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Confined creep of geotextile in a compacted sand fill

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ABSTRACT: this work deals with the influence of soil confinement on creep behavior of geotextiles. A full-scale field experiment was conceived to study this matter. Two samples of nonwoven polypropylene geotextile were inserted in different depths in a compacted sand fill with 3 m high and 16 m long and loaded by constant tensile load during a 1000 h period. To maintain a constant load during the test dead weights were used together with specially designed steel structures. The sand fill and the samples were instrumented with several kinds of transducers in order to measure strains, displacements, soil pressures and temperatures. Direct shear testes were conducted to measure the mechanical properties of the interfaces. An interpretation model to analyze the field results is proposed. The confined creep behavior in field is compared with in-isolation creep results obtained from laboratory tests.

1 INTRODUCTION

Engineers have to face an important question that is not quite well answered when using geosynthetics to reinforce soil structures. That question is the creep behavior.

Creep is a property common to all polymeric materials. Characterized by the increasing elongation of the material under constant load.

The creep behavior is one of the most important properties to evaluate when determining the allowable tensile strength of a geosynthetic in soil reinforcing applications.

The allowable tensile strength can be determined using reduction factors on the wide width tensile strength ($t_{max.}$). That factors account for various effects like creep, chemical degradation, installation damage, etc. For example, the reduction factor for creep of nonwoven polypropylene geotextiles can be as low as 20% (Task Force #27 1991).

Such reductions can make the use of geotexiles on reinforcement applications less competitive in terms of cost or nonviable. Therefore the understanding of the creep behavior of geotextiles is fundamental to reduce the uncertainties involved in estimating the allowable tensile loads. This work presents a small effort for the comprehension of the factors that influence the creep behavior of a nonwoven needle punched polypropylene geotextile.

1.1 *Importance of soil confinement on creep behavior of a geotextile*

The creep of geotextiles was more intensively studied since the 1980's. Therefore, it is a relatively new subject. There are still some points of disagreement that must be clarified. One of the most discussed points is the soil confinement influence on creep behavior.

The reduction factors used for creep at present are based on the interpretation of unconfined creep test results. However, the monitoring of several structures of reinforced soil has shown considerably smaller creep strains than those predicted by unconfined creep tests (Barret 1985, Delmas 1988). McGown et al. (1982) realized laboratory creep tests under soil confinement with pressures of 100 kPa. Several kinds of geotextiles were used. The confinement reduced the primary creep about 40 to 60% for the case of nonwoven needle punched geotextile. The secondary creep rates were also significatively reduced. It appears that the unconfined creep tests grossly overestimate the creep strains of the nonwoven geotextiles.

Creep is predominantly a function of stress level, time, temperature, some environmental factors and the molecular structure of the polymer (Koerner 1990).

In the case of geotextiles, the structure plays a major role in the stress-strain-time behavior. The creep test of a yarn reflects the properties of the polymer. In a nonwoven geotextile the yarns are not aligned in the direction of the loading. The yarns are located in a sinuous pattern, and consequently, the creep behaviors of geotextile and yarn are quite different.

The strain of a geotextile can be divided in two components. One is the strain of the yarns and the other is its rearrangement. Den Hoedt (1986) points out that it is not possible yet to determine the relative importance of each component.

It is not well understood the reason why soil confinement can improve the mechanical and time dependent behavior of a geotextile. There are 3 possible mechanisms that can explain that feature. The soil confinement tends to increase the internal friction between yarns, restrain their realignment and penetrate inside the geotextile, again restraining the movements of the yarns (FHWA 1998).

Koerner et al. (1993) state that the creep tests of geotextiles must be executed under confinement to produce reliable results, especially in the case of nonwovens.

In addition, to obtain reliable results about the influence of soil confinement on the creep of nonwoven geotextiles it is important to conduct field experiments so that the size effects are minimized.

2 EXPERIMENTAL FILL AND LOADING CONDITIONS

A field experiment was conceived to assess the effects of soil confinement on the creep behavior of a nonwoven geotextile (Becker 2001). A fill was constructed by compacting layers of medium sand. Two samples of the nonwoven, needle punched polypropylene geotextile Geofort G300 were used. Its physical and mechanical properties are shown in Table 1.

