NONWOVEN GEOTEXTILES: EVALUATION OF BEHAVIOUR IN CONFINED CREEP TESTS

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Abstract: This work presents results of creep on nowoven geotextiles executed in confined tests. In the equipment used, the reinforcement is confined among soil layers, allowing both materials to have freedom to undergo deformations over time. In these tests, a stress vertical is applied to the soil. Two soil types were used, a pure sand and a sandy silt clay. Polypropylene nowoven geotextile reinforcement material was used with resistance characteristics compatible with the test equipment. The results indicated that the deformation of the geotextile was affected by the characteristics of the confining soil. In addition, unconfined creep tests were carried out using loadings equivalent to those used in the confined creep tests. This was to evaluate the effect of the soil presence on the creep of nowoven geotextile. The results demonstrated that the presence of the confinement reduced the total deformations with time for the geotextile assessed. This confirms the need and the importance of studies, in which the real conditions that the reinforcement will be submitted to in the works are applied.

Keywords: geotextile, creep, soil-reinforcement interaction.

INTRODUCTION

The polymer materials exhibit a time dependent stress-strain behavior, and accordingly two separate aspects are traditionally identified: creep and stress relaxation. Such behavior is extremely important in the soil reinforcement structures because, in this application, the reinforcement is required during the design life. The possibility of excessive deformation and rupture are potentially harmful effects of these mechanisms that can influence the proper performance of a structure of reinforced soil.

Current design procedures lack a suitable analytical procedure to quantify such a time-dependent response. Thus, a large reduction factor ranging from approximately 2 to 5 (depending upon the type of polymer) is applied to the short term ultimate strength of the material.

The procedures for design have resulted in works with excellent performance without showing significant deformation depending on the time. In works implemented, the strain measures have been smaller than the values expected on the basis of results of creep tests in the laboratory. Thus, although the methods to project structures that have an appropriate behavior over time, the actual mechanism developed in the long-term is still very poorly understood.

The knowledge accumulated indicates that the presence of confinement can reduce the creep of nonwoven geotextiles.

Another controversial issue is the possibility that the creep deformation of the geotextile reinforcement to be affected by the time-dependent deformation characteristics of the confining soil. Wu & Helwany (1996) argue, for example, that when the geosynthetic reinforcement in isolation tends to deform faster than the confining soil, the confining soil will restrain creep deformation of the reinforcement. However, when evaluating the results of research concerning the matter, it is clear that those mechanisms of soil-reinforcement interaction, over time, have not been adequately discussed and proven.

Considering this scenario, research on the time dependent behavior of geosynthetics are necessary and highly justifiable, as the biggest reduction factor applied to the short term ultimate strength, is due to the possibility of creep. The attestation of lesser creep of strengthening due to restrictions caused by soil could, for example, enable the adoption of methods of scaling less conservatively, further reducing the costs involved in this type of solution.

These aspects ratify the importance of the subject and are presented as basic motivation for the development of this work, which scope was to assess the creep on nonwoven geotextiles executed in confined tests. The tests were conducted using two types of soil: a pure sand and a sand silt clay. As reinforcement material was used a nonwoven geotextile of polypropylene with characteristics of compatible resistance with the used equipment. Besides, also unconfined creep tests accomplished with equivalent loadings to the registered in the confined creep tests, to evaluate the effect of the soil presence in the creep of nowoven geotextile.

MATERIALS AND METHODS

Equipment

The equipment used was designed and developed by Costa (2004). The design of this equipment was based on the premise that both the soil as geotextile should have freedom to undergo deformations with time (Costa & Bueno, 2006).

Figure 1 shows a schematic representation of the equipment. It consists basically of a box fixed to a table of support, a set of grips for fixing the geotextile, a system for applying vertical stress to the mass of soil and a system to record the deformation of geotextile. In this equipment, a geotextile with dimensions of 200 x 200 mm is confined between layers of soil to 100 mm thick.

