stages.

$$\varepsilon(t) = \varepsilon_0 + \varepsilon_I + \varepsilon_{II} + \varepsilon_{III} \tag{1}$$

where ε0 is the instantaneous strain and εI, εII, and εIII are the primary, secondary, and tertiary creep strains, respectively.

The ε0 is composed from both recoverable (elastic) and irrecoverable (plastic) instantaneous stain. However, the final sudden creep strain increase before rupture does not necessarily occur: it is typical for PE (polyethylene) and PP (polypropylene) not for PET (polyester) at standard load levels and temperatures. Based on the dominant creep stage, there are three types of creep generation: dominant primary creep, dominant secondary creep, and dominant tertiary creep as shown in **Figure 3** [4].

As already very well known, the creep behavior of geosynthetics depends from the following factors:

a. polymer nature and polymer structure;

b. geosynthetics structure (nonwoven, woven, and integral structure);

c. loading conditions;

d. temperature conditions;

e. soil environment conditions, and so on.

Therefore, to investigate more specifically the long-term tensile creep of geosynthetics, it is necessary to know the effect of each of the above-mentioned factors on load-strain behavior.

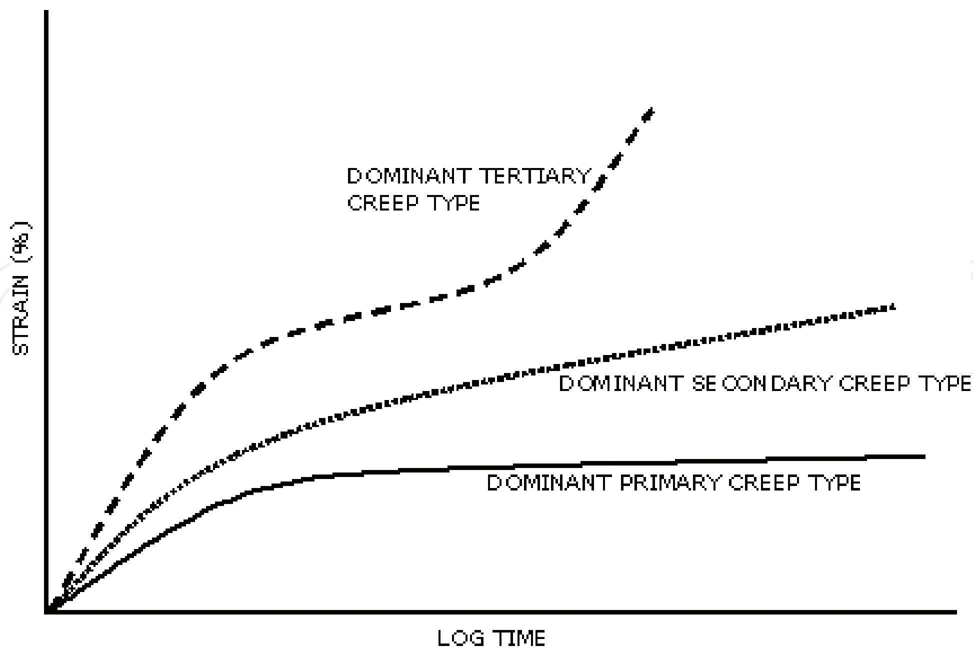

Figure 3. Type of creep behaviors generation.

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Nevertheless, polymer structure parameters such as molecular weight, molecular orientation, and crystalline volume, degree of branching, and draw molecular ratio are also very important to evaluate creep sensitivity of polymers.

3. Time-temperature superposition principle

Laboratory tests can only be conveniently conducted for about a week or so. Consequently, one must use a method of extrapolating short-time tests over several decades of time so that a lower limit of the modulus can be determined for use in design. On the other hand, it is also sometimes difficult to obtain very short time-scale data, and a method is needed to extrapolate data obtained under practicable experimental conditions to these short-time scales. An empirical extrapolation method is available for amorphous polymer systems and, in general, for systems where structure does not change during the period of testing. Time and temperature have essentially equivalent effects on the modulus values of amorphous polymers, in that the shapes of the curves are similar and the modulus values in each region are about equal. Because of the equivalent effect of time and temperature, data at different temperature can be superposed by shifting individual curves one at a time and consecutively along the log t axis on the reference temperature T_0. This time-temperature superposition procedure has the effect of producing a single continuous curve of modulus values extending over many decades of log t for reference temperature. This constructed plot is known as the master curve.

Before the curves can be shifted to make the master curve, the modulus values should be corrected for density and temperature to obtain *reduced modulus* values, $E(t)_{reduced}$

$$E(t)_{reduced} = \left(\frac{T_0}{T}\right)\left(\frac{\rho_0}{\rho}\right) E_r(t) \tag{2}$$

where T_0 = reference temperature, K; ρ_0 = density at T_0; ρ = density at T.

The density correction (ρ_0/ρ) is not usually very large. The temperature correction (T_0/T) is suggested by a rubber-elasticity theory. This procedure asserts that the effect of temperature on viscoelastic properties is equivalent to multiplying the time scale by a constant factor at each temperature. In mathematical terms, it is expressed as

$$E_T[a(T)] = E_{T_0}(t) \tag{3}$$

where the parentheses indicate functional dependence and the brackets indicate multiplication. The quantity $a(T)$ is called the *shift factor*, and it must be obtained along the log time scale necessary to match the curve. The parameter $a(T)$ is chosen as unity at the reference temperature and is a function of temperature alone, decreasing with increasing temperature.

An important empirical correlation has been developed by which the shift factor can be computed for temperature between T_g **and** T_g **+ 100°C**. This correlation was developed by Williams, Landel, and Ferry, and the so-called WLF equation is expressed as

$$\log a(T_0) = \frac{-C_1(T - T_0)}{C_2 + T - T_0} \tag{4}$$

for $T_0 = T_g$, $C_1 = 17.44$ and $C_2 = 51.6$, while for $T_0 = T_g + 45°C$, $C_1 = 8.86$ and $C_2 = 101.6$.