The two samples were inserted in different depths and loaded for a 1000 h period as shown in Figure 1.

Samples 1 and 2 were inserted at depths of 0.5m and 2.5m from the top, respectively. The confining stresses were approximately 10 and 50 kPa.

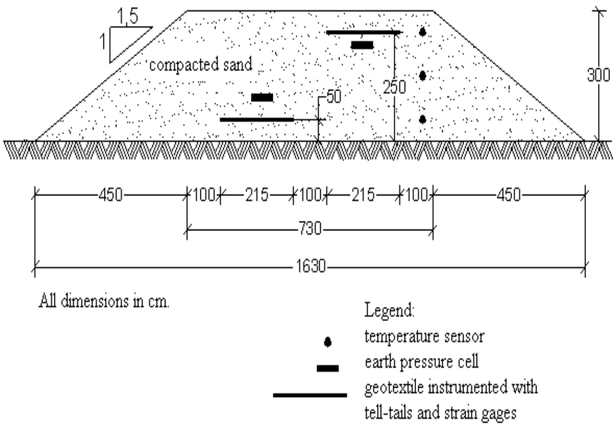

Figure 1. Transversal section of the experimental sand fill.

The geotextiles were instrumented by high elongation strain gages and tell-tales. In the fill were also inserted temperature sensors and earth pressure cells.

Table 1. Properties of the geotextile

Properties	Reference Values
Tensile strength (wide width)	22 kN/m
Elongation at rupture	60%
Apparent opening size	110 µm
Mass per unit area	300 g/m^2
Roll width	2,15 m
Thickness	2,8 mm

The front part of geotextiles was clamped to a set of metallic jaws and reinforced by epoxy resin to reduce strains. To maintain the unreinforced part under constant vertical stress the reinforced part was extended to the end of the vertical projection of the slope and involved in a lubricated HDPE geomembrane to reduce the friction against the surrounding soil.

During the test the geotextile was pulled outward the fill by the jaws as shown in Figure 2. To maintain the load constant during the 1000 h metallic beams were used to construct a loading frame. The necessary force was supplied by means of a system of cables and dead weights installed in the loading frame. The applied load was calculated to apply a tensile stress of 60% t_{max} in the beginning of the unreinforced part.

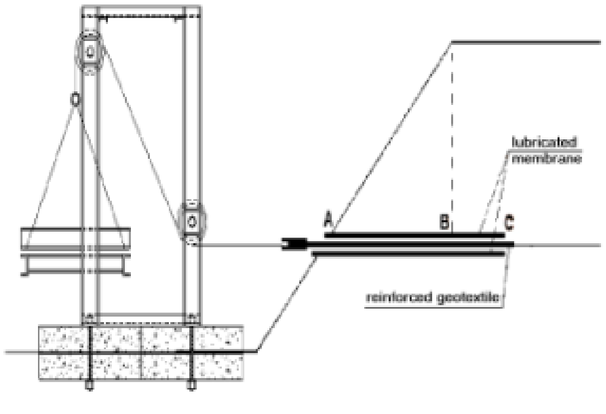

Figure 2. Lateral view of the loading frame and longitudinal section of the fill.

3 THEORETICAL MODEL OF STRESS TRANSFER UNDER CREEP

The tell-tales and strain gages were installed on the geotextile as shown in Figure 3. Each geotextile was instrumented with 8 tell-tales allowing the unreinforced part to be divided in seven regions of influence.

Strain gages read deformations and tell-tales read displacements. One can obtain the average strain of the region between two tell-tales as follows:

$$\varepsilon_i = (\Delta H_i - \Delta H_{i+1}) \div L_i \tag{1}$$

Where ε_i = average stain of geotextile in region i (between tell-tales i and i+1); ΔH_i , ΔH_{i+1} = difference between the present reading and the first reading for tell-tales i and i+1; L_i = distance between tell-tales i and i+1.