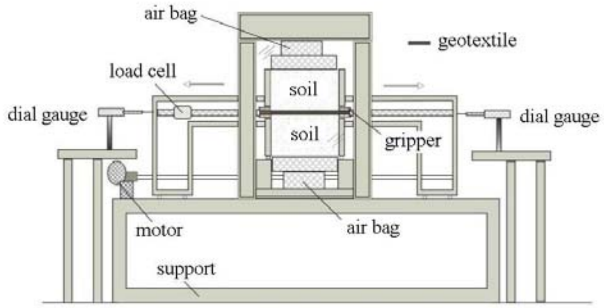

Figure 1. Configuration of the used equipment (Costa, 2004)

Instrumentation

System for obtaining the geotextile strain

Reinforcement strain was measured by the displacements of rods fixed to the geotextile. Four different rods are used to monitor displacements of four points in the geotextile, allowing the acquisition of geotextile strain in distinct excerpts. The displacements of the rods are recorded by the use of dial gauge.

The rods used are made in stainless steel with 0.6 mm diameter (used in dental treatments). These rods are lubricated with silicone grease and slips inside a tube of protection of stainless steel, with outside diameter equal to 0.8 mm.

To obtain the displacement of the rods, dial gauges are used with course of 50 mm and resolution of 0.01 mm.

System for obtaining the force on the walls

In tests of confined creep, the active force is obtained through a load cell, positioned between the grip and frame (Figure 1).

System for application of the vertical stress

To implement the vertical stress to the mass of soil, two chambers pressurized with compressed air were used, positioned at the base and at the top of the test specimen. The device consists of an aluminum frame which is set in a rubber membrane.

To control the pressure, manometers with capacity of 200 kPa are applied and with a resolution of 2 kPa.

Geotextile and soils

Geotextile properties

All tests were performed using a nonwoven geotextile of polypropylene, which main characteristics are presented in Table 1. The tensile strength corresponds to the longitudinal direction of the material, direction in which it was tested in confined creep tests.

Table 1. Properties of the geotextile used (Kamiji, 2006).

Properties	Average	Coefficient of variation (%)
Mass per unit area (NBR 12568)	41.90 g/m²	2.63
Tensile strength (NBR 12824)	1.50 kN/m	7.38
Strain at failure	54.37 %	3.85

Two tests of unconfined creep were conducted to characterize the geotextile and allow the comparison of results with tests on the element of reinforced soil. Figure 2 shows the results of unconfined creep tests, made on the basis of the Brazilian Standard NBR-15226 (ABNT, 2005). The levels of loading applied (10 and 35% $T_{ult.}$) were selected according to the level of load recorded in confined creep tests.

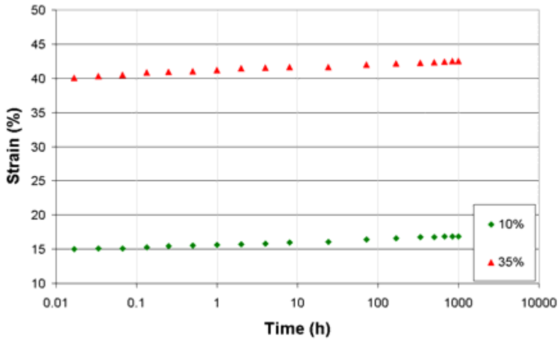

Figure 2. Results of unconfined creep tests for 10 and 35% T_{ult}.

Soils properties

Figure 3 shows the particle size distribution of the soils used in confined creep tests, obtained according to the Brazilian Standard NBR-7181 (ABNT, 1984).

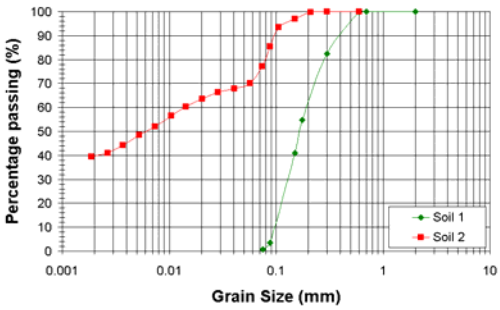

Figure 3. Particle size distributions for soils used.