3.1. TTS principle in polyethylene

The modeling of the creep results has been carried out by many researchers in the past three decades. A creep model consisting of two thermally activated Eyring-rate processes has been proposed by Ward and coworkers, particularly for ultra-high molecular weight polyethylene fibers. It has been seen that even in isotropic PE, this model could describe the creep response successfully. The corresponding Arrhenius plot of the dynamic data (log a_T vs. 1/T) is shown in **Figure 4** [5]. It is evident that the irrecoverable creep can be approximated by a single temperature-activated process with the activation energy of 118 kJ/mol over the entire region of stress and temperature experimentally covered. Therefore, there should be a linear relationship between log a_T and 1/T that may be described by the Arrhenius equation:

$$a_{T/Tref} = \exp\left[\frac{E}{R}\left(\frac{1}{T} - \frac{1}{T_{ref}}\right)\right] \tag{5}$$

where E = Arrhenius activation energy (118 kJ/mol), R = gas constant (8.314 $Jmol^{-1}$ K^{-1}), T = absolute temperature (K), and T_{ref} = reference temperature (K).

3.2. Relation between activation energy and creep load for geosynthetics

- The modern development of the theory of reaction rates may have come from the proposal made by S. Arrhenius to account for the influence of temperature on the rate of inversion of sucrose. He suggested that an equilibrium existed between inert and active molecules of the reactant and that the latter only were able to take part in the inversion process. By applying the reaction isochrones to the equilibrium between inert and active species, it can be readily shown that the variation of the specific rate of the reaction with temperature should be expressed by an equation of the form

$$\ln K = \ln A - \frac{E}{RT} \tag{6}$$

where E is the difference in heat content between the activated and inert molecules. An A is a quantity that is independent of or varies relatively little with temperature. Subsequently, the Arrhenius Eq. (6) was written in the equivalent form

$$K = Ae^{-E/RT} \tag{7}$$

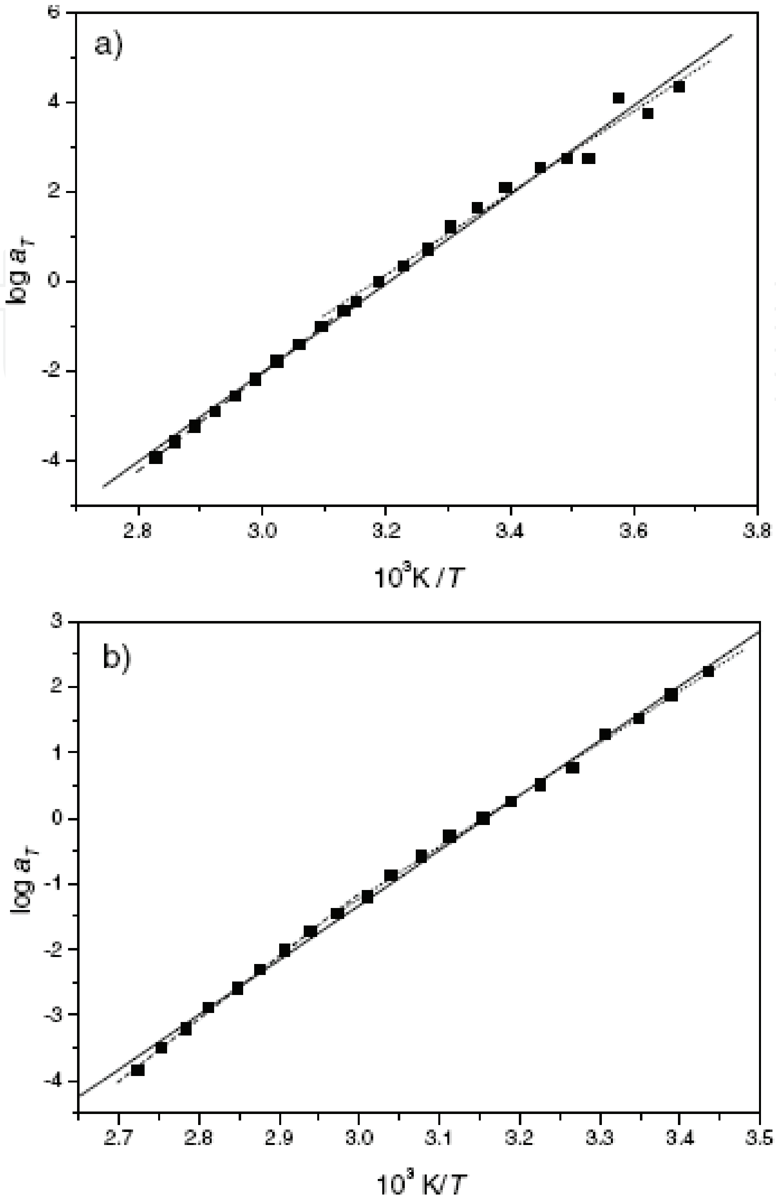

Figure 4. Arrhenius plot of the temperature shift factor from dynamic mechanical storage modulus. Squares: experimental results; solid line: fitting considering all points; dashed line: fitting in the high-temperature region: dotted line: fitting in the low-temperature region: (a) results for PEc and (b) results for PEs.

and it is now generally accepted that a relationship of this kind represents the temperature dependence of the specific rates of most chemical reactions, and even of certain physical processes, provided that the temperature range is not large, the quantities *A* and *E* can be taken as constant.

- Most of the methods to calculate the activation energy are about chemical reaction and phase transitions. The method about the geosynthetics viscoelastic properties is as follows.

The relation between temperature *T* and creep strain-rate ($\dot{\varepsilon}$) can be expressed in the mathematical expression, the Arrhenius Equation, in the form:

$$\dot{\varepsilon} = Ae^{\frac{-E}{RT}} \quad (8)$$

where $\dot{\varepsilon}$ = creep strain-rate, t^{-1}, A = a pre-exponential rate constant, t^{-1}, E = experimental activation energy (cal/mol), R = universal gas constant (= 1.987 cal/mol-K), and T = absolute temperature (°K).

