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TENSILE AND CREEP BEHAVIOR OF GEOSYNTHETICS USING CONFINED-ACCELERATED TESTS

COMPORTEMENT EN TRACTION ET EN FLUAGE DES GÉOSYNTHÉTIQUES À L'AIDE D'ESSAIS ACCÉLÉRÉS EN CONDITIONS CONFINÉES

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ABSTRACT – A major aspect in geosynthetics creep analysis is the load level applied to the specimen, usually referred as a percentage of the geosynthetic ultimate tensile strength (UTS). Since both tensile and creep standard tests are performed with in-isolation specimens, they may not reproduce the possibly significant effect of soil-geosynthetic interaction. A new creep testing machine was recently developed and successfully addressed this concern. However, further developments allowed tensile tests to be performed in the same conditions used in nonconventional creep ones. This paper presents the results of nonconventional tensile tests performed with a woven biaxial polyester geogrid. They were used to define its UTS in the same conditions employed in creep tests performed with the new equipment. Despite changes in tensile curves shapes were found, the UTS from confined, accelerated and confined-accelerated tensile tests were quite similar to those obtained with standard tensile test procedure.

1. Introduction

The tensile strength of geosynthetics is considered one of the most important properties of geosynthetics (Koerner, 2005). Standard tensile tests are performed with in-isolation specimens, loaded at a constant rate up to their rupture (ASTM D 4595 and ASTM D 6637), while elongation and load are computed. Its results are essential to define the creep load (ASTM D 5262) as a percentage of the ultimate tensile strength (UTS).

Similarly to tensile tests, creep tests are performed with in-isolation specimens. The lack of soil-geosynthetic interaction and the test duration are the two main concerns in geosynthetics creep analysis using standard tests. These concerns were extensively investigated, but only independently (McGown et al., 1982; Elias et al., 1998; Thornton et al., 1998; Zornberg et al., 2004; Bueno et al., 2005; Jones and Clarke, 2007). In order to address both aspects simultaneously, an innovative creep testing routine was recently developed using a new piece of equipment (França and Bueno, 2011). Thus, simultaneously confined and accelerated creep tests were able to be performed, with any combination of temperature and soil confinement condition. As a result, confined, accelerated and confined-accelerated creep tests were performed.

Despite its proper performance, the need of a operator-independent loading system was advised. Moreover, the first version was not able to perform tensile tests in both confined and accelerated conditions. Consequently, the load level used in nonconventional creep tests were referred as a percentage of the UTS value obtained in standard tensile tests, with in-isolation specimens at room temperature. This may have led to misinterpretation of nonconventional creep tests results, since changes in creep behavior may have occurred due to the variation of the tensile strength of in-soil specimens.

A second version of the loading system was developed (Avesani, 2013). The new loading system is operator-independent and allows both tensile and creep tests to be conducted in the same temperature and soil confinement conditions. As a result, the creep load used in non-conventional tests can be referred as a percentage of the UTS value obtained under the same condition.

This paper presents preliminary tensile tests results performed with both a needle punched nonwoven geotextile and a woven biaxial geogrid, manufactured with polyester fibers and ribs. These tests were conducted after performing creep tests in nonconventional conditions. The geogrid was subjected to a more comprehensive set of tests, including those in confined, accelerated and confined-accelerated conditions. In addition, the geogrid was subjected to conventional tensile tests in the new equipment. The geotextile, on the other hand, was only used in preliminary tensile tests.

2. Equipment description

The initial purpose of the new equipment was to conduct confined-accelerated creep tests on geosynthetic specimens. Soil confinement is reproduced by means of a pressurized air bag while three electrical resistances located in the lower portion of the testing chamber increases the test temperature. The initial objective was fully achieved (França and Bueno, 2011). Further improvements provided an operator-independent loading system (Figure 1) (Avesani, 2013; França et al., 2013). This also allowed tensile tests to be performed.

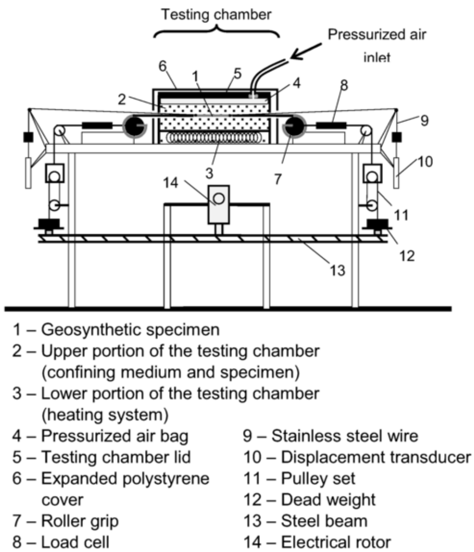

Figure 1. Experimental set up used in both creep and tensile tests.

