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Load-deformation behaviour of virgin and damaged non-woven geotextiles under confinement

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ABSTRACT: This paper examines the influence of confinement on the mechanical behaviour of virgin and mechanically damaged nonwoven geotextiles. In-soil tensile tests were performed on different types of geotextiles and confining materials under normal stresses between 25 kPa and 150 kPa. Three types of sands and geotextiles were used in the tests. The influence of different types and dimensions of damages were also investigated under in isolation and in-soil conditions. The effects of confinement and the presence of the damages were quantified. It was observed that confinement reduces the detrimental effects of the damages.

1 INTRODUCTION

Reinforced soil structures are arrangements of two elements with different properties and complementary functions: the soil, which can be chosen to present good compression strength and the reinforcement, which can present good tensile strength. The combination of these two materials results in a stronger and less deformable structure than the soil alone. The behaviour of a reinforced soil structure depends on the soil strength and on the mechanical properties of the reinforcement. Stiffer reinforcements require less deformation to mobilize significant tensile forces in the reinforcement, which will yield to a less deformable reinforced mass. Extensible reinforcements must not be used in situations where deformations of the reinforced structure are limited by stability or serviceability constraints.

Despite nonwoven geotextiles being considered extensible reinforcements, several examples of old structures reinforced with these materials have presented little deformations due to the geotextile stiffness increase caused by the confinement by the surrounding soil (McGown et al. 1982). In this context, the study of the mechanical behaviour of these materials under confinement, using in-soil tensile tests, is important to improve design parameters and to increase the use of non-woven geotextiles in reinforced soil structures, particularly those of low to moderate heights.

Because of the relevance of confinement to the tensile stiffness of nonwoven geotextiles, this work examines the mechanical behaviour of these materials in tension confined by different soils, including the influence of confinement on the tensile properties of mechanically damaged geotextiles. Some aspects relevant to the in-soil behaviour of nonwoven geotextiles are investigated and discussed in the following sections.

2 TEST APPARATUS AND MATERIALS

2.1 *Test Apparatus*

A test apparatus developed at the University of Brasília was used for the in-soil tensile tests (Palmeira 1996). The main characteristics of the apparatus are presented in Figure 1.

The in-soil tensile cell is a metallic box 20 cm wide, 22 cm long and 6 cm high, laterally open. The geotextile specimen (200 mm × 100 mm) is installed at the centre of the box and clamps allow for the application of the tensile force. A pressurized rubber bag provides a uniformly distributed confining stress on the top layer of the confining soil material.

The movable pair of clamps that hold the geotextile specimen is connected to a hydraulic cylinder,

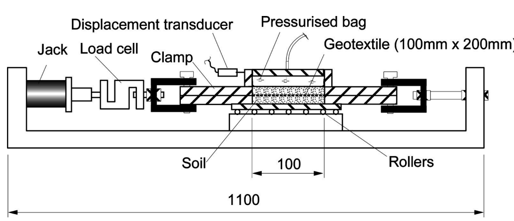


Figure 1. In-soil tensile test apparatus.

Table 1. Some characteristics of the geotextiles used.

Geotextile	$\mu^{(1)}$ (g/m^2)	t_{GT} (mm)	J (kN/m)$^{(2)}$
GA	200	2.9	21
GB	300	2.6	31
GC	400	3.8	42

Notes: (1) μ = mass per unit area, t_{GT} = geotextile thickness; (2) J = tensile stiffness from wide strip tensile tests in isolation.

which applied the tensile load at a constant rate of strain of 2%/min. The arrangement of the test is such that negligible friction is developed along the soil-geotextile interface during the test as both materials deform horizontally by the same amount, in contrast to what occurred in previous similar apparatus (McGown et al. 1982, Leshchinsky & Field 1987, Siel et al. 1987, Kokkalis & Papacharisis 1989, Palmeira et al. 1996, for instance). Tensile loads and displacements of the geotextile ends are measured by a load cell and four displacement transducers, respectively.

