Geogrid creep and tensile tests performed with nonconventional equipment

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ABSTRACT: Creep behavior of geosynthetics is commonly determined by means of creep tests performed with in-isolation specimens. Soil-geosynthetic interaction and duration of the tests were already addressed in previous studies with nonconventional conditions tests. However, since the applied load level in creep tests is referred as a percentage of the geosynthetic tensile strength computed from short-term tests, it is necessary to create a procedure to reproduce the same nonconventional conditions in tensile tests. Thus, this paper presents the improvement of the equipment developed to perform nonconventional creep tests in order to make it capable of conducting nonconventional tensile tests. The main adjustments regarded the loading system and the specimen elongation measurement system with video camera. A biaxial geogrid was used in preliminary tensile tests to verify the equipment performance. Results obtained with the new equipment were quite similar to those from standard apparatus. However, further improvements are still necessary, mainly regarding the specimen elongation measurement system.

Keywords: Geosynthetics, tensile strength, confined-accelerated conditions.

1 INTRODUCTION

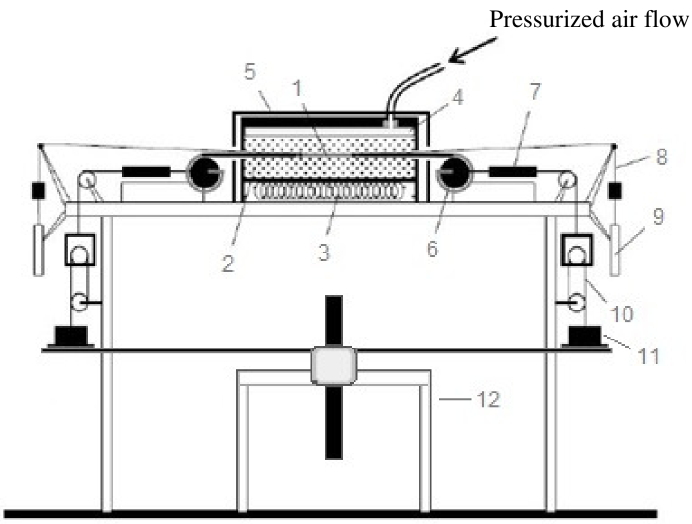
In geosynthetics reinforced soil (GRS) structures, geosynthetics are subjected to an approximately constant load during their design life (Bueno et al., 2007; Koerner, 2005). Thus, creep tests gain attention in predicting long term behavior of such materials. Two main negative aspects are related to tests used to determine creep behavior of geosynthetics. Firstly, in-isolation specimens are subjected to constant loads during the tests. Thus, the possibly significant effect of soil confinement is not considered. In addition to this, creep tests are time-consuming and may become costly since they are performed during long periods of time. This controversial topic has been studied by several researchers, who have published different approaches in order to consider both aspects, but only separately (Elias et al., 1998; Thornton et al. 1998; Jeon et al., 2002; Zornberg et al., 2004; Bueno et al., 2005; Jones and Clark, 2007; Tong et al., 2009; Yeo et al., 2009; McGown et al. 1982; Costa, 2004, Mendes et al., 2007, Ding, et al., 2009 and Kamiji et al., 2009). An innovative apparatus was developed by França (2012), which was previously published by França and Bueno (2011). It is capable of considering both aspects (time and soil confinement) simultaneously. Further development in the loading system was provided by Avesani (2013), which allowed a smoother loading path during loading phase of the creep tests.

It is well recognized that creep tests load levels are referred as a percentage of the tensile strength obtained with short term tensile tests. Since the creep testing equipment developed by França (2012) was not designed to perform tensile tests, load levels used in creep tests were based on tensile strength obtained with in-isolation specimens in standard apparatus. Thus, the load level of creep tests at any condition (in-isolation specimen test, confined test, accelerated test, and confined-accelerated test) was computed as a percentage of the tensile strength obtained from the same tensile test, conducted with in-isolation specimens. In this regard, the need of both tensile and creep tests performed in the same condition has grown in order to allow better analysis of creep test results. Therefore, this paper presents the preliminary results from new improvements provided to the creep equipment in order to make it capable of conducting tensile test in confined, accelerated and confined-accelerated conditions.