Eq. (8) shows that creep strain-rate increase with temperature and with the decrease in the activation energy, providing that all other factors affecting creep are kept constant. Eq. (8) is usually used in predicting creep rate for longer time intervals. Although time t is not an explicit parameter in the equation, the ratio between $\dot{\varepsilon}_1$ at temperature T_1 and $\dot{\varepsilon}_2$ at temperature T_2 presents a multiplier coefficient of the kinetics μ that can be used in shifting strain rates along the time axis. This relationship is expressed in the form:

$$\ln\mu = \ln\left(\dot{\varepsilon}_1/\dot{\varepsilon}_2\right) = \frac{E}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right) \quad (9)$$

One of the inherit problems in the used Arrhenius equation arises from the difficulty in determining the activation energy E from creep tests as the strain-rate is constantly changing during the test. However, a common and simple technique for the estimation of E consists of applying rapid change in temperature during creep under constant load. Creep strain rates $\dot{\varepsilon}_1$ and $\dot{\varepsilon}_2$ are measured before and after the change in temperature from T_1 and T_2, respectively, and E can be determined from Eq. (9). The evaluation of the activation energy E, according to the reference, is as follows:

The activation energy at various creep loads was assessed through testing HDPE geogrid specimens at various elevated temperatures and loading levels. The HDPE geogrid specimens were placed inside the test ovens and were tested at various temperatures ranging from 32 to 71°C. A hydraulic system applied creep loads ranging from about 18 to 40% of $T_{max.}$ The first set of tests on the geogrid consisted of increasing the temperature incrementally every 20 h while maintaining the load constant. The slopes of strains before and after the change in temperature represented creep strain rates at these temperatures and loading levels. The application of Eq. (9) resulted in an estimation of the activation energy for each loading level.

4. Stepped isothermal method (SIM) for geosynthetics

According to the former working draft of the ASTM standard test procedure, SIM is defined as "a method of exposure that uses temperature steps and dwell times to accelerate creep response of a material being tested under load." It departs from traditional accelerated time-temperature superposition (TTS) work in that it uses a single specimen per test and employs temperature steps throughout the test duration. While the data is shifted using principles well established by TTS work.

The single specimen/multiple temperature steps approach allows for the following three advantages over conventional elevated temperature testing.

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a. Reduces uncertainty in selecting appropriate shift factors to construct master curves.

b. Facilitates the reduction of uncertainty associated with inherent variability of multispecimen tests.

c. Can develop 100-year master curves in a relatively short period of testing time (16–32 h).

A description of the SIM method and its application to geonet creep testing has been discussed by Thoronton et al. [6]. The influence of temperature on creep is illustrated hypothetically in **Figure 5**; creep strain increases with increasing temperature. Stated differently, a given value of material strain can be reached within shorter times by using higher test temperatures. This principle is used in Stepped Isothermal Method (SIM) to obtain creep information within time periods significantly lower than those required for conventional creep testing. A typical SIM experiment is explained graphically in **Figures 5** and **6**. A series of successively higher temperature increments are implemented on a test specimen at a constant stress. Strain is measured during each temperature increment.

For example, temperature step in **Figures 7** and **8** can be 7°C, and a total of six such steps are utilized. Each temperature step can be 1000 s long, that is, each temperature is maintained constant for 1000 s. The resulting strain is illustrated in **Figure 7**. Each strain increment plots linear on log time scale provided some restrictions and conditions specific to each material are observed. These conditions relate to material failure or rupture strength and melt or softening temperature.

In general, the lower the temperature and stress, the better behaved the relationship between time and strain. The result of rescaling the raw SIM data is shown **Figure 8** as a plot of creep modulus versus log (t − t′). The term t′ is actually a set of rescaling terms that create matching slopes between the isothermal dwells in log time space. The result of shifting the rescaled data is the master creep modulus curve of **Figure 6**. Note that the modulus curve extends beyond the 114y (106 h).

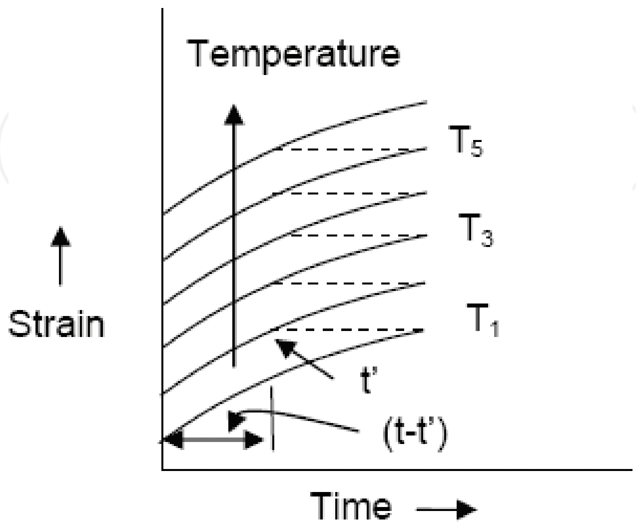

Figure 5. Effect of stress and temperature curves on creep behaviour.