The specimen must be positioned into the upper portion of the testing chamber, immediately after the placement of the first soil layer. Two apertures (5 mm wide) in side walls allow the specimens to reach the roller grips outside the testing chamber. Then, the cover soil layer is placed over the specimen, followed by a pressurized air bag and the chamber lid, which is attached to the chamber walls. In the meanwhile, a thermocouple is inserted into the soil to measure the temperature nearby the specimen (test temperature). The specimen is then attached to the roller grips and the assembly is ready to start the test. Finally, a polystyrene cover surrounds the testing chamber to reduce heat loss during tests at elevated temperature.

After the basic set up of the new equipment, two types of tests can be performed: tensile and creep ones. Both tests use the same loading system. It comprises a steel beam which supports two sets of dead weights. They are positioned on both sides of the equipment and connected with steel cables to the roller grips. An electrical rotor controls the downward movement of the beam, providing a smooth and homogenous loading rate in both sides of the specimen (Figure 2). The loading rate can be programed by means of an automated controller.

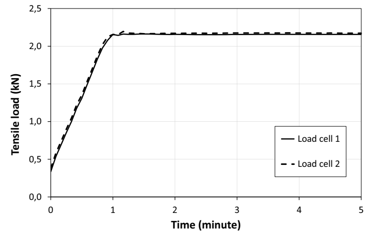

Figure 2. Example of the loading process (first five minutes of the test) of a confined-accelerated creep test performed with a woven biaxial geogrid.

The only difference between tensile and creep tests is the amount of dead weights used in each test. Tensile tests with the new equipment employ higher loads since they have to reach the rupture of the specimens. The amount of dead weight used in these tests is calculated in order to exceed the UTS obtained in standard tensile tests. Thus, the tensile load increases while the steel beam moves downward up to specimen failure. Conversely, lower loads are used in creep tests, as the creep load is a percentage of the UTS from standard tensile tests. In this case, specimen elongation due to creep is computed for a certain time.

3. Geosynthetic materials

Two different polyester-based geosynthetic materials were used in the tests presented in this paper: a biaxial woven geogrid and a nonwoven geotextile (Table 1). Both materials were firstly subjected to standard tensile tests. Then, the geogrid was used in both tensile and creep tests with the new equipment in different conditions regarding soil confinement and test temperature. Afterwards, nonconventional creep tests were performed with the nonwoven geotextile. Only preliminary nonconventional tensile tests have been performed so far and are not presented in this paper.

4. Creep tests

The creep behavior of both geosynthetic materials were investigated by means of conventional and nonconventional creep tests. Conventional tests were performed with standard equipment, as described in ASTD D 5262, in different load levels. On the other hand, nonconventional tests were conducted with the new equipment with specimens subjected only to 50% of UTS. Different series of tests were performed with each geosynthetic material, as presented in Table 2.

Creep tests were interpreted according to the representation proposed by Zornberg et al. (2004). This regards the representation of creep tests results in terms of creep strains *versus* the logarithm of the ratio between a given time (t_i) and the time at the end of load application (t_0), taken one minute after the start of the loading process. The slope of the linear adjustment is defined as creep index (T_α) and represents the creep strain rate of the test. In addition, it was noticed that to any value of t_0 greater than that explained earlier will result in the same slope.

Table 1. Tested geosynthetic materials.

Characteristic	Nonwoven geotextile	Biaxial woven geogrid
Manufacturing process	Needle punched	Woven
Predominant polymer	Polyester	Polyester
Mass per unit area (g/m²)	263 (6.1%)[1]	N/A[2]
Aperture size (mm)	N/A[2]	35.0
Nominal thickness (mm)	2.8 (5.6%)[1]	N/A[2]
Tested direction	XMD[3]	MD[4]
UTS (kN/m)[5]	14.1 (12.4%)[1]	19.7 (1.9%)[1]
Elongation at break (%)	68.1 (9.3%)[1]	9.6 (4.4%)[1]

Notes: [1]numbers in parentheses correspond to the coefficient of variation computed in each parameter; [2]non-applicable; [3]cross-machine direction; [4]machine direction; [5]UTS from standard tensile test according to ASTM D 4595 and ASTM D 6637.

Table 2. Creep tests features.

Creep test type	Biaxial woven geogrid	Nonwoven geotextile
Conv.[1]	20-50% of UTS 1,000 h	20-60% of UTS 1,000 h
Accel.[2]	50% of UTS 114 h / 36°C	50% of UTS 112 h / 35°C
Conf.[3]	50% of UTS 116 h / 26°C	50% of UTS 160 h / 26°C
Conf.-accel.[4]	50% of UTS 120 h / 36°C	50% of UTS 131 h / 37°C

Notes: [1]conventional test; [2]accelerated test; [3]confined test (50 kPa); [4]confined-accelerated test (50 kPa).