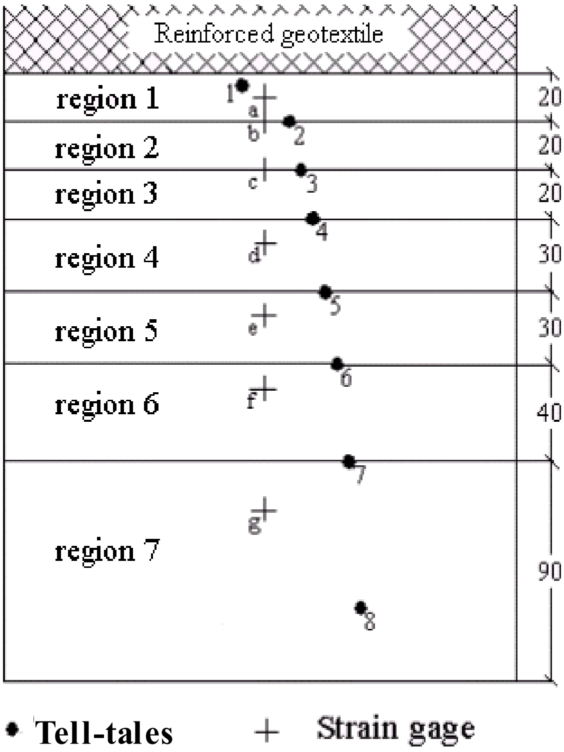

Figure 3. Location of tell-tales and strain gages

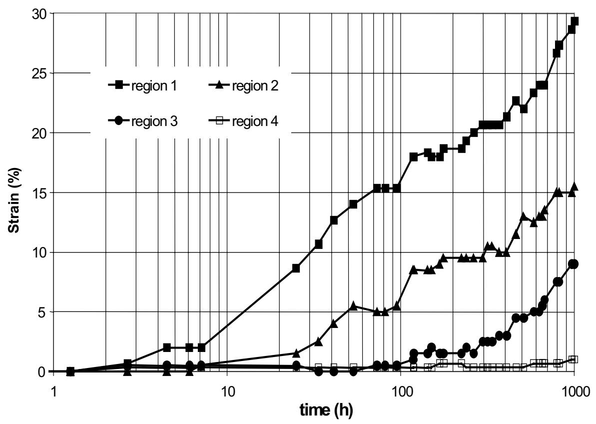

Figure 4. Strain vs. log (time) data for geotextile 1 (tell-tales).

The strains obtained are shown in Figure 4. One can easily see that the strains are not constant along the geotextile length. Only the regions 1, 2, 3 and 4 are displaced.

The tensile stress is not constant along the geotextile length because stress is transferred to the surrounding sand by friction. The geotextile shows variable strains because of its extensibility. The maximum strain is located near to the beginning of the unreinforced part decreasing toward the free end (FHWA, 1998).

To assess the transfer of stress between soil and geotextile interface shear tests using the fixed shear box setup (Ingold, 1984) were conducted. The box used is a squared one, sides of 63.5mm. The geotextile was glued in a wooden block firmly fixed in the lower part of the shear box, as shown in Figure 5.

Test results yield a sand-geotextile friction angle of 41.8º. The peak is reached for displacements of approximately 1mm and there is not post peak loss of resistance.

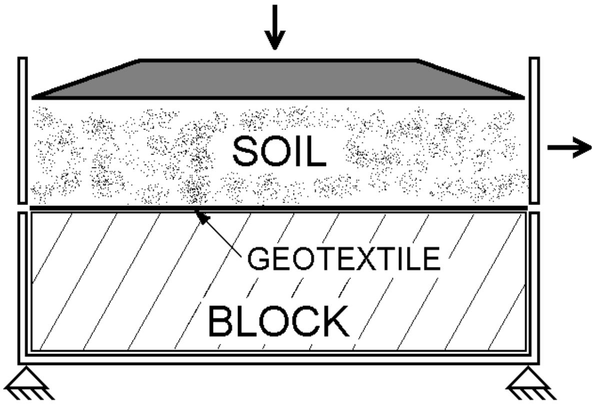

Figure 5. Fixed shear box test configuration.