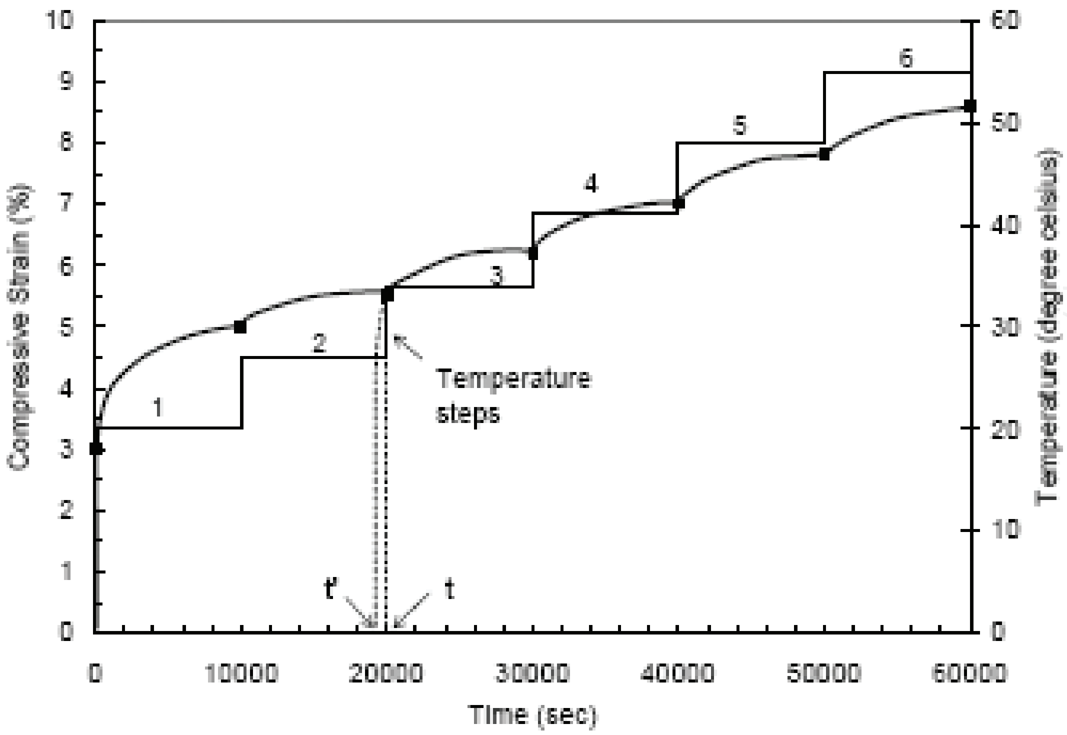

Figure 6. Schematic of SIM method.

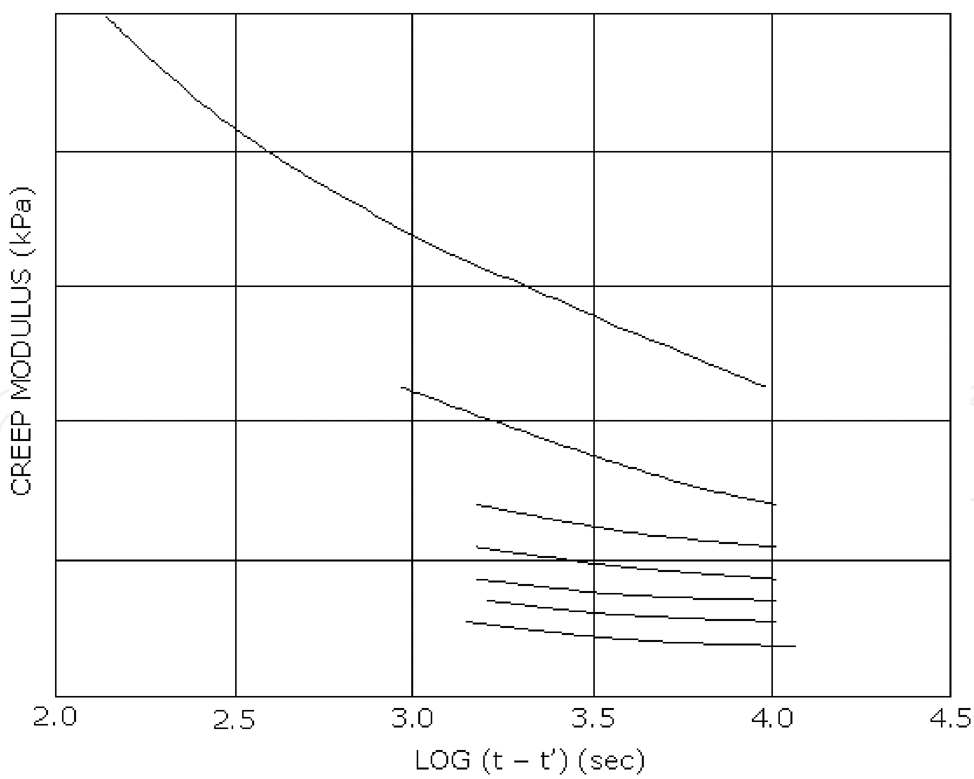

Figure 7. Creep modulus versus log (t – t′) after rescaling.

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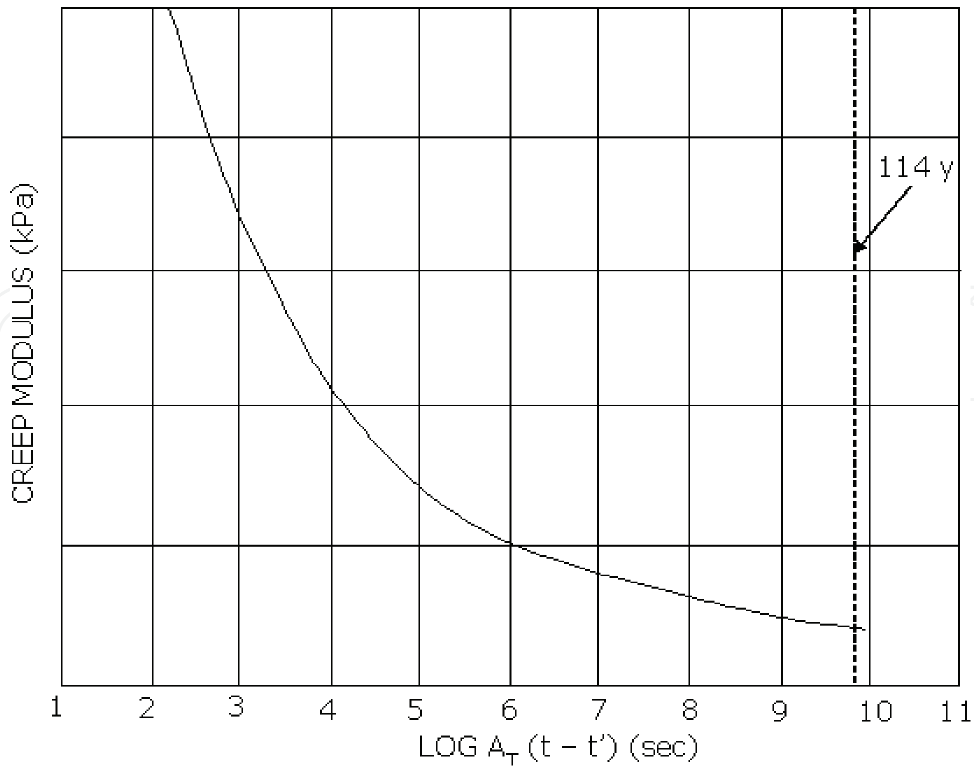

Figure 8. Creep modulus versus log AT (t − t′) (sec).