Soil 1 is a pure sand, collected from the São Carlos region. This is classified as SP according to Unified System of Classification. The coefficient of non-uniformity of the material is equal 2.7.

The maximum void ratio (e_{max}) for the sand, obtained by the Brazilian Standard NBR-12004 (ABNT, 1990), is equal to 0.87, corresponding to a minimum specific dry weight ($\gamma_{d,min}$) equal to 14.2 kN/m³. The minimum void ratio (e_{min}), determined in accordance with the Brazilian Standard NBR-12051 (ABNT, 1991), is equal to 0.50, equivalent to a maximum specific dry weight ($\gamma_{d,max}$) equal to 17.7 kN/m³. The specific solids weight is equal to 26.5 kN/m³.

Triaxial compression tests, published by Costa (2004), revealed peak friction angle values (ϕ'_p) shown in Table 2.

Table 2. Peak friction angle measured for the soil 1 (Costa, 2004).

D_r (%)	σ_3 (kPa)	ϕ'_p (º)
100	50	39.9
	100	39.2
	200	38.2

Soil 2 is a sandy silt clay, collected from the Araras region. This is classified as CL according to United System of Classification. The Atterberg limits (liquidity and plasticity) and the specific solids density are shown in Table 3.

Table 3. Properties of the soil 2 (Patias, 2005).

Properties	Test Value
LL (%)	46
LP (%)	27
ρ_s (g/cm³)	2.650

The maximum specific dry density and the optimum moisture content of the soil 2, according to the Brazilian Standard NBR-7182 (ABNT, 1984), are 1.541 g/cm³ and 23% respectively. Triaxial compression tests, published by Patias (2005), revealed parameters of resistance shown in Table 4.

Table 4. Parameters of resistance obtained in the triaxial tests for soil 2 (Patias, 2005).

Test	Parameter	Test Value
UU	c (kPa)	109.4
	ϕ (º)	22
CU (Saturated soil)	c (kPa)	49.1
	ϕ (º)	17.2
	c' (kPa)	22.1
	ϕ' (º)	29.6

TESTS

The tests are listed in Table 5 which shows the main characteristics of the soil used in tests.

Table 5. Tests

Test	Soil	D_r (%)	w (%)	Degree of compaction (%)	Vertical stress (kPa)
1	1	100	-	-	70
2					85
3					100
4	2	-	w_{ot}	95	70
5					85
6					100

RESULTS AND DISCUSSION

Figures 4 and 5 present results of confined creep tests showing the strain versus time curves. The deformation was obtained on the basis of the observed displacements in rods fixed to the geotextile.

In all tests strains over time were recorded, showing that the presence of soil did not remove the geotextile creep. The soil 1 collapsed under a vertical stress of 100 kPa after 16.07 minutes of the test.

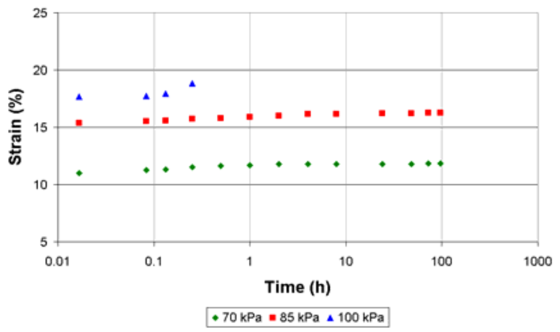

Figure 4. Results of confined tests – Soil 1.

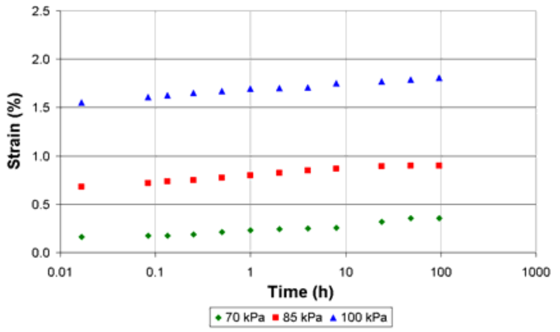

Figure 5. Results of confined tests – Soil 2.

