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On the evaluation of stepped isothermal method for characterizing creep properties of geotextiles

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ABSTRACT: This paper evaluates the application of the Stepped Isothermal Method for characterizing creep properties of geotextiles. Conventional and SIM tests were performed on two types of non-woven geotextiles: a polypropylene and a polyester geotextile. Conventional tests were conducted at 10 and 40% of the ultimate tensile strength of the material, in accordance to ISO 13431. SIM tests were performed at the same load levels in four steps, under temperatures of 22, 40, 50 and 60^0 C. Each step was 2 hours long and each temperature rise last only 1 min. The master curves for the polypropylene geotextile, which at ambient temperature is above its glass transition temperature, extended up to 100,000 hours. However, the shift time was shorter for the polyester geotextile. The greatest difference between creep coefficient between conventional and SIM tests was about 20%. Based on these results one can conclude that the application of SIM for characterizing creep properties of geotextiles is feasible, even for a polyester geotextile, but the answer depends on the load level.

1 INTRODUCTION

Creep properties are important parameters in the design of geosynthetic-reinforced soil structures. Traditional approaches for the determination of creep behavior comprise the application of a sustained load and the measurement of the elongation of specimens as a function of time while temperature and humidity are kept constant. Test time length can reach 1,000 hrs (ISO 13431) or 10,000 hrs (ASTM D 5262). For this reason conventional creep tests are time consuming, require high environmental control for a long period of time and are, therefore, expensive.

To overcome these difficulties it has being suggested to run accelerated creep tests (THORTON *et al.*, 1997, THORTON, 1998, FARRAG & SHIRAZI, 1997, FARRAG, 1998). This kind of test can present good results and greatly reduce costs and time needed for creep characterization (BARAS, 2001). This paper discusses the application of Stepped Isothermal Method (SIM), proposed by THORNTON (1998) and used successfully to test geogrids, to characterize geotextile creep.

2 LITERATURE REVIEW

Creep behavior of geosynthetics depends basically on polymer and geotextile type, load level and temperature. Confinement is another important factor for nonwoven geotextiles (COSTA, 1999). However the influence of polymer type and temperature requires further discussions, since these are the most important factors related to accelerated testing.

The commonest polymers used to produce geotextiles are Polypropylene (PP), Polyester (PET), Polyethylene (PE), and Polyamide (PA). Information on the behavior of polymers is found in (DEN HOEDT, 1986).

Temperature has been used to accelerate viscous and viscoelastic phenomena of polymers for several decades (THORTON *et al.*, 1997). Temperature changes modify the creep rate of geotextiles and, generally speaking, an increase in temperature accelerates the creep behavior of geotextiles (MATICHARD *et al.*, 1990). Elevated temperatures associated with methods of time-temperature superposition (TTS) are used to reduce test duration (ALLEN, 1991).

An important issue related to accelerated testing is the glass-transition temperature (T_g). Below this temperature, the molecules in amorphous regions of the polymer are frozen and the polymer chains do not have mobility (FELDMAN, 1989). Geotextiles produced from polymer whose T_g is below the ambient temperature are more susceptible to creep than geotextiles manufactured with a polymer with high $T_{g.}$. Polypropylene's glass-transition temperature, for example, lies in the range between –15 to -10^0C and the T_g of polyester is about 75^0C. This may explains the lower susceptibility of polyester geotextiles to creep at ambient temperature when compared with polypropylene ones (HOLLAWAY, 1993).

Accelerated tests are performed as conventional creep tests. The only difference is that temperature is varied in the former. Accelerated tests also use the same equipment of conventional tests plus a controlled temperature chamber. Examples of the apparatus used in accelerated tests can be viewed in (FARRAG & SHIRAZI, 1997).

Figure 1 shows how a creep master curve is graphically obtained from a test carried out at four temperature levels. From a set of accelerated test data a unique curve is obtained rescaling the creep times corresponding to each test step conducted at temperatures above the reference temperature.

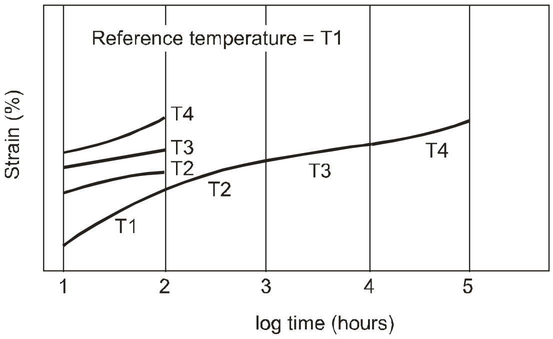

Figure 1 – Horizontal shift of temperature-creep results to form a master curve (FARRAG, 1998).