The creep behavior from SIM on HDPE geogrids may be different than that from the TTS method because the low glass transition temperature (T_g) and melting temperature (T_m) of HDPE resin. When performing SIM on PET geogrids, the test temperature range is below the T_g (~70°C), and the material is in a glassy state. On the contrary, HDPE geogrid is tested in its rubbery state and relatively close to the T_m (124°C) at the same test temperature range. Plastic deformation would be a governing factor in the creep behavior of HDPE, particularly at the high testing temperatures.

The creep mechanism of SIM and TTS of HDPE is evaluated using the activation energy, which is obtained by plotting the shift factor against reciprocal test temperatures according to Arrhenius equations.

$$a_T = A \exp\left(\frac{-E}{RT}\right) \quad (10)$$

where E is the activation energy for the creep deformation, R is gas constant, and T is the test temperature

Table 1 shows the activation energy values of six creep tests based on SIM and TTS procedures in the referenced study [7]. For the same loading, the energy values resulting from SIM and TTS are very similar. The activation energy decreased linearly with stress, as shown in **Figure 9**.

Y. G. Hsuan [7]		Lothspeich and Thornton [10]		Farrag [14]	
Stress/method	E (kJ/mol)	Stress/method	E (kJ/mol)	Stress/method	E (kJ/mol)
10% UTS/SIM	302	37% UTS/SIM	230	19% UTS/TTS	91
20% UTS/SIM	257				
30% UTS/SIM	227 ± 10			23% UTS/TTS	102
40% UTS/SIM	198				
10% UTS/TTS	271			31% UTS/TTS	96
20% UTS/TTS	219				

Table 1. Activation energies with shift factor and strain-rate.

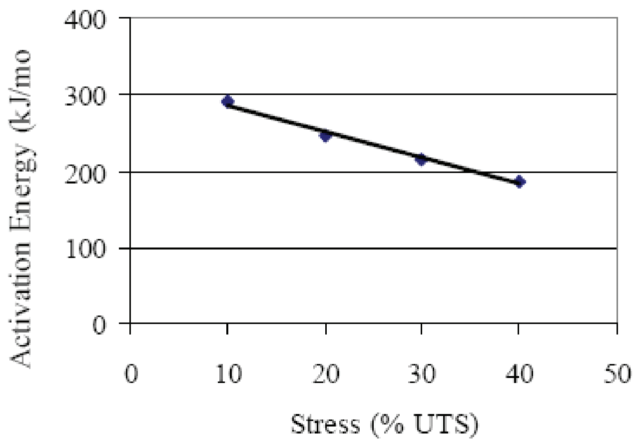

Figure 9. Activation energy versus applied stress.

This similar result for PET yarns and PP woven geotextile were also observed, respectively, [6, 8] and this behaviour was accounted as stress decreases the thermal energy requiring for polymer flow [9].

However, the activation energies resulted from this study as well as those calculated from data published is much higher than other published values [10]. It was found an activation energy value of 118 kJ/mol for PE fibers and an energy value of 85 ± 30 kJ/mol was obtained by studying the stress relaxation of an oriented HDPE [11, 12]. Creep performance tests using TTS with test durations of 1,000 hours were done at each temperature [13, 14]. The activation energies calculated from their shift factor at different applied load are presented in **Table 1**, and the values are closer to the published range for polyethylene materials. The high activation energy values from this study may result from the short test duration, which is only 10,000 s (2.7 h) for each temperature step. The discrepancy in activation energy values suggests that the creep mechanism is different between the short-term SIM and long-term TTS or conventional creep tests. Caution must be carried out when SIM and short-term TTS procedures are applied to new geosynthetics that do not have long-term creep data to be compared. However, once the verification is confirmed, SIM or short-term TTS can be extremely useful to evaluate similar geosynthetics with the same polymer type.

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5. Comparison between SIM and conventional creep tests

5.1. Tensile creep test results

Figures 10–13 show the examples of creep curves derived from the results of the conventional long-term creep tests and the SIM tests [15]. The SIM tests are shown as thick lines, and the conventional tests are shown as thin lines. In this reference, the criteria used for comparison are the strain after 1 h (the initial strain), the strain at the end of the conventional test (final strain), and the difference between these strains (the time-dependent strain). The total strain at any time is the sum of the initial strain and the time-dependent strain. At the risk of oversimplification, the strain developed at 1 h could be taken to be that occurring during construction and that after 1 h as the strain generated in service.

Figure 10 shows the derived creep curves for polypropylene fabric. At a load of 56 kN/m (27% of tensile strength), the SIM data give a higher strain than the measured values. For example, at 122,374 h, the results of the conventional test give a total strain of 7.92% and a time-dependent strain of 3.21%, while for the equivalent time, the SIM data predict strains of 9.61 and 4.95%, respectively. Thus, the time-dependent strain is over predicted by 1.74% strain or 54% as a proportion of the actual strain. At a load of 114 kN/m (55% of tensile strength), the initial strain (i.e., at 1 h) recorded in the conventional test was 8.62%, while the SIM data predicted a value of 6.73%: this wide variability is not an unusual phenomenon in creep testing. The variability can be reduced by performing additional “ramp-and hold” tests ,and indeed the tests were used to adjust the initial strain of the conventional tests.

Nonetheless, the two creep curves are reasonably parallel until close to the rupture point of the specimen. At 7967 h, the point at which the rate of strain in the conventional test began to

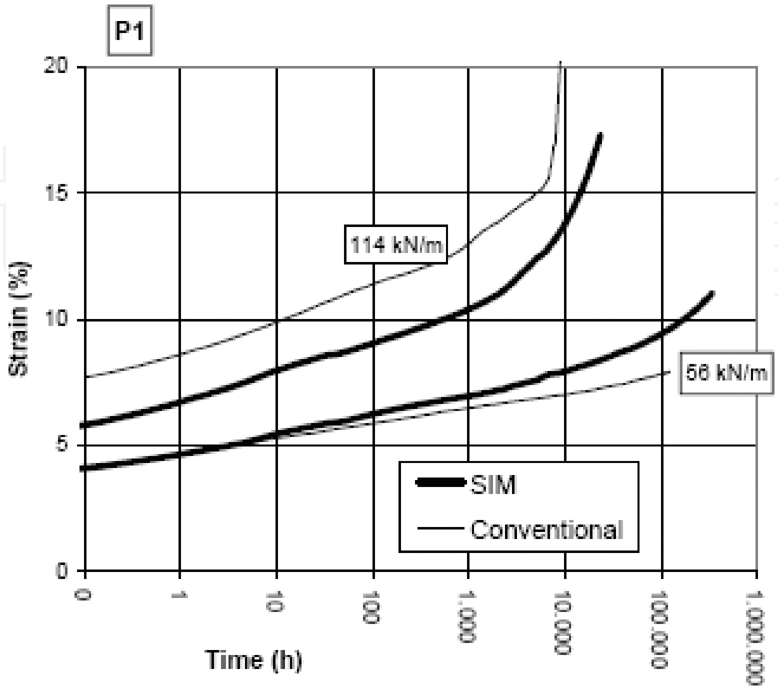

Figure 10. Comparison between results of conventional and SIM tests on material (polypropylene fabric Terram W20/4).