Figure 3 presents the linear adjustment obtained in creep tests performed with different geosynthetic specimens in several conditions.

As expected, the test temperature increase produced higher creep strains rates in tests conducted with both in-isolation and confined specimens. In addition, the conventional creep tests resulted in greater creep strains in those conducted with higher load levels. Regarding the nonconventional creep test results, both geosynthetic materials creep behavior was highly affected by soil confinement. Reductions in creep index as high as 88% and 79% were noticed with nonwoven geotextile and geogrid specimens, respectively. It indicates a strong relation between the soil confinement and the creep strains in both the nonwoven geotextile and the geogrid.

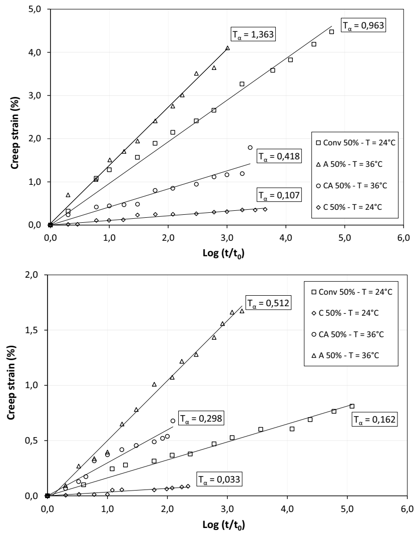

Figure 3. Creep strains at 50% of UTS: a) nonwoven geotextile; b) woven biaxial geogrid.

5. Tensile tests

As previously mentioned, standard tensile tests were used to define the UTS of each geosynthetic material. Then, nonconventional tensile tests were conducted with the new equipment in order to verify the magnitude of UTS under confined, accelerated and confined-accelerated conditions. Moreover, conventional tensile tests were also performed with the new equipment to compare their results with those from standard tensile tests. Each set of tests was performed with five different specimens.

Nonconventional tensile behavior of the nonwoven geotextile is currently under study. Preliminary results present a slight reduction in UTS and a substantial decrease in elongation at break. However, these conclusions are still under investigation and further results will be presented in future publications. On the other hand, the geogrid was used in a more broad set of tests. Conventional and confined tensile tests using the geogrid were performed at room temperature, while accelerated was conducted at 36 and 48°C. Confined-accelerated tests were performed at 36°C only (Table 3).

Conventional tensile tests performed with the new equipment resulted in very similar UTS compared to that obtained with standard apparatus, notwithstanding the variability of results were expressively higher. In addition, conventional tests with the new equipment led to smaller elongation at break values. This aspect is still under investigation.

Table 3. Geogrid tensile test results.

Tensile test type	Load (kN/m)	Elongation at break (%)
Conventional	19.7 (1.9%)[1]	9.6 (4.4%)
Conventional (new equipment)	19.5 (5.2%)	5.3 (9.0%)
Confined[2]	21.1 (4.2%)	7.3 (13.0%)
Accelerated (36°C)	18.3 (6.2%)	5.2 (9.4%)
Accelerated (48°C)	18.2 (1.4%)	6.1 (5.1%)
Confined-accelerated[2] (36°C)	21.0 (2.0%)	7.1 (14.9%)

Notes: [1]coefficient of variation are presented in parenthesis; [2] normal stress equal to 50 kPa.

The change in UTS noticed in nonconventional tensile tests lay within a strict range (±8% of UTS from standard test). It indicates that the geogrid UTS is not significantly affected by both soil confinement and temperature in the tested conditions. However, further tests are predicted, once the temperature effect is not in agreement with the technical literature. Moreover, improvements in the new equipment are necessary to reduce the results variability, which was greater than the one found in standard tests. Besides, elongation at break changes did not present any pattern in the tests performed so far. Thus, further improvements are also predicted to address this aspect.

6. Conclusions

This paper presented nonconventional tensile and creep tests performed with a nonwoven geotextile and a woven biaxial geogrid. The following conclusions are drawn from the present study:

- Modifications on the new creep testing equipment allowed tensile test to be performed in both conventional and nonconventional conditions;
- Creep tests conducted with nonwoven geotextile and woven biaxial geogrid showed a significant reduction in creep strains due to soil confinement;
- UTS values obtained in conventional tensile tests performed with the new equipment are in agreement with those found with the standard procedure. Conversely, elongation at break did not follow the same trend.
- UTS found under nonconventional tensile tests had a slight variation compared to UTS obtained with standard tests using the geogrid. On the contrary, elongation at break computed in nonconventional tests was smaller than those found in standard tests.
- Further improvements in the new equipment are still necessary in order to reduce the variability of results and to provide more reliable values of elongation at break.

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