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Standard Test Method for Accelerated Compressive Creep of Geosynthetic Materials Based on Time-Temperature Superposition Using the Stepped Isothermal Method[1]

This standard is issued under the fixed designation D7361; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers accelerated testing for compressive creep properties using the ~~Stepped Isothermal Method~~stepped isothermal method (SIM).

1.2 The test method is focused on geosynthetic drainage materials such as HDPE geonet specimens.

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

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

1.5 This method can be used to establish the sustained load compressive creep characteristics of a geosynthetic that demonstrates a relationship between time-dependent behavior and temperature. Results of this method are to be used to augment results of compressive creep tests performed at 20 ± ~~1°C~~1 °C and may not be used as the sole basis for determination of ~~long term~~ long-term compressive creep behavior of geosynthetic material.

1.6 The values stated in SI units are to be regarded as the standard. The values 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 regulatory limitations prior to use.*~~

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1.8 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D1621 Test Method for Compressive Properties of Rigid Cellular Plastics
D2990 Test Methods for Tensile, Compressive, and Flexural Creep and Creep-Rupture of Plastics
D4439 Terminology for Geosynthetics
D5262 Test Method for Evaluating the Unconfined Tension Creep and Creep Rupture Behavior of Geosynthetics
D6364 Test Method for Determining Short-Term Compression Behavior of Geosynthetics

3. Terminology

~~3.1 *Definitions:* For definitions related to geosynthetics see Terminology D4439.~~

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[1] This test method is under the jurisdiction of ASTM Committee D35 on Geosynthetics and is the direct responsibility of Subcommittee D35.02 on Endurance Properties.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

3.1.2 For definitions related to creep, see Test Methods D2990 and D5262 and Terminology D4439.~~definitions related to creep see Test Methods D2990, D5262 and D4439.~~

3.2 *Definitions of Terms Specific to This Standard:*

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

3.2.1 *compressive creep*—time-dependent deformation that occurs when a specimen is subjected to a constant compressive load.

3.2.2 *compressive creep modulus*—in SIM analysis, the load divided by the percent compressive strain at any given point in time.

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

3.2.4 ~~*time-temperature superposition*—~~*mean test temperature*—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.~~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 established temperature ramp time, and finishing at a time just prior to the subsequent temperature reset.

3.2.5 *offset modulus method or pointing*—data analysis method used to normalize any prestrain in the samples by shifting the origin of a stress-versus-strain curve to an axis origin of coordinates, that is, to coordinates (0,0).

3.2.6 *ramp and hold (R+H) test*—a creep test of very short duration, for example, 100 to 1000 s.

3.2.7 *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 ~ when the displacements are generally to shorter times (attenuation) or the symbol a_T when the displacements are generally to longer times (acceleration).

3.2.8 *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.

3.2.9 ~~*mean test temperature*—~~*time-temperature superposition*—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 established temperature ramp time, and finishing at a time just prior to the subsequent temperature reset.~~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.

~~3.3.7 *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, that is, to coordinates (0,0).~~

3.2.10 ~~*ramp and hold (R+H) test*—~~*viscoelastic response*—~~a creep test of very short duration, for example, 100–1000 seconds.~~refers to polymeric creep, strain, stress relaxation, or a combination thereof.

~~3.3.9 *dwell time*—time during which conditions (particular load) are held constant between temperature steps.~~

~~3.3.10 *compressive creep modulus*—in SIM analysis, the load divided by the percent compressive strain at any given point in time.~~

4. Summary of Test Method

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 ~~*compressive creep*—~~*Compressive Creep*—Constant compressive load in conjunction with specified temperature steps and dwell times are used to accelerate compressive creep strain response.

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

5. Significance and Use

5.1 Use of the SIM decreases the time required for creep to occur and the obtaining of the associated data.

5.2 The statements set forth in ~~Section~~ 1.5 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 drainage applications.

NOTE 1—Currently, SIM testing has focused mainly on geonets made from ~~high density~~ high-density polyethylene. Additional testing on other materials is ongoing.

5.4 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 *Loading Platens*—Loading platens for SIM and R+H tests should conform to Test Method D6364, Standard Test Method for Determining the Short-Term Compression Behavior of Geosynthetics.

6.2 *Testing Machine*—A universal testing machine or a dead-weight loading system with the following capabilities and accessories shall be used for testing:

6.2.1 ~~load~~Load measurement and control,

6.2.2 ~~strain~~Strain measurement,

6.2.3 ~~time~~Time measurement,

6.2.4 ~~environmental~~Environmental temperature chamber to facilitate control of test conditions,

6.2.4.1 ~~temperature~~Temperature measurement and control facilities,

6.2.5 ~~other~~Other environmental measurement and control, and

6.2.6 ~~computer~~Computer data acquisition and control.