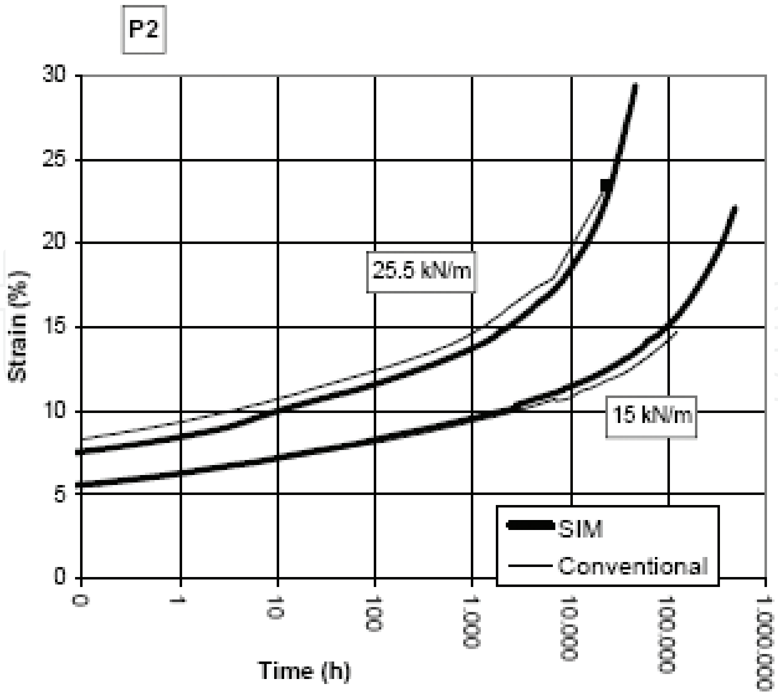

Figure 11. Comparison between results of conventional and SIM tests on material (polypropylene fabric Lotrak 45/45).

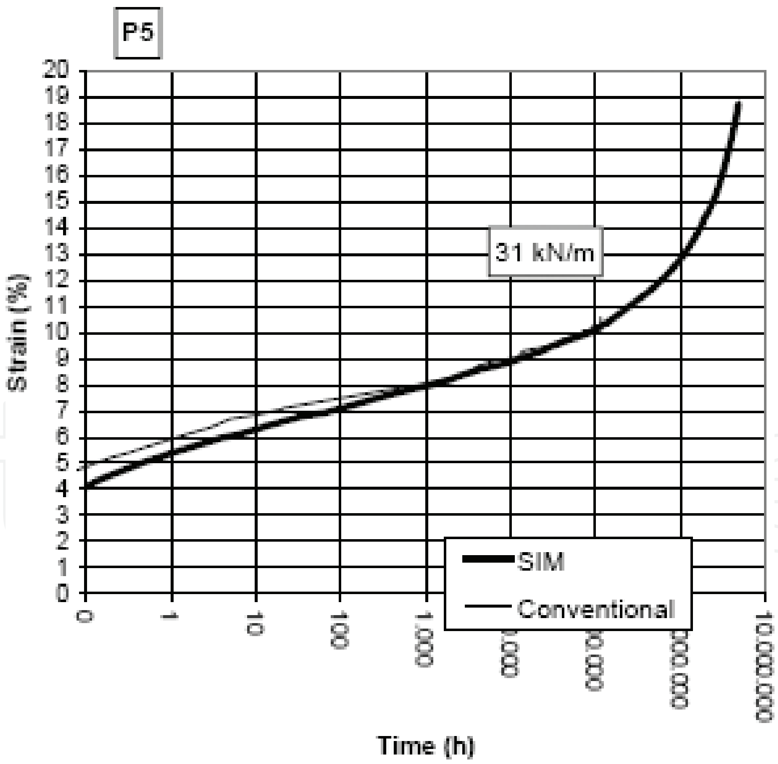

Figure 12. Results of conventional and SIM tests for polyethylene grid. Tensile strength 77.2 kN/m; tests at 31 kN/m (40%).

increase substantially, the total measured strain was 17.08%, while the predicted value was 13.19%. The time-dependent strains at this point were 8.46 and 6.46% respectively; thus, this strain was overpredicted by 2.0% or by 24% proportionally. The specimen in the conventional

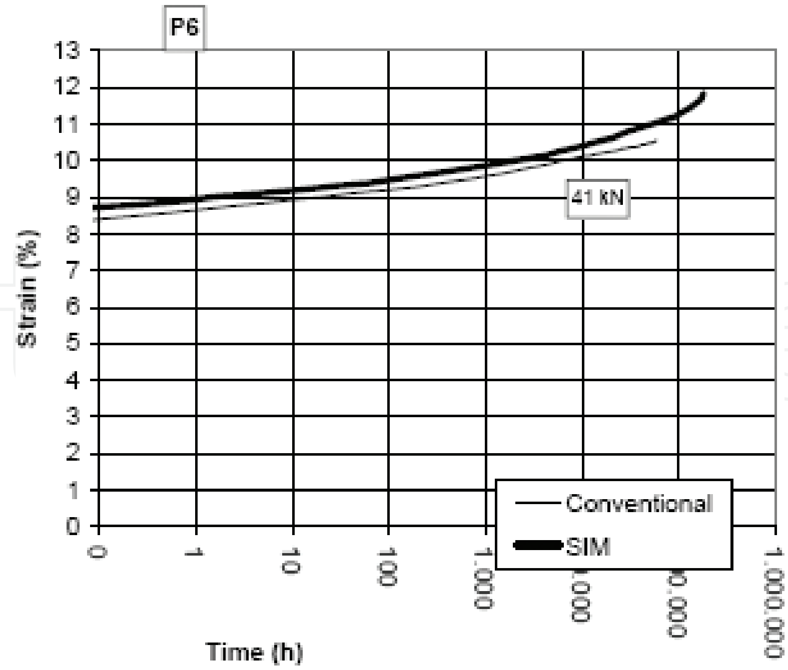

Figure 13. Results of conventional and SIM tests for polyester strip. Tensile strength 58.5 kN/m; tests at 41 kN/m (70%).

test ruptured after 9825 h at about 19% strain. The SIM test was terminated after the equivalent of 23,340 h at which point the strain was 17.3%.