2.2 *Materials*

The geotextiles used in the tests were nonwoven needle punched geotextiles formed by polyester monofilaments. To minimise the scatter of test results due to the variation of geotextile mass per unit area, the geotextiles specimens were weighted one by one and those with mass per unit area varying more than 5% from the average weight were discarded. The relevant characteristics of the geotextiles tested are summarised in Table 1.

The materials used to confine the geotextiles were a coarse and uniform sand (Leighton Buzzard sand 14/25 – code LBS), with particle diameters varying between 0.6 mm and 1.2 mm, a fine sand from Corumbá river, Brazil (code CRS), with particle diameters between 0.06 mm and 0.42 mm, a uniform sand (code SSB) slightly coarser than soil LBS and wooden plates (WP) with plan, even and lubricated surfaces to minimise the friction between the plates and the geotextile specimen. The reduction of the friction between plates and geotextile was achieved by using double layers of a thin plastic film and grease on the surfaces of the plates. The tests with wooden plates allowed the study of the influence of confinement only, without the effect of geotextile impregnation by soil particles. The main characteristics of the three sands used in the tests are presented in Table 2.

Damaged geotextile specimens were also tested for the evaluation of the influence of confinement on their tensile responses. Different types of damages were investigated including circular holes, horizontal and vertical cuts, inclined cuts and "Y" shaped cuts.

Table 2. Confining materials characteristics.

Property	Soil LBS	Soil CRS	Soil SSB
G (g/cm^3)	2.66	2.68	2.58
D_{10} (mm)	0.60	0.61	0.64
D_{50} (mm)	0.80	0.20	1.14
D_{85} (mm)	1.05	0.38	1.68
C_u	1.3	4.1	1.4

Notes: G = soil particle density, D_{10}, D_{50} and D_{85} = diameters for which 10%, 50% and 85% of the particles in weight are smaller than those diameter, respectively; C_u = coefficient of uniformity (= D_{60}/ D_{10}).

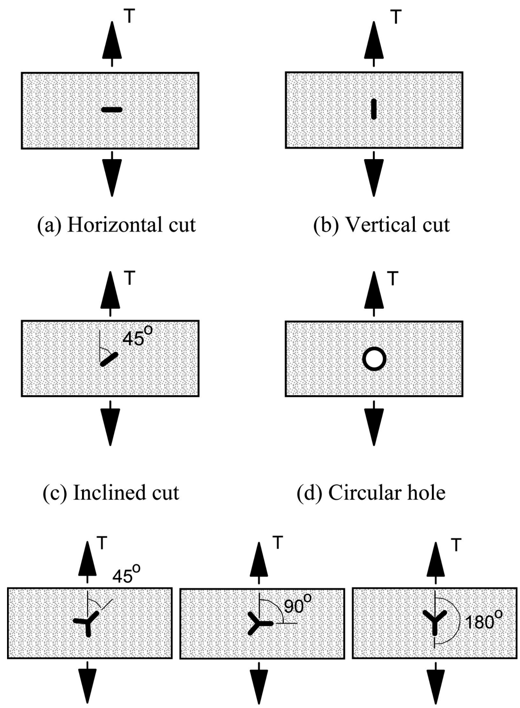


Figure 2. Types of damages investigated.

Figures 2(a) to (e) schematically presents the types of damages investigated.

Additional information on test equipment and methodology can be found in Mendes (2005) and Mendes and Palmeira (2006).

3 RESULTS OBTAINED

Tensile tests on nonwoven geotextiles were performed varying the confining material, geotextile confining

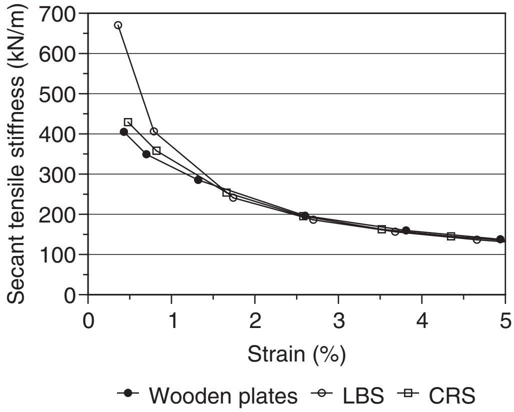


Figure 3. Secant stiffness against tensile strain for different confining materials – confining stress of 50 kPa.

stress and type of mechanical damage to study the influence of these variables on the geotextile tensile stiffness. The confining stresses used varied between 25 kPa and 150 kPa.