With regard to the type of soil, Figure 6 shows a difference between the total strain obtained in tests on the soils 1 and 2.

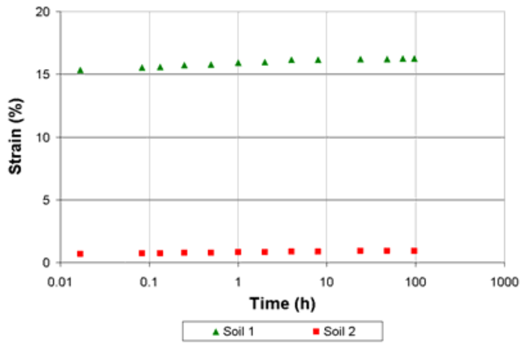

Figure 6. Results of confined tests for soils 1 e 2 under vertical stress of 85 kPa.

Initially, the differences in the strain can be attributed to the type of soil because the material used as reinforcement and vertical stress applied was equal. However, we must consider that the load registered in the geotextile in both tests is equivalent.

Figures 7 and 8 show the variation of the load with time for confined tests to the soil 1 and 2, respectively. The load values registered in the reinforcement are expressed as a percentage of the ultimate tensile strength resistance (% $T_{ult.}$).

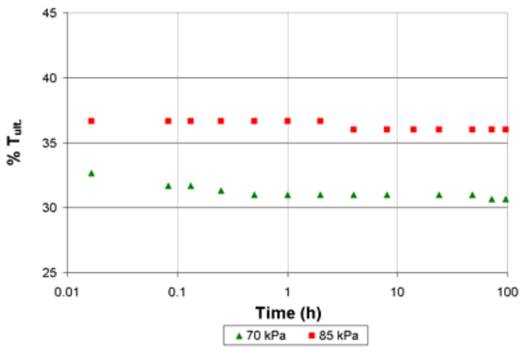

Figure 7. Variation of the load with time for confined creep tests – Soil 1.

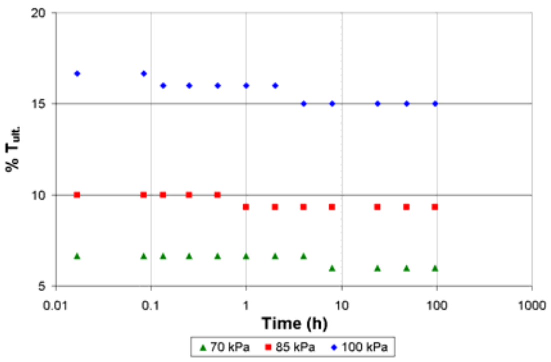

Figure 8. Variation of the load with time for confined creep tests – Soil 2.

A great difference of load measured in both tests can be seen. For the test with soil 1 and vertical stress of 85 kPa, the load recorded was about 3.5 times higher than for the test with soil 2. For a vertical stress of 70 kPa the load registered in the test with soil 1 was up to 5 times higher than that registered in the test with soil 2. The smaller values of load, recorded in reinforcement of the tests on soil 2, are due to small soil deformability in the conditions of the tests, as in the confined creep tests the mass remained stable even without the anchorage presence.

One factor contributing to strain small presented in the tests with the soil 2, refers to the characteristics of soil resistance, since this gives cohesion and friction angle. In this case, beyond the friction angle, the presence of cohesion improves the soil strength and gets the structure more stable justifying the strain reduction in the tests on the soil 2.

Figures 7 and 8 also allow to check the variation of force over time, since the creep reflects the behavior of materials over time undergone a constant loading. In this sense, notice that the registered load presented a small variation during the tests. The biggest variation initially observed (t = 1 min) occurred for the test with the soil 2 under vertical stress of 70 kPa, which there was a reduction of 10% in load after 10 h of the test.