Considering these results a linear loss of tensile stress was assumed along the geotextile length. The rate of stress loss is constant and can be determined as follows:

$$T_{friction} = 2 \times B \times \sigma'_v \times \tan(\delta) \tag{2}$$

Where T $_{friction}$ = tensile force lost by friction along the length of the geotextile (friction rate); σ'_v = vertical effective stress; B = width of the geotextile; e δ = sand-geotextile friction angle.

The length necessary to the transfer all the tensile stress from the geotextile to the sand is as follows:

$$L_{transf.} = t \div T_{friction} \tag{3}$$

Where L $_{transf}$ = geotextile length necessary to transfer all the stress to the sand; and t = tensile stress in the beginning of the unreinforced part.

On the four mobilized regions it was assumed that the tensile force is approximately constant during the test and equal to the average value:

$$\mathrm{T}_{avg.} = \left(\mathrm{T}_{beg.} + \mathrm{T}_{end}\right) \div 2 \tag{4}$$

$$\mathrm{T}_{end} = \mathrm{T}_{beg.} - \mathrm{T}_{friction} \times \mathrm{L}_{region} \tag{5}$$

Where T $_{avg}$ = average tensile force within a region; T $_{end}$ = tensile force at the end of a region; T $_{beg}$ = tensile force at the beginning of a region; L $_{region}$ = length of a region.

Figure 6 shows the assumed model.

It is also assumed that the elongation of the geotextile does not affect the friction rate $T_{friction}$. The strain of the geotextile actually increases the length of regions during the test. The result is that more load in transferred to the sand in the same region. However, that effect can be neglected because the “extra length” is small compared to the length of regions.

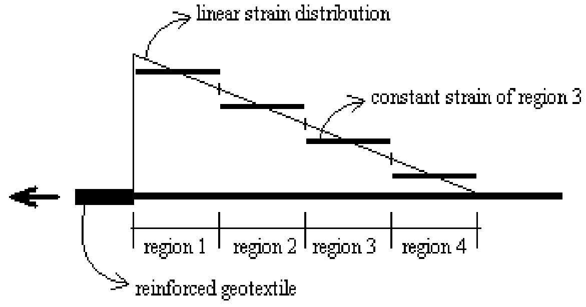

Figure 6. Assumed Model of strain distribution in Geotextile.

Using those assumptions the values of average tensile stress of Table 2 were obtained.

Table 2. Load distribution in region 1.

Region	1	2	3	4
L $_{region}$ (cm) (L$_{transf}$= 80 cm)	20	20	20	30
T $_{beg}$ (kN)	29,5	22,2	14,8	7,5
T $_{end}$ (kN)	22,2	14,8	7,5	0
%t $_{max}$ Beginning of region	62,4	46,9	31,4	15,8
%t $_{max}$ End of region	46,9	31,4	15,8	0
% average t $_{max}$	54,6	39,1	23,6	5,3

In other words, one single sample can provide four different percentages of t $_{max}$.

4 RESULTS AND BACK ANALYSIS

The assumption of a constant friction rate implies a linear distribution of strain as represented in the model shown in Figure 6. Figure 7 shows the strain distribution of geotextile 1. One can easily see that the distribution is approximately linear, as expected.

It is also evident that about 80 cm are necessary to transfer all tensile stress to the sand, as predicted by equations (2) and (3).

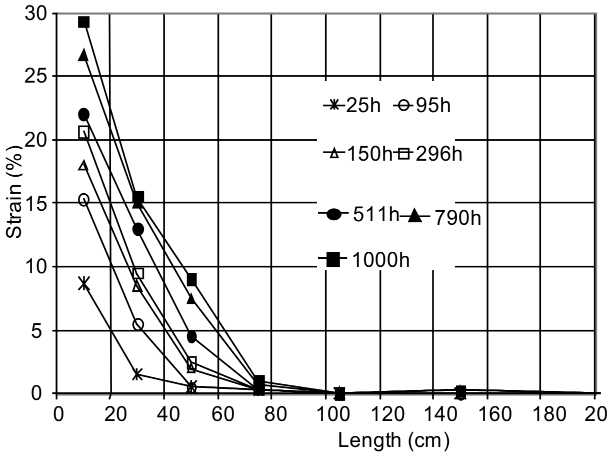

Figure 7. Strain distribution measured on geotextile 1.