3.1 *Tests on virgin geotextile specimens*

Figure 3 presents the variation of secant tensile stiffness of geotextile GA versus tensile strain for test under 50 kPa normal stress and different confining materials. The results show no significant influence of the confining material for the type of apparatus used, except for the test with sand LBS and for strains below 1%. This greater influence for sand LBS can be attributed to the angular shape of the particles of this soil which are likely to interlock more efficiently with the geotextile fibres.

The influence of the confining stress on the secant stiffness of geotextile GC obtained for different strains in tests with soil LBS is shown in Figure 4. The result obtained in wide strip tests in isolation (in air) is also presented for comparison. The results show a significant increase on the secant tensile stiffness due to confinement. It can also be noticed a rather linear relationship between secant stiffness and confining pressure.

3.2 *Tests on damaged geotextiles*

Figure 5 presents the ratio between secant tensile stiffness values at 2% tensile strain for virgin (J_{2o}) and damaged (J_{2d}) geotextiles in tests in isolation. It can be observed that for the dimensions of the damages the circular hole, the horizontal cut and the "Y" shaped cut were the most detrimental for the stiffness of the geotextile. The damages caused reductions of tensile stiffness up to 20%.

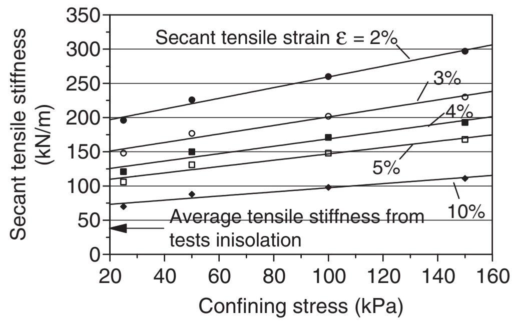


Figure 4. Influence of the confining stress on geotextile tensile properties – geotextile GC, soil LBS.

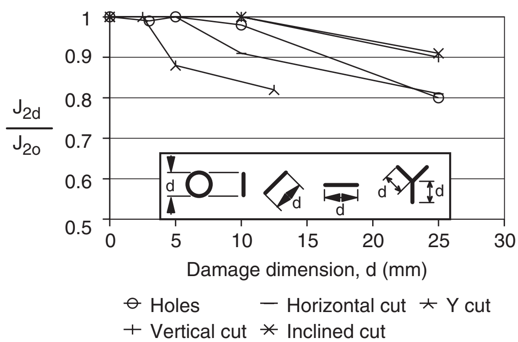


Figure 5. Tensile tests on damaged geotextile specimens of geotextile GB in isolation.

The shapes of some of the damages on geotextile GB at the beginning of the test and at a tensile strain of 30% are presented in Figures 6(a) to (c). Both the initial circular hole (Fig. 6a) and the horizontal cut (Fig. 6b) tend to degenerate to elliptical shapes during the test, but with the open area of the hole being significantly greater than that of the cut. The "Y" cut evolves similarly to a heart like shape with increasing strains (Fig. 6c).

Figures 7(a) and (b) show results of in-soil tensile tests on damaged specimens of geotextile GA confined in soil SSB under a confining stress of 100 kPa. Reductions of secant tensile stiffness were observed for cut lengths (d) equal or greater than 25mm, particularly for strains below 1% (Fig. 7a). For $d = 50$ mm the reduction of secant tensile stiffness of the damage geotextile was of the order of 20% for tensile strains between 0.5 and 2%. The results in Figure 7(a) obtained for horizontal cuts up to $d = 25$ mm were close to those obtained for the virgin specimens, which shows that confinement tends to reduce the detrimental effects of this type of mechanical damage. The "Y" shaped cut caused secant tensile stiffness reductions between 22% and 34% for tensile strains between 0.5%

