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EFFECTS OF SOIL CONFINEMENT AND ELEVATED TEMPERATURE IN TENSILE BEHAVIOR OF GEOSYNTHETICS

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ABSTRACT

Tensile behavior of geosynthetics is affected by several aspects (e.g. temperature, soil confinement, loading rate, and specimen size) and is determined by means of standard short term tensile tests. Since in-isolation specimens are used, they may not reproduce the soil-geosynthetic interaction found in field conditions. In addition, temperature may become an important issue in waste disposal systems and in geosynthetics reinforced pavements. This paper presents a new apparatus developed to perform in-soil tensile tests at elevated temperature with geosynthetics. It was adapted from confined-accelerated creep tests equipment, with improvements in the loading and the elongation measurement systems. A biaxial geogrid was used in preliminary tensile tests to verify the equipment performance. Results obtained with in-isolation specimens at room temperature were quite similar to those obtained in standard tensile tests. Tensile strength and secant tensile modulus values were reasonably similar in all conditions tested.

1. INTRODUCTION

Tensile behavior of geosynthetics is one of their main characteristics when dealing with reinforced soil structures design (Koerner, 2005). It is commonly determined by means of standard short term tensile tests with in-isolation specimens at room temperature. The tensile strength and the secant tensile modulus of the geosynthetic material can be computed from the result of these tests. Several aspects may have influence in the tensile behavior of geosynthetics (e.g. temperature, soil confinement, loading rate, and specimen size). Literature has reported many studies regarding these issues (McGown et al., 1982; Elias et al., 1998; Campos et al., 2010). These aspects have been considered by means of either different test routines or equipment improvements.

Since in-isolation specimens are used in standard tensile tests, they may not reproduce the soil-geosynthetic interaction found in field conditions. In addition, temperature may become an important issue in geosynthetic reinforced soil structures built in waste disposal systems and in geosynthetics used as pavement reinforcement. Therefore, among the aspects which affect tensile behavior of geosynthetics, both soil confinement and temperature may play an important role. Previous studies were also performed regarding them, but only independently. It was also investigated in terms of creep behavior (Elias et al., 1998; Thornton et al. 1998; Zornberg et al., 2004; Bueno et al., 2005; Jones and Clark, 2007; McGown et al. 1982 and Kamiji et al., 2008). An important contribution was provided by

França and Bueno (2011) regarding creep behavior of geosynthetics. These authors have published an innovative creep test piece of equipment capable of performing simultaneously confined and accelerated tests. This equipment was improved by Avesani (2013) and França et al. (2013) in order to allow confined tensile tests at elevated temperature to be conducted with geosynthetics. This paper presents preliminary tensile tests results obtained with in-soil specimens at elevated temperature. They were interpreted in terms of secant modulus. In addition, a brief description of necessary improvements to the creep equipment is provided.

2. MAIN IPROVEMENTS OF THE CREEP TESTING EQUIPMENT

The creep testing equipment reported by França and Bueno (2011) was firstly improved to become operator-independent by Avesani (2013). Also, Avesani (2013) provided a loading system with programmable loading rate. Since, higher loads were expected in tensile tests compared to those used in creep tests, the loading system was redesigned and reinforced with steel beams. Figure 1 presents a schematic view of the new creep testing equipment, after Avesani (2013). Figure 2 shows a photograph from the top of the equipment.

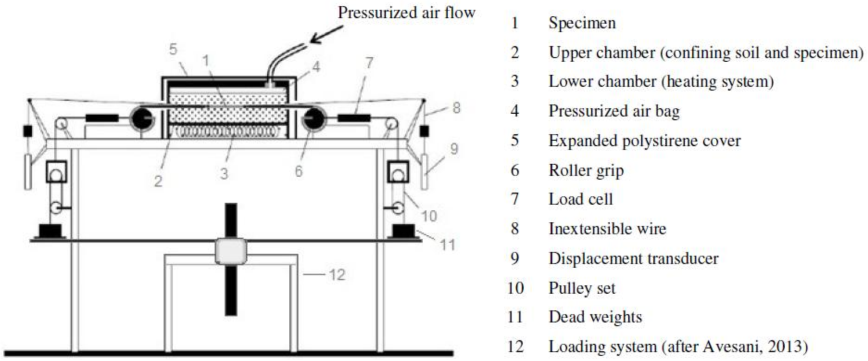


Figure 1. Schematic view of the new creep testing equipment, after Avesani (2013).