The Stepped Isothermal Method (SIM) proposed by THORTON (1998) is an attractive method for obtaining the master curve. In this method the uncertainties of the shift factor due to material variability vanishes because only one sample is used to find out the master curve.

A SIM creep test begins as a conventional test under a constant load at a reference temperature measuring deformation as time increases. This is called a test step. At the end of a step keeping constant the applied load the temperature is rapidly increased. The temperature rise cannot last long because the physical state of the specimen before and after the temperature variation must remain unchanged. Under this new test condition a second part of the time x deformation curve is registered. This procedure is repeated for each new temperature rise until a master curve is obtained. Further details can be seen in THORTON (1998).

3 MATERIAL AND METHODS

The tests were performed with two geotextiles with manufacturing features shown in table 1.

Table 1 – Geotextile manufacturing features.

Characteristic	Geotextile A	Geotextile B
Polymer	PP	PET
Type of fiber	Staple	Continuous filaments
Fabric style	Non woven needle-punched	Non woven needle-punched

Table 2 and 3 show results of mass per unit area and tensile strength for the tested geotextiles.

Table 2 – Geotextile mass per unit area

Geotextile	Mass per unit area	Mass per unit area obtained (NBR 12568)	
	(g/m²)	(g/m²)	C.V (%)
A	300	320	7,26
B	300	312	7,82

Table 3 – Tensile strength

Geotextile	Tensile test (NBR 12824)			
	Longitudinal Direction		Transversal direction	
	(kN/m)	CV (%)	(kN/m)	CV (%)
A	13,37	3,38	19,71	8,10
B	19,90	3,75	17,39	13,95

Conventional creep tests were conducted according to ISO 13431, and the accelerated tests were performed based also on the same standard.

Figure 2 shows the equipment used to carry out the tests, which is composed of a loading frame, a clamping system and a controlled environmental chamber. The creep loads were applied by dead weights and the specimen strains were measured by a photographic technique. Further details of the equipment can be found in BARAS (2001).

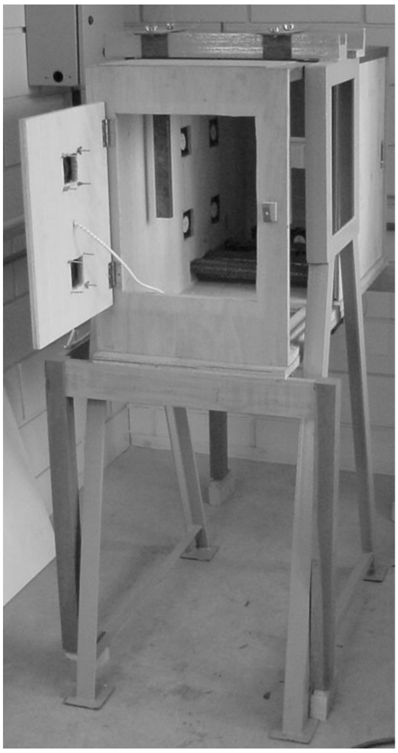

Figure 2 – View of accelerated testing equipment.

The internal device responsible for the temperature control is composed of electrical resistances (15 kW), fans and thermocouples. The external devices include a temperature controller and fans for air injection into the chamber.

For a constant loading increment SIM tests were conducted according to the following steps:

1st step: The sample was loaded at ambient conditions (about 22ºC) and the temperature was kept constant for 2 hours;

2nd step: temperature rise of 16 to 17ºC per minute to reach 40ºC. Afterwards the temperature was maintained unchanged for 2 hours;

3rd step: temperature rise of 10ºC per minute to reach 50ºC. After that the temperature was maintained unchanged for 2 hours;

4th step: step of 10ºC per minute until 60ºC. Afterwards the temperature was kept constant for 2 hours;

The accelerated tests were carried out up to 60ºC, an upper limit defined based on PET glass-transition temperature.

4 RESULTS AND DISCUSSION

Figures 3, 4, 5 and 6 show conventional and SIM creep curves for materials tested under loading levels of 10 and 40% of the ultimate tensile strength.

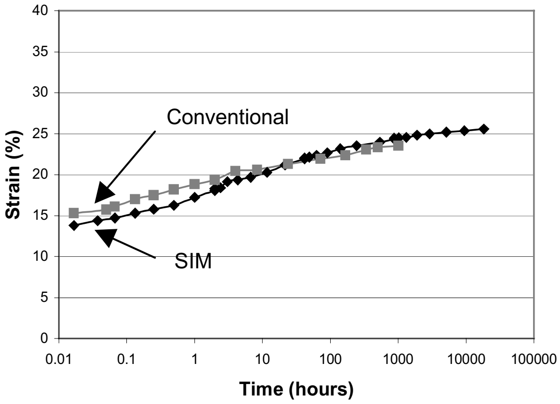

Figure 3 – Creep curves for geotextile A (10% of the ultimate tensile strength).