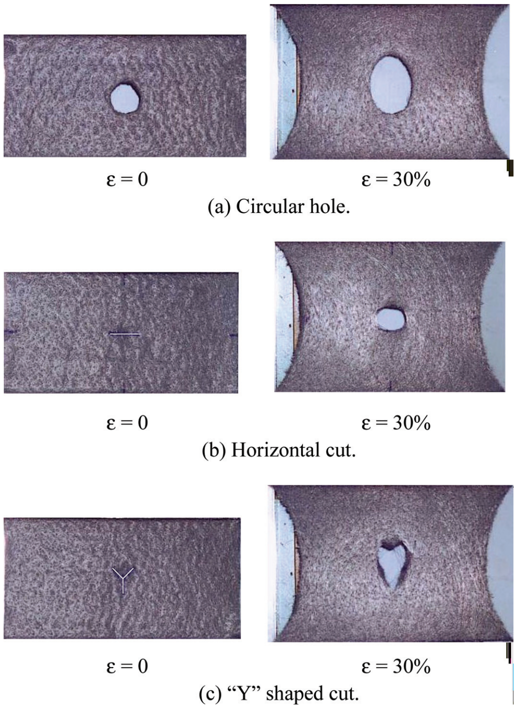
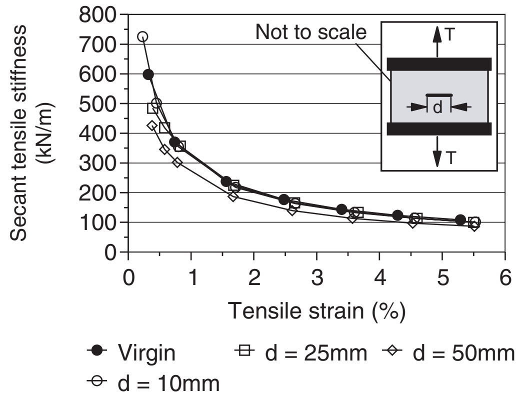
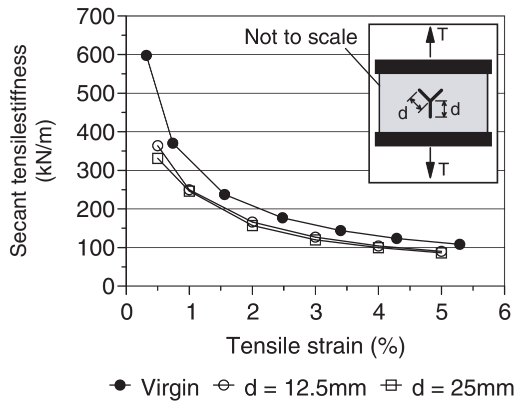


Figure 6. Shapes of damages at different strain levels – geotextile GB.



(a) Horizontal cuts



(b) “Y” shaped cuts

Figure 7. Tensile behaviour of confined damaged geotextile GA.

and 2% (Fig. 7b). This type of damage had a more important effect on the secant tensile stiffness than the horizontal cut.

4 CONCLUSIONS

This paper presented a study on the influence of confinement on the mechanical properties of virgin and damaged geotextiles. The results obtained showed significant increases of geotextile tensile stiffness due to confinement. It is important to point out that for the type of testing equipment used these increases were smaller than those obtained in tests with previous in-soil tensile test equipment, where friction develops between soil and geotextile. In the latter type of apparatus the shear stresses on the geotextile surface provide an additional constraint to geotextile fiber stretching, yielding to stiffer responses of the geotextile. For tests in the equipment described in this paper the behaviour of the geotextile was rather independent on the type of confining material used for tensile strains above 2%.

The circular hole, horizontal cut and Y shaped cut were the types of damages that caused the most detrimental effects on the geotextile mechanical properties in tests on virgin geotextiles in isolation. It was also observed that the confinement of the geotextile by the soil reduced the detrimental effects of the damages.

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