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Technical note

Influence of soil confinement on the creep behavior of geotextiles

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ABSTRACT

This work addresses the influence of soil confinement on the creep behavior of geotextiles by presenting the results of a full scale field test. Two samples of nonwoven polypropylene geotextile were inserted at different depths in a 3 m high compacted sand fill. The samples were loaded with a constant tensile load during a 1000 h period. To maintain a constant load during the test, a system of weights, pulleys and load cells was used. The sand fill and the samples were instrumented with several types of transducers in order to measure strains, displacements, applied forces, soil stresses and temperature. Direct shear and inclined plane tests were conducted to measure the mechanical properties of the interfaces. An interpretive model is proposed to analyze the field results. The confined creep behavior in the field is compared with results obtained by other authors and with in-isolation creep results obtained from laboratory tests.

1. Introduction

Creep behavior and stress relaxation have to be taken into account when using geosynthetics in the design of reinforced soil structures. Creep is common to many materials, including all polymers.

Creep behavior is one of the most important properties to be evaluated when determining the allowable tensile strength of a geosynthetic in soil reinforcing applications.

Long-term design strength can be determined using isochronous curves or by applying conservative reduction factors to the wide-width tensile strength (T_f). Bueno (2010) states that reduction factors typically range from 2 to 7. For example, the reduction factor of nonwoven polypropylene geotextiles can be as high as 5 (Task Force #27, 1991; Holtz et al., 1998).

Such reductions are based on results of in-isolation creep tests. However, some authors have found that in-isolation creep tests tend to over-predict creep strain in some geosynthetics (McGown et al., 1982; Den Hoedt, 1986; Holtz et al., 1998). Koerner (2012) considers that, while expensive and time-consuming to perform, confined creep tests are important for setting realistic creep reduction factors.

In spite of the research conducted until now, the mechanism of confined creep is not yet fully understood, and its effect is usually disregarded in reinforced soil design. Several apparatuses have been developed for confined creep testing, but their results are difficult to compare because their boundary conditions are very different (McGown et al., 1982, Costa, 1999; Wu and Helwany, 1996; Boyle and Holtz, 1996; França and Bueno, 2010; 2011).

Nonwoven geotextiles are currently seldom used to reinforce soil walls and slopes, but they were widely used approximately two decades ago. There are countless nonwoven reinforced structures around the world still in service. Some of these structures could be reassessed to allow load increases if their creep reduction factors are proven to be excessive. Nonwoven geotextiles used in other geotechnical applications can be under tensile stresses for long periods also.

1.1. Importance of soil confinement on geotextile behavior

Soil confinement can affect the stress-strain behavior of some geotextiles, especially nonwoven ones (Yuan et al., 1998; Koerner, 2012). For geogrids and woven geotextiles, the effect of confinement may be negligible.

The fibers of the nonwoven geotextiles are not aligned in any preferential direction but rather are sinuous and random. The strain of a nonwoven geotextile can be divided into two components. One is the strain of the fibers and the other is the strain due to their

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rearrangement, known as structure deformation. Den Hoedt (1986) speculated that structural deformation could represent up to 50% of the total strain in needle punched nonwovens.

Under soil confinement, geotextiles may exhibit increases in short-term tensile strength (McGown et al., 1982; Ling et al., 1991; Leshchinsky and Field, 1987; Elias et al., 1998) and modulus, especially at lower strains (McGown et al., 1982; Boyle et al., 1996; Siel et al., 1987; Ling et al., 1991; Leshchinsky and Field, 1987; Yuan et al., 1998; Elias et al., 1998). Some authors have concluded that confinement does not influence rupture elongation (Leshchinsky and Field, 1987; Ling et al., 1991), whereas others have stated that rupture elongation is reduced (Elias et al., 1998).

1.2. Unconfined creep of geotextiles

Three stages may be identified in typical unconfined creep results (Fig. 1). After an almost instantaneous deformation due to load application, the primary stage of creep begins. There is a fast increase in deformation, but the creep rate decreases. After a transition, secondary creep begins and the creep rate declines slightly. In some tests, after a critical strain, a tertiary stage begins and the creep rate increases leading to creep rupture (Cazzuffi et al., 1997).

According to Mitchell and Villet (1987) and Allen (1991) creep behavior in the primary stage is strongly affected by structural deformation, whereas in the secondary and tertiary stages, the type of polymer controls the behavior.

Cazzuffi et al. (1997) concluded that the shape of the time vs. strain curve depends on the dominant creep stage (Fig. 1c).