2 NEW CREEP TESTING EQUIPMENT

Essentially, the creep testing equipment developed by França (2012) comprises a rigid metallic chamber, in which the specimen is placed. Then, it is loaded from both sides while two tell tales provide readings that allow the determination of specimen elongation. Two different systems are used. The first one elevates the test temperature and the second one applies normal stresses on the specimen during the tests. The combined use of both systems allows three different conditions to be achieved with the new creep testing equipment: a) creep tests at elevated temperature (accelerated tests); b) creep tests under soil confinement (confined tests); and c) both conditions being used in the same test (confined-accelerated tests).

Despite it satisfactory performance, the creep testing equipment loading system was operator dependent. In order to overcome this aspect, Avesani (2013) has provided a new automated loading system. This improvement has allowed more reliable tests to be perfomed. Figure 1 presents a schematic view of the new creep testing equipment, after Avesani (2013).



1	Specimen
2	Upper chamber (confining soil and specimen)
3	Lower chamber (heating system)
4	Pressurized air bag
5	Expanded polystirene cover
6	Roller grip
7	Load cell
8	Inextensible wire
9	Displacement transducer
10	Pulley set
11	Dead weights
12	Loading system (after Avesani, 2013)

Figure 1. Schematic view of the new creep testing equipment, after Avesani (2013).

3 RESULTS

The creep testing equipment was improved to allow short term tensile tests to be performed. This section presents such improvements and preliminary results as well.

3.1 *Improvements in the creep testing equipment*

Several adjustments have been provided to the first version of the creep testing equipment, developed by França (2012). It was converted to an operator-independent apparatus after Avesani (2013), since the new loading system was turned into a programmable system. It comprised a steel horizontal beam that holds the dead weight from both sides of the equipment simultaneously. The downward movement of the beam was controlled by an electrical rotor, providing a smooth and homogenous loading rate in both sides of the specimen. Loading rate was programed by means of an automated controller. Further description is found in França et al. (2013).

Despite its satisfactory performance in creep tests, the loading system settled by Avesani (2013) was not capable of resisting higher loads, necessary for tensile tests. This was due to the location of the electrical rotor, placed beside the equipment. In order to make the equipment capable of applying higher loads, the first adjustment performed during this research is related to the location of the electrical rotor settled by Avesani (2013). A new loading system was then provided, with the rotor placed bellow the equipment. This improvement prevented eccentric loads in the loading system. In addition, steel reinforcements were provided to the support beam. Both measures allowed tensile tests to be performed since higher loads can be reached with the new equipment.

The second improvement provided to the creep testing equipment regards its elongation measurement system. In the first version (França, 2012), the elongation was measured by means of two tell tales attached to both sides of the specimen and connected to LVDT´s. In order to verify the reliability of this system, a video camera was used to record the specimen elongation during the tests. Fixed points were used as references while points on the specimen were followed. At the end of the test, the film was edited and several images were selected. Specimen elongation is computed by means of analyzing the location of the points on the specimen related to the reference points. This procedure is well established in the laboratory where the tests were conducted. Figure 2 illustrates this data acquisition set. Figure 3 presents an example of the image treatment software used to calculate specimen elongation.

Figure 2. Data acquisition set with video camera, reference and on-specimen points.