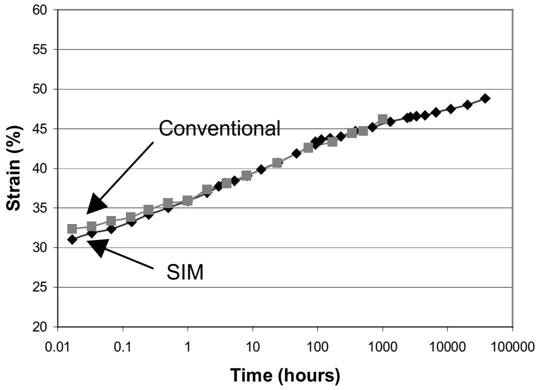

Figure 4 – Creep curves for geotextile A (40% of the ultimate tensile strength).

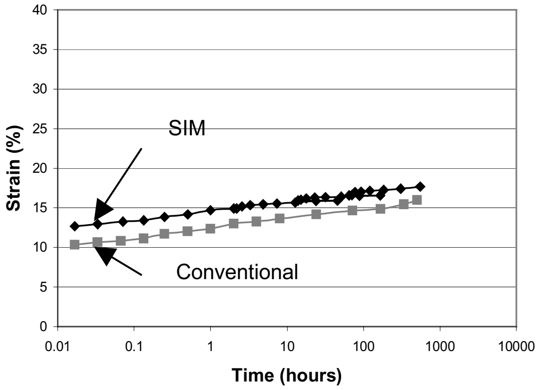

Figure 5 – Creep curves for geotextile B (10% of the ultimate tensile strength).

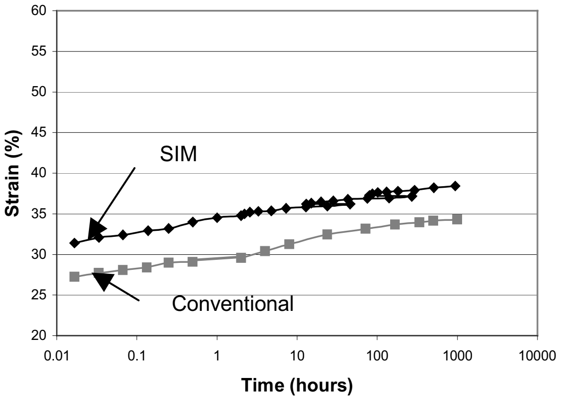

Figure 6 – Creep curves for geotextile B (40% of the ultimate tensile strength).

Results showed that the master curves for the polypropylene geotextile, which at ambient temperature is above its glass transition temperature, extended up to 100,000 hours. However, the shift time was shorter for geotextile B (PET). Anyway, the shift time for geotextile B can still be considered satisfactory.

The results also show that the loading level affects the shift time. This effect was more pronounced for geotextile A than for geotextile B, probably due to thermal contraction that accompanies the increases in temperature for geotextile B (PET).

Conventional and SIM creep curves for both geotextiles showed good agreement. Differences are basically due to initial strains.

A linear regression was used to fit the experimental data. The slope of the line (b), i.e. the creep coefficient, was used to compare the conventional and the SIM results. Table 4 shows the creep coefficient values observed for SIM and the conventional tests. The greatest discrepancy in creep coefficients between conventional and SIM tests reached about 20% what is acceptable considering the tensile strength variability of geotextile B.

Table 4 – Creep coefficients (b) for SIM and conventional tests.

Load level (% of tensile strength)	b	R^2	b	R^2
A	SIM		Conventional	
10	17,70	0,98	18,59	0,99
40	36,36	0,99	36,71	0,99
B	SIM		Conventional	
10	14,59	0,98	12,42	0,99
40	34,31	0,98	29,83	0,98

Considering results of other creep tests conducted with the same materials it can be stated that conventional and SIM creep curves showed good agreement for both geotextiles up to loads corresponding to 40% of the material ultimate tensile strength.

5 CONCLUSIONS

The use of the Stepped Isothermal Method (SIM) is feasible for characterizing the creep behavior of polypropylene and polyester geotextiles. Considering the tested materials, the application of SIM showed be effective up to loading levels of 40% of the material ultimate tensile strength. Further research is being conducted to verify the applicability of SIM for characterizing the creep rupture behavior of geotextiles.

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