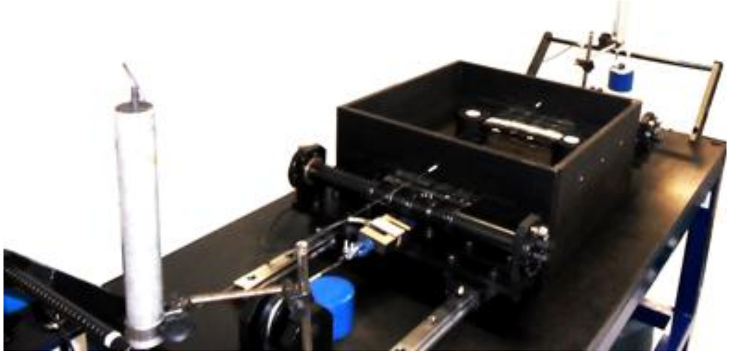


Figure 2. Photograph from the top of the tensile test equipment.

The original creep testing equipment was provided with tell tales connected to the specimen by means of inextensible steel wires. Displacement transducers were used to measure the displacement of two points on the specimen and then, compute specimen elongation. Figure 3 shows a view of the displacement transducer and dead weights used in the elongation measurement system.

Figure 3. Displacement transducer and dead weight.

A second elongation measurement system was provided in order to verify the accuracy of displacement transducers system. It comprises a video camera installed above the geosynthetic specimen and a set of both on-specimen and reference points. Reference points were placed below the geosynthetic specimen while on-specimen points were followed during the tensile test, as presented in Figure 4. It is important to note that this system could only be used in tests with in-isolation specimens. The tests were fully recorded and different frames were selected from each one. Afterwards, the frames were used to compute the specimen elongation at a different time. Figure 5 presents the basic screen of the software used in this process. It was developed in the Laboratory of Geosynthetics of the University of Sao Paulo.

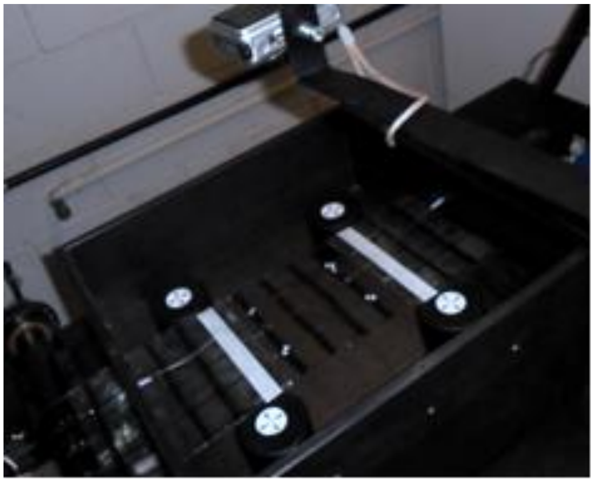
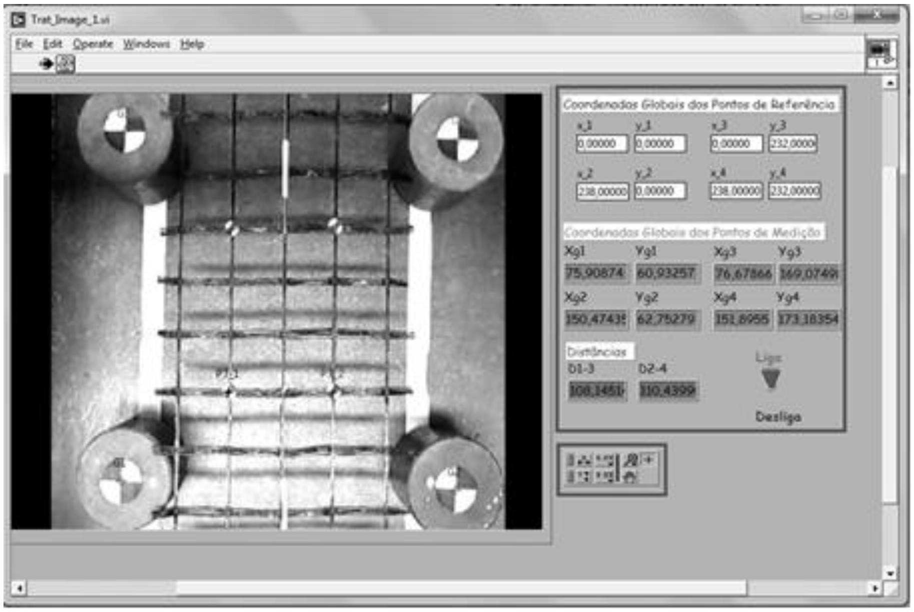


Figure 4. Data acquisition set with video camera, reference and on-specimen points (França et al., 2014).