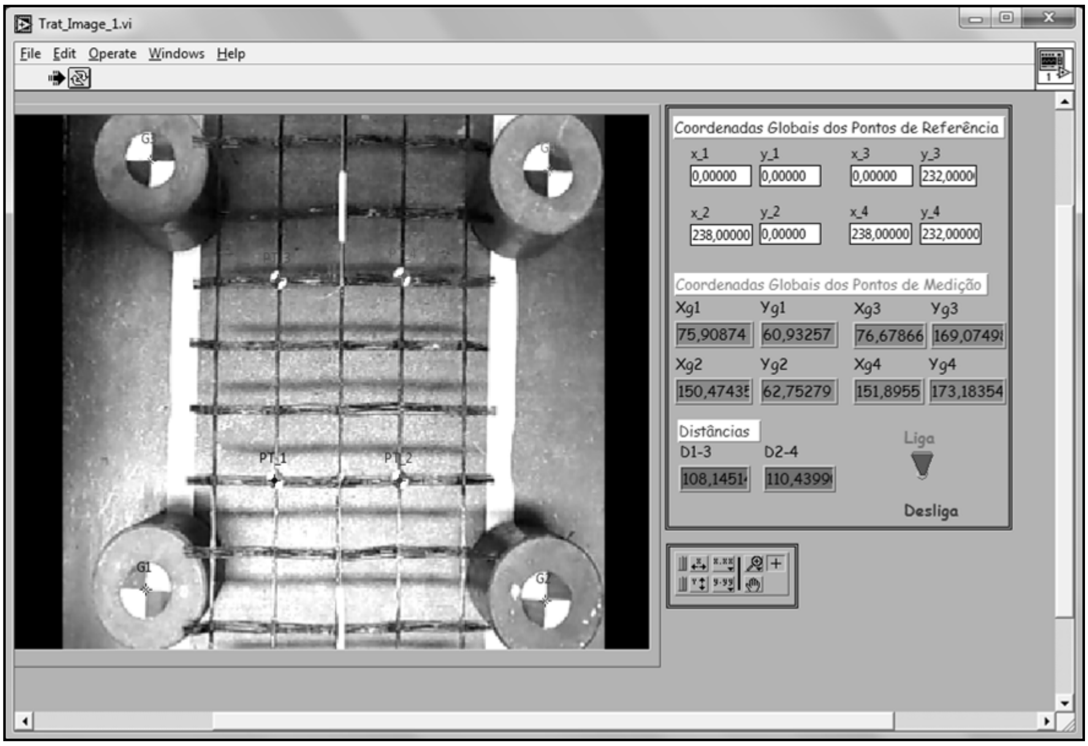


Figure 3. Image treatment software used to calculate specimens elongation.

3.2 *Test results*

Two set of tensile tests were performed in this research. A biaxial polyester geogrid was used in these tests, which was also used by França (2012) and Avesani (2013). Thus, tensile tests are related to creep ones conducted previously. The geogrid was subjected to tensile creep tests according to ASTM D 6637, resulting in tensile strength in machine direction of 19.5 kN/m (coefficient of variation equals to 1.9%)

and elongation at break of 9.6% (coefficient of variation equals to 4.4%). These values are referred as reference values in the comparisons provided later in this paper. All specimens were taken and loaded in the same test direction in this research. Confined and confined-accelerated tests were performed with loose sand as confining medium. It was classified as SP according to Unified Soil Classification System, and was dropped into the testing chamber at 45% of relative density in dry condition.

The first test set comprised all four testing conditions reproduced by the new creep/tensile testing equipment, i.e. conventional, accelerated, confined and confined-accelerated tensile tests. The original telltale system was used in order to verify specimen elongation in this set. Readings taken during the first set of tests indicate coherent tensile strength values. Confined and confined-accelerated conditions resulted in slightly higher tensile strength values, as presented in Table 1. This may be caused by soil-geosynthetic interaction during the tests. Accelerated test resulted in lower, yet approximate, tensile strength values compared to reference ones.

Table 1. Tensile test results performed with the creep/tensile testing equipment in different testing conditions.

Test designation	Tensile strength (kN/m²)	Elongation at break (%)
Conventional	19,5 (5,2%)	5,3 (9,0%)
Accelerated (36°C)	18,3 (6,2%)	5,2 (9,4%)
Accelerated (48°C)	18,2 (1,4%)	6,1 (5,1%)
Confined	21,1 (4,2%)	7,3 (13%)
Confined-Accelerated	21,0 (2,0%)	7,1 (14,9%)

On the contrary of tensile strength pattern, elongation at break was found to be lower than the reference values. In addition, coefficient of variation of specimen elongation was significantly higher than those obtained in reference tests. This behavior may be due to the elongation measurement system, which is adequate for creep tests but not suitable for tensile tests. In summary, the results show that the creep/tensile testing equipment had an acceptable performance regarding tensile strength determination, while further improvements are still necessary to have reliable measurements of specimen elongation.