1.3. Confined creep of geotextiles

The reduction factors used for creep at present are usually based on the interpretation of unconfined creep test results. However, the monitoring of several reinforced soil structures has shown equal or smaller creep strains or rates than those predicted by unconfined creep tests (Barrett, 1985; Mitchell and Villet, 1987; Delmas, 1988; Allen and Bathurst, 2002). Those results are difficult to compare because the real tensile load is usually estimated instead of measured.

Koerner et al. (1993) state that 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 in order to minimize size effects. Sample trimming to reduce samples sizes for laboratory tests implies cutting fibers and therefore reduces restraints on fiber realignment thus affecting the geotextile's behavior.

McGown et al. (1982) conducted laboratory creep tests under sand confinement with normal stresses of 100 kPa. The equipment's boundary conditions could be described as similar to a confined wide-width test. Several types of geotextiles were used. The confinement reduced the primary creep by 40%–60% in the case of a nonwoven needle-punched geotextile. The secondary creep rates were also noticeably reduced.

Since then, several authors have conducted confined creep tests on nonwoven geotextiles in different apparatuses.

Wu and Helwany (1996) concluded that soil confinement increased or decreased geotextile creep depending on soil type. Normal stress and tensile loads were estimated.

Boyle (1995) developed a device similar to Wu & Helwany's with a capacity to measure reinforcement tensile loads. The stresses were kept constant; however, the tensile load declined during the test.

Elias et al. (1998) used an apparatus similar to the one described by McGown et al. (1982) and concluded that creep strain is significantly reduced in nonwoven geotextiles and that the creep of a geotextile may be affected by time-dependent sliding between fibers called shear creep. The authors believe that the normal stresses were high enough (69 kPa and 138 kPa) to increase friction between fibers and prevent their sliding, thereby improving the creep behavior of nonwovens.

França and Bueno (2010) and França and Bueno (2011) presented results of confined and confined-accelerated creep tests on a polyester non-woven geotextile conducted in laboratory. The boundary conditions were similar to a confined tensile test, and the load was measured at both ends of the sample, but the load level in the center of the sample was not known. The normal stress was 30 kPa. The authors concluded that the confinement considerably reduced both the initial strain and creep rate.

Wu and Hong (1994) conducted confined creep tests on nonwoven needle-punched geotextiles. The confining stresses were 0 kPa, 50 kPa, 100 kPa and 200 kPa. The authors found a significant reduction in creep only for 200 kPa.

Comparison of those results is difficult because of their different boundary conditions, mainly tensile load level, tensile load distribution, normal soil stress, soil type, test duration and method of measuring (or estimating) tensile load. Furthermore, an ideal test should replicate the strain and stress conditions of reinforced soil structures, which was not the case for many tests.

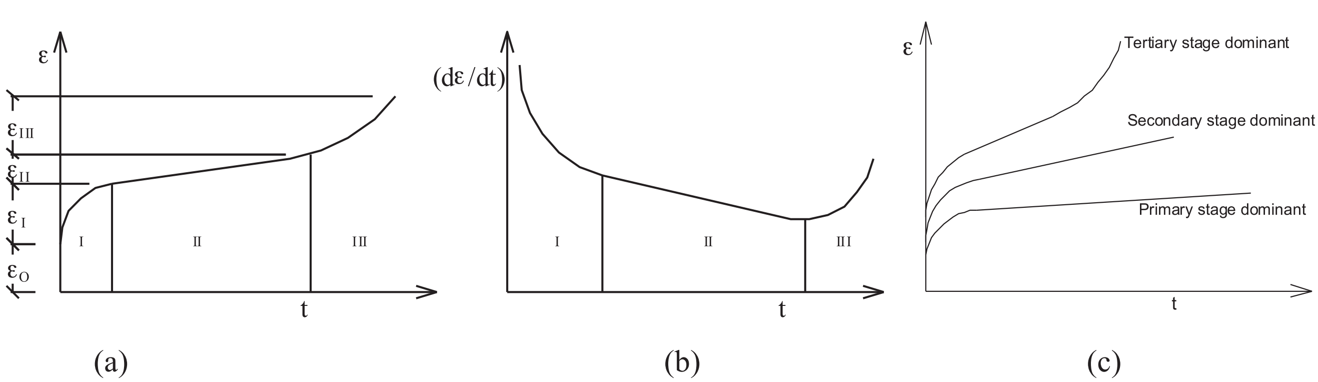

Fig. 1. Primary, secondary and tertiary stages of geotextile creep: (a) time *vs.* strain, (b) time *vs.* strain rate and (c) creep behavior according to the dominant creep stage (Cazzuffi et al., 1997).