Figure 11 shows the creep curves for polypropylene fabric. As shown in **Figure 11**, the creep curves derived from both types of test are in good agreement. At a load of 15 kN/m (31% of tensile strength), the total strain at the end of the conventional test (121,175 h) was 14.71%, and for the equivalent time, the SIM data predicted a strain of 15.62%. The time-dependent strains were 8.48 and 9.36%, respectively; thus, the difference was 0.88% strain – or 10% proportionally. At a load of 25.5 kN/m (52% of tensile strength), in the conventional test, the total strain after 6617 h was 17.90%, and for the equivalent time, the SIM data predict a value of 17.13%. For the same duration, the time-dependent strains are in excellent agreement at 8.71 and 8.69%, respectively. The specimen in the conventional test ruptured after 23,109 h at 23% strain, and the specimen in the SIM test ruptured after the equivalent of 49,000 h at 31% strain.

Figure 12 shows the creep curves for material polyethylene grid Tensar at 31 kN/m (40% of ultimate tensile strength). There is excellent agreement between the creep curves derived from the results of the conventional test and that predicted by the SIM data. The strain measured at the end of the conventional test (at 113,179 h) was 10.25% and that predicted by the SIM data was 10.23%. For this time, the time-dependent strains were 4.34 and 4.85%, respectively – a difference of 0.51 or 12% proportionally.

The principal objective of the tests undertaken on material Paraweb strip was to compare the creep-rupture characteristics, and so the tests were not necessarily performed at the same load levels. However, the results of a pair of tests that were undertaken at the same load (of 40.95 kN/strip, or 70% of tensile strength) are shown in **Figure 13**. The data from the conventional test indicate a strain of 10.64% at the end of a test (at 69,558 h) and a time-dependent strain of 2.00%. The predicted strains derived from the SIM test were 11.11 and 2.17%, respectively.

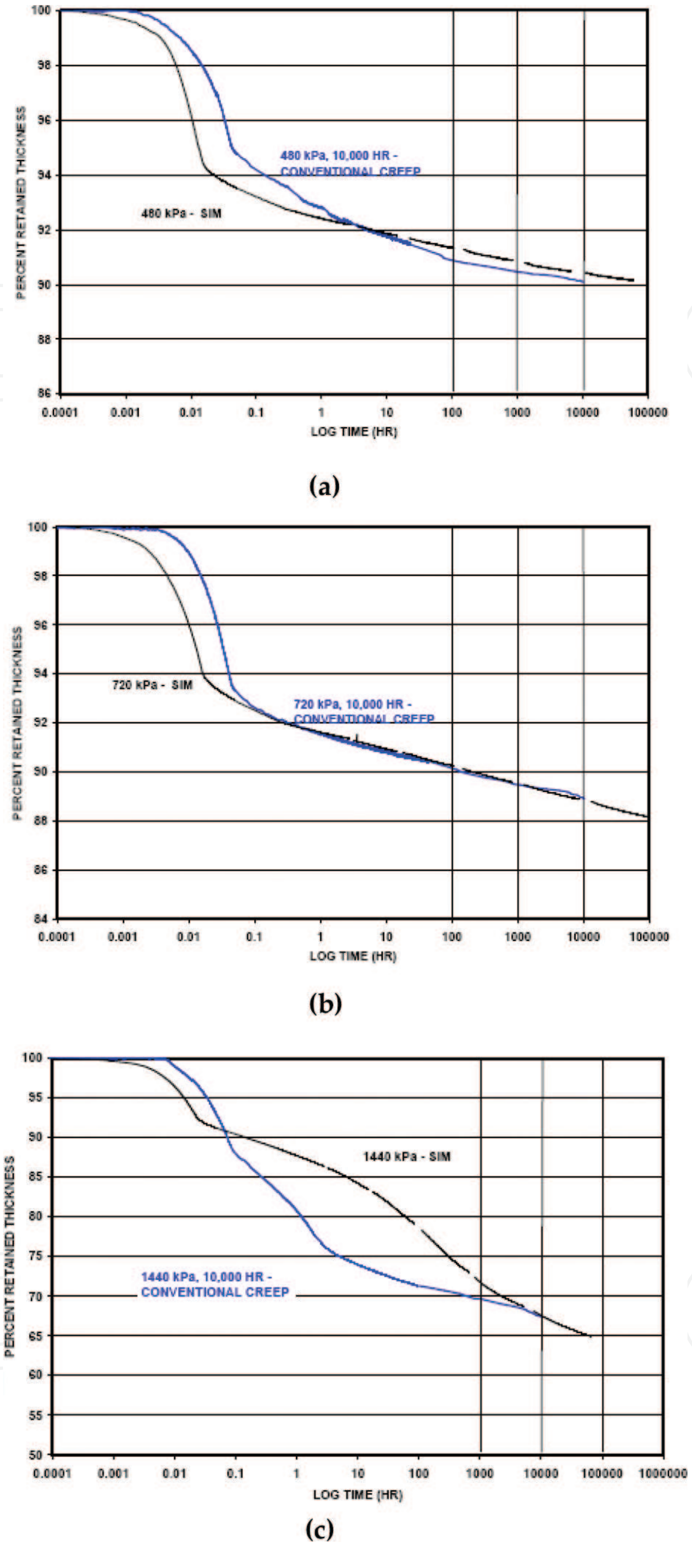

Figure 14. Comparison of 10,000-h creep response. (a) at 480 kPa, (b) at 480 kPa, and (c) at 1440 kPa.