Coordenadas Globais dos Pontos de Referência

x_1 0,00000
y_1 0,00000
x_3 0,00000
y_3 232,0000
x_2 238,00000
y_2 0,00000
x_4 238,00000
y_4 232,00000

Coordenadas Globais dos Pontos de Medição

Xg1 75,90874
Yg1 60,93257
Xg3 76,67866
Yg3 169,0749
Xg2 150,4743
Yg2 62,75279
Xg4 151,8955
Yg4 173,18354

Distâncias

D1-3 108,1451
D2-4 110,4399

Figure 5. Image treatment software used to compute specimens elongation (França et al., 2014).

3. TEST RESULTS

Two sets of tensile tests were perfomed in this research, both with a biaxial geogrid in machine direction (19.5 kN/m @9.6% elongation, according to ASTM D 6637). Poorly graded sand (SP) at 45% of relative density was used as confining medium in tests with in-soli specimens. 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). Specimen elongation was computed with the original telltale system. The second tensile tests set were performed in order to evaluate the original telltale based elongation measurement system. Therefore, besides the original telltale system, the video camera set was used in tests performed in conventional condition only. Further description of these tests is presented in França et al. (2014). Despite the aim of this paper is to present these results in terms of secant modulus, a brief report of the differences between both elongation measurement systems is provided.

The curves obtained in both methods presented the same trend, with greater differences in the beginning of the tests (Figure 6). Displacement readings computed from images showed a variable elongation rate. This effect may be explained by observing the tests, since the side ribs of the geogrid moved in a variable and non-constant way. Thus, the reference point placed over these ribs moves and stops as the loading reaches the rib. The curves obtained with tell tales, in their turn, presented a very linear behavior compared to those from imaging system, due to measurements taken in the central ribs of the specimens. It is important to notice that the ribs failures occurred randomly in each specimen.

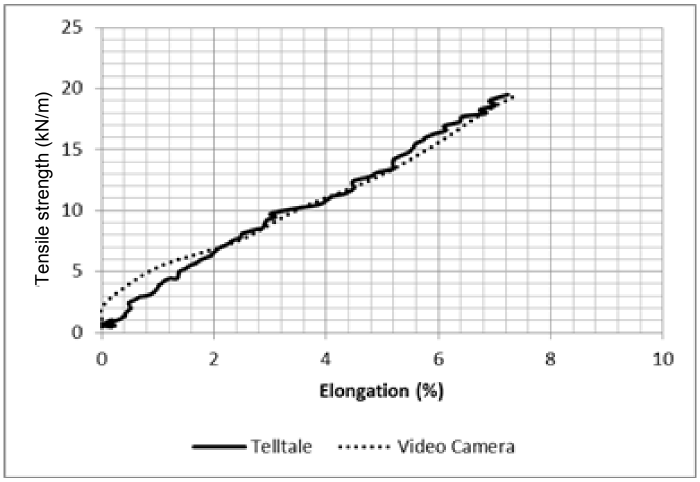


Figure 6. Tensile strength versus elongation curves obtained by both imagery and original methods.

Tensile strength of specimens were approximately equal to 19.5 kN/m, indicating a tensile behavior similar to nominal values provided by the manufacturer. However, mean elongation at break (7.4%) were about 25% smaller than the one obtained with standard tests (9.6%). Since bigger specimens are necessary in tests performed with the new equipment, necking process and other aspects may bring some difficulties to this comparison. In addition, the coefficient of variation of data obtained with imaging system was smaller than the one resulted from tell tales measurement. Finally, the results showed constant secant tensile stiffness values in all tests, indicating the proper behavior of the new equipment. Table 1 presents the secant tensile stiffness for one test in order to show the difference between the two elongation measurement systems.

Table 1. Secant tensile stiffness @ 2% elongation, in kN/m.

Specimen number	Tell tales	Image system
1	2,70	2,00
2	2,10	1,60
3	2,10	1,80
4	2,10	2,80
5	2,20	3,30
Coefficient of variation	11.6%	31.3%
Average	2.24	2.30

4. CONCLUSIONS

This paper presented the new tensile testing equipment based on the creep testing equipment firstly presented by França and Bueno (2011) and fully presented by França (2012). Several adjustments were described and tensile test results were presented. The following conclusions are drawn from the present study:

- Tensile tests under confined conditions and at elevated temperature were performed properly.
- Tensile strength values obtained with the new equipment were very close to those from standard tests.

- Elongation at break values were quite lower in tests performed with the new equipment. This may be due to adjustments in the clamp system.
- Secant tensile stiffness provided by both elongation measurement systems were very similar.

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