In order to check the influence of confinement in the geotextile creep unconfined creep tests were conducted with equivalent loadings to the registered in the confined creep tests.

Figures 9 and 10 show results of tests with and without confinement for used geotextile.

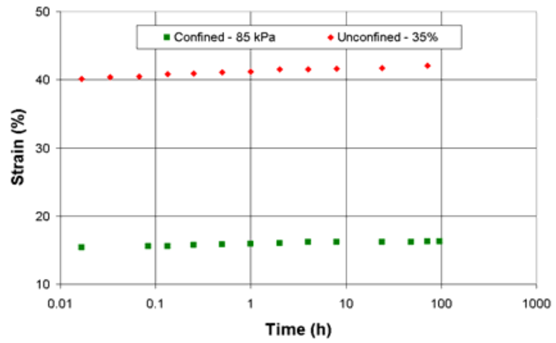

Figure 9. Comparison between confined and unconfined creep test – Soil 1.

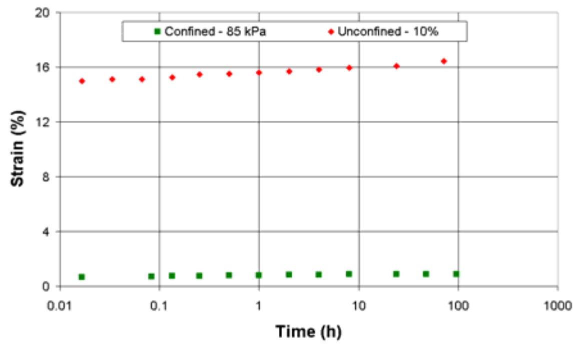

Figure 10. Comparison between confined and unconfined creep test – Soil 2.

In reference to the confinement, notice that their presence has actually reduced the total strain presented by geotextile over time. By adjusting the data presented in Figures 9 and 10 through the log function shown in the Expression (1), it is possible to quantify the susceptibility to the creep of geotextile. Table 6 presents the results found.

$$\varepsilon = a + b \cdot \ln(t) \quad (1)$$

Where z is total strain in percentage, t is the time in hours and a and b are constant obtained by the adjustment.

Table 6 Results of settings using the expression (1).

Test	**Constants**		**Coefficient of determination (R^2)**
	a	**b**	
Unconfined – 35%	41.167	0.221	0.963
Confined – Soil 1	15.855	0.107	0.941
Unconfined – 10%	15.620	0.165	0.983
Confined – Soil 2	0.794	0.028	0.983

Comparing themselves the values of "a", referring to the strain for t = 1 h, we can say that there was a reduction of 61.5% for the confined test to the soil 1 and 94.9% for the confined test with the soil 2.

Through the values of "b" obtained for the adjustments, referring to the tendency to present creep, we can say that there was a reduction of 51.6% for the confined test to the soil 1 and 83.0% for the confined test with the soil 2.

Hence the results demonstrated that the presence of the confinement reduced the total strains with time for the geotextile assessed.

CONCLUSIONS

The main conclusions from the evaluation of the creep on nonwoven geotextiles are as follows:

- The presence of confinement actually reduced the total deformation of the geotextile used. For the confined creep test with the soil 1 and vertical stress equal to 85 kPa a tendency of the geotextile to creep was approximately 50% lower than for the unconfined creep test. For the confined creep test with the soil 2 and vertical stress equal to 85 kPa a tendency of the geotextile to creep was approximately 85% lower than for the unconfined creep test;
- The type of soil influenced significantly the loads recorded in geotextile. For a vertical stress equal to 85 kPa, for example, the maximum load recorded in reinforcement was 3.5 times higher for the test with the soil 1 in comparison with the test done with the soil 2;

- The presence of cohesion improves the soil strength and makes the structure more stable justifying the strain reduction in the tests on the soil 2.

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