The high initial strain and low time-dependent strain are typical of polyester. The difference in the time-dependent strains is small at 0.17% strain or at 9% proportionally.

As noted earlier, there can be quite a wide variability in the measurements of the initial strain in creep tests. In the conventional tests, the creep curve was adjusted using the following procedure:

- Perform two additional creep tests at the same load, each lasting just 1 h.
- Measure the strains after 1 h.
- Calculate the average of the strains after 1 h for the long-term test and the two additional tests.
- Subtract the strain after 1 h for the long-term creep test from this average.
- Add this difference to all strains measured for the long-term creep test.

In effect, the above shifts the entire long-term creep curve such that it passes through the average strain measured after 1 h, and the time-dependent strain is unchanged. This procedure has been named "ramp-and-hold" [6]. The data from the SIM tests were not adjusted. The agreement in the time-dependent strains determined by the conventional and SIM tests is no better than that between the final strains, but it would have been worse had the initial strains of the conventional tests not been corrected. This shows that better estimates of the initial and final strains can be obtained by undertaking these additional ramp-and-hold tests.

5.2. Tensile creep test results

The examples of the 10,000-h creep response and the comparison to the creep response at the same load generated via SIM testing are shown in **Figure 14(a)–(c)** [16]. The 10,000-h creep reduction factors were determined. Also, the calculated reduction factors for predicted 10,000 h and 35-year service lives from both conventional and accelerated creep testing are summarized in **Tables 2** and **3**. According to the results of this reference, while 10,000 h and 35-year creep reduction factors at 480 and 720 kPa were substantially similar as a result of SIM and conventional testing, they were observed to differ by as much as 66% at 1440 kPa. However, the cause of this difference was found to be related to the retained thickness at the relatively short duration of 100 h. As seen in **Figure 14(c)**, significant differences in the thickness response to loading and the onset of creep at 1440 kPa were manifest in less than 10 h of test time. This is clearly unrelated to the elevated temperatures used during SIM testing.

Load (kPa)	10,000 h RF_{CR} at 20°C	10,000 h RF_{CR}-SIM	Difference
240	NA	1.038	NA
480	1.056	1.041	−1.4%
720	1.057	1.071	+1.3%
960	NA	1.135	NA
1200	NA	1.288	NA
1240	1.323	1.963	+48%

Table 2. SIM versus conventional testing at 10,000 h.

Load (kPa)	35 Year RF_{CR} at 20°C	35 Year RF_{CR}-SIM	Difference
240	NA	1.049	NA
480	1.065	1.075	+0.9%
720	1.113	1.118	+0.4%
960	NA	1.281	NA
1200	NA	1.601	NA
1240	1.652	2.739	+66%

Table 3. SIM versus conventional testing at 35 years.

6. Review of creep for geosynthetics

The behavior of geosynthetics may be classified into three groups: (1) temperature-independent, stress-dependent deformation, asymptotic to a final creep value (PET geotextiles), (2) temperature- and stress-dependent deformation, only under a threshold mainly of stress deformation are asymptotic to a final creep value (HDPE-extruded geogrid), and (3) temperature- and stress-dependent deformation (woven PP-slit film geotextiles). The creep behavior of PET non-woven and PP woven geotextiles is not modified by the confining pressure; however, the total strain of PP non-woven geotextiles is strongly reduced with a confining pressure of 50 kPa and no more with higher confining pressure. The strain reducing increases with the level of load. From these results it seems that a confining pressure on a geotextile does not modify the structural creep but can strongly modify the polymer creep. This modification is effective with low values of the confining pressure. It makes one feel sorry that the reason why was not explained.

In this study, the performance limit strain was about 15%, but they do not use these values because it is seen that there was no evidence of the onset of rupture occurring at strains of less than 16% and the strain time and Sherby-Dorn curves show that the grids behave in a predictable manner, and there are no sudden changes in performance. Thus it can be decided that the performance limit strain of 10%, safe, if conservative, design criteria for the ultimate load condition of that product. However, it is seen that the sudden change near the 15% and the importance is the reason why how to generate these Sherby-Dorn curves. From this time, it can be that the use of the 10% limit performance strains to the most of geosynthetic reinforcements. This is very sad to the geosynthetics research field. Another thing is the application and analysis of time-temperature superimposition principle. it is seen that the shifted the raw strain data to the time scale without any explanation of theory or shift mechanism.

The purpose of this study was to make sure about the various aspects of the test procedure, such as the type of clamping, the loading time, the minimum length of the specimens, the required testing time, the extrapolation procedure, and the level of the accuracy of the prediction. And as suggested the time-temperature superposition, using the creep modulus curves, has been used to extrapolate the behavior of integral geogrids to 106 h. The time shift between the curves at 20 and 30°C is equal to 100 or 102.0, while the time shift between 20 and 40°C is equal to 2000 h or 103.301. This means, practically, that 1 h of creep testing at 30°C produces the same elongation than 100 h at 20°C, for the same testing condition; or 104 h at 30°C corresponds to 106 h at 20°C and similarly for the 40°C testing, with a 2000 factor.

Using the new SIM, over 15 load specific master creep modulus curve were generated, some of which extended to over 100-year design lifetimes, each from a single specimen in a test that was completed in less than 18 h. The results of the conventional and SIM procedures were found to be an equivalent for the polyester products examined. Recently, the compressive creep behavior of a geonet was also evaluated using SIM and the compressive creep test about the EPS Geofoam was evaluated using SIM.

7. Conclusions

The final comment about the compressive creep test and data interpretation as follows:

1. Description of the compressive mechanism of the geonet (exactly not compression but perpendicular compression) is very important because the creep mechanism of tension and compression are quite deferent.
2. To reduce the specimen-to-specimen, many ramp-and-hold (in the case of tension creep: 1 h) tests are recommended.
3. Loading rate is also important because it makes initial strain value (εi). To check the non-affected loading rate, prior to the main creep test, some kind of short-term test is needed.
4. The loading level may be a decision according to the site-specific conditions.
5. If the time-temperature superposition will be used, the exact answer about that what shift factor value is used in this study. How these values are used? Why the method to calculate the shift factor was used? Is strongly needed to the qualified paper?
6. The method to assess the RF_{creep} also will be reviewed because the value will be changed according to the applied load. Maybe to find the applying load value that satisfies the performance limit strain at the design time.

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