7. Sampling

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

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

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

8. Test Specimens

8.1 Specimens should be at least 120 ~~mm ×~~ by 120 mm (4.7 ~~in. × 4.7 in.).~~by 4.7 in.).

8.2 *Number of ~~tests—~~Tests:*

8.2.1 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 onset of creep strain or modulus curve should be confirmed using at least two R+H tests.

9. Conditioning

9.1 Compression testing via Test Method D6364 and SIM testing shall be conducted using 20 ± ~~1° C~~ 1 °C as the reference or temperature standard. If the laboratory is not within this range, perform tests in a suitable environmental chamber capable of controlled cooling and heating. The environmental chamber should have a ~~programmable-~~programmable or set-point controller so as to maintain temperature to 20 ± ~~1°C.~~1 °C. When agreed to, a reference temperature other than ~~20°C~~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 (see Note 2).

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

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

10.3 Testing temperatures are to be within ~~±2°C~~±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.

NOTE 2—Laboratory experience has suggested that the use of calibrated thermocouples located near, affixed to, or embedded within the test specimen may facilitate a successful temperature compliance test for the specimen material. It is suggested that the laboratory perform the planned SIM temperature steps using an unloaded sacrificial test specimen and, with the use of these thermocouples, measure the temperature change of the specimen at its thickest or most mass-dense region. The time required for the specimen to reach the target temperature is recorded and used as the minimum dwell time. The upper limit of the temperature ramp time is not known. Successful tests with some materials have been run with temperature ramp times of up to ~~four minutes.~~4 min.

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

10.4.1 Temperature steps and dwell times must be such that the ~~steady state~~ 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 the identified ramp time.

11. Procedure

11.1 The same or similar load or strain control shall be applied to the load ramp portion of R+H and SIM tests. The load rate control (in units of kN per ~~min.)~~min) that is applied shall achieve a narrow range of strain rates expressed in percent per minute, as agreed upon. Generally, 10 % of the nominal thickness of the test specimen per minute or 1.0 ± 0.1 ~~mm per minute~~ mm/min (0.04 ± 0.004 ~~inches per minute),~~ in./min), whichever is greater, will be satisfactory.

NOTE 3—A linear ramp of load ~~vs.~~versus time will not generally result in a ~~linear strain vs. time~~ linear-strain-versus-time relationship because ~~stress vs. strain~~ stress-versus-strain curves are not linear for most geosynthetic materials.

11.2 Achieve the test loads for R+H and SIM tests within ~~± 2 %~~ ±2 % of the target loads, and maintain any achieved load within ~~± 0.5 %~~ ±0.5 % of its values for the duration of the test. A brief overshoot of the target load that is within ~~± 2%~~±2 % of the target load and limited to a 1 to ~~2 second~~ 2-s 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 Inspect the specimen installation to be sure the material is properly aligned with the platens and with the loading axis.

11.5 Ensure that the load cell used is calibrated properly such that it will accurately measure the range of compressive loads anticipated.

11.6 Ensure that the extensometer used (if any) is calibrated properly such that it will accurately measure the range of compressive strains anticipated.

11.7 Time, load, and deformation 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.

11.8 The environmental chamber and temperature cooler shall be capable of maintaining the specimen temperature within ~~±1°C~~±1 °C in range of 0 to ~~100°C,~~100 °C, and of changing the specimen temperature by up to ~~15°C,~~15 °C, within the identified ramp time (see Note 2).

11.9 Unless otherwise agreed upon, the temperature steps for polyolefin geosynthetics shall not exceed ~~7°C.~~7 °C.

NOTE 4—Examples that have been successful are a ~~7°C~~7 °C step with a ~~10 000 second~~ 10 000-s dwell time for HDPE.

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

11.11 The temperature data acquisition rate during SIM shall be a minimum of once per minute.

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

12. Calculation

12.1 *Ramp and Hold (R+H) Results:*

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

12.1.2 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.

12.2 *SIM Test Results (See Appendix X1 for Examples):*

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

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

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

12.2.4 Report the compressive creep modulus and compressive strain ~~vs.~~versus log time curves as rescaled and vertically shifted above and after employing horizontal shifts of the elevated temperature 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.

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

12.2.6 Prepare a plot of the logarithm of the cumulative shift factor ~~vs.~~versus temperature.

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