Therefore, the proposed model of stress transfer is considered to be valid. It was not possible to accomplish the test of geotextile 2, due to successive ruptures of its reinforced part. The reasons of those ruptures will not be investigated in this work.

Figure 8 shows the Sherby-Dorn curves of the geotextile 1 under confinement. For all regions the creep rates were decreasing.

However, for region 1, after 25% of deformation the curve seems to increase again. It could be related to the beginning of the tertiary creep stage.

Figure 9 shows the comparison between the confined creep behavior for the regions 1, 2 and 3 of geotextile 1 and the results of unconfined laboratory tests. The unconfined creep curves for 25%, 40% e 55% of t_{max} were obtained by means of interpolation using the curves of 20%, 40% e 60% t_{max} (Bueno 2000)

The soil confinement alters the creep behavior of the studied geotextile. The initial deformation, very high in the unconfined test, is negligible in the confined test. McGown et al. (1982) also observed that the confinement reduces significatively the primary creep. The authors assert that the secondary creep rates were also reduced. It was not observed in this research.

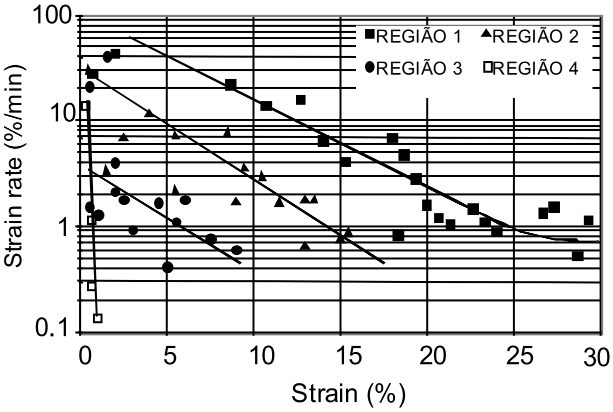

Figure 8. Sherby-Dorn curves for geotextile 1.

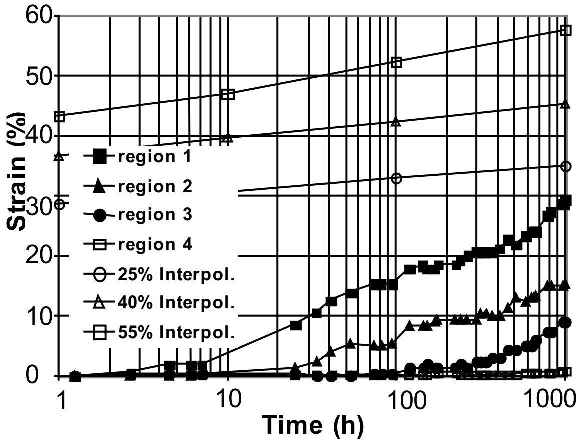

Figure 9. Confined and unconfined creep behaviors for geotextile 1.

Probably the change in creep behavior is due to the restriction of movements and elongation of the yarns caused by the soil grains.

The confined tests show strains smaller than those of the unconfined tests during the whole test.

The creep rates of the confined test decrease with time to the 1000 h period but are greater than the unconfined laboratory creep tests.

5 CONCLUSIONS

The results shown are not supposed to solve the complicated question of the soil confinement influence on creep behavior of geotextiles. However, it is hopped that they contribute to stimulate the study of this matter.

The comparison between the unconfined and confined results demonstrates that the soil confinement can modify the creep behavior of the studied geotextile. The initial strain and the total creep strains are reduced.

The greater deformation occurs near to the beginning of the unreinforced part and decrease toward the free end.

The mechanical properties of the sand-geotextile interface obtained in the fixed shear box test and the assumption of linear distribution of strain along the geotextile are in good agreement with the field results.

The temperature sensors indicated that the medium temperature of the fill at the depth of geotextile 1 was 20.5º C the maximum and minimum temperatures were 23º C and 18º C.

6 ACKNOWLEDGEMENTS

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