The second tensile tests set were performed in order to evaluate the elongation measurement system. Thus, besides the original telltale system, the video camera set was used in tests performed in conventional condition only. In fact, the video camera system produced more reliable data since the coefficient of variation of data analyzed with this system was lower than the one obtained when the telltales system is used to compute specimen elongation. Despite that, coefficient of variation from the video camera analysis is still significantly higher than reference values. Further improvements are necessary in order to address this aspect. Table 2 summarizes the results from the second tensile tests set.

Table 2. Tensile test results performed with the creep/tensile testing equipment in conventional condition – analysis of the elongation measurement system (average tensile strength equals to 19.0%).

Elongation measurement system	Elongation at break (%)	Coefficient of variation (%)
Telltale	6.3	17.1
Video Camera	7.0	10.4

3.3 *Comparison between tensile tests in conventional condition*

Tensile tests at conventional condition (in-isolation specimen at room temperature) were performed with the new creep/tensile testing equipment in this research. Additional tensile tests were conducted by França (2012) with the same geogrid and according to ASTM 6637. Figure 4 presents an example of test results from each type of equipment.

Despite tensile strength values were quite similar in both curves, their shape is significantly different. Tests conducted with the creep/tensile testing equipment resulted in very low elongation up to tensile load equal to 5 kN/m, approximately. After such value, both curves present the same trend. This behavior may be caused by different factors, such as specimen-grip accommodation, the use of steel cables to connect dead weights, load cells and roller grips, and the time the electrical rotor takes to reach the programmed speed (about five seconds). These aspects are under analysis and further improvements will be provided to the creep/testing equipment in order to make it capable of producing tensile test results similar to those obtained with the ordinary apparatus.

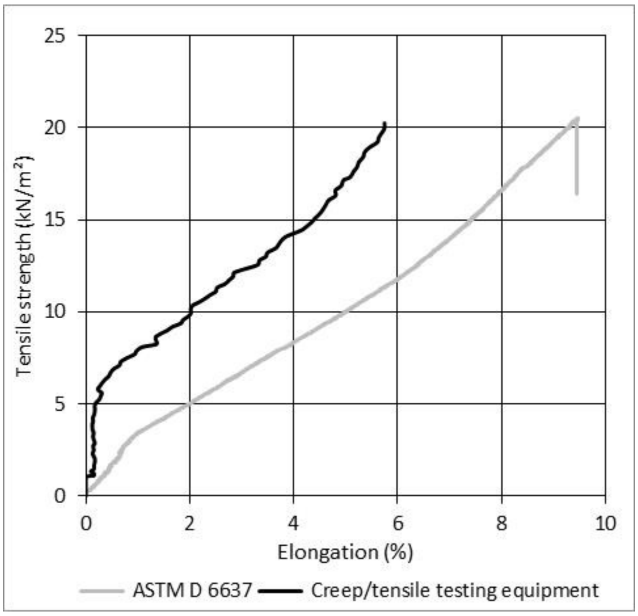


Figure 4. Comparison between tensile tests in conventional condition.

4 CONCLUSION

This paper presented the new creep/tensile testing equipment based on the creep testing equipment developed by França (2012). Several adjustments were necessary to allow both tensile and creep tests to be performed with this equipment. In addition, preliminary tensile tests were conducted in order to verify the tensile behavior of a biaxial geogrid under nonconventional conditions, i.e. confined and/or accelerated tests. Besides, a set of tensile tests were performed to check the behavior of the video camera system used to measure specimen elongation. The following conclusions are drawn from the present study:

- The creep testing equipment developed by França (2012) was adjusted to perform tensile tests on geosynthetics. Tensile strength values were in agreement with those obtained with standard equipment (ASTM D 6637). On the other hand, elongation at break found in tests conducted with the creep/tensile testing equipment was significantly lower than reference values. This indicates the need of further improvements in the new equipment.
- The loading system developed by Avesani (2013) was enhanced to support higher load values, necessary to tensile tests. This new version presented a satisfactory performance.
- The video camera system used to compute specimen elongation provided more reliable results since resulted in lower coefficient of variation in comparison with the telltale systems.
- Tensile strength in confined and confined-accelerated conditions was somewhat higher than the values found in conventional condition. On the contrary, accelerated test resulted in lower tensile strength values compared to reference ones.
- Further improvements to the creep/tensile testing machine are predicted regarding the specimen elongation measurements system.

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