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In-soil tensile behaviour of geotextiles confined by fine soils

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ABSTRACT: This paper presents a study on the behaviour of non woven geotextiles under tension confined by fine grained soils. A preliminary numerical analysis of the test is also discussed. The results suggest that fine grained soils may provide high levels of confinement and that arching can occur causing the vertical pressure on the geotextile during the test to be substantially smaller than the value applied at the sample top.

1 INTRODUCTION

Geosynthetics have been extensively used for soil reinforcement. For steep slopes and retaining walls good quality fill materials have been recommended for a stronger and less deformable structure. Very little can be found in the literature on the use of fine grained soil as fill material despite the economical interest in using such soils. The knowledge of load-extension characteristics for non woven geotextiles confined in soil is required if deformations of reinforced structures are to be calculated. The aim of this work is to compare the behaviour of non-woven geotextiles in tension when confined by fine and coarse soils as well as to investigate the test configuration in order to evaluate some factors that may influence the results obtained. To do so, a preliminary numerical analysis of the test was performed as a part of the research programme.

2 EQUIPMENT AND MATERIALS USED

The apparatus used for the tests is similar to the one presented in McGown et al (1982)and is schematically shown in Figure 1. The soil sample is 200 x 200 x 40 mm and rests on a rigid base. The vertical pressure on top is provided by a pressurised rubber bag. Rigid clamps transfer the tensile load from the hydraulic jack to the rigid geotextile ends (impregnated by epoxy resin). Load and displacement transducers allow for the mesurement of forces and displacements.

The wide geotextile strip sample was 200 x 100 mm and the tensile load was applied normal to its largest dimension to maximize plane strain conditions. The box internal walls and the rigid geotextile ends were lubricated (plastic films and grease) to minimise friction in those regions. A strain rate of 2.7%/min was used in all tests.

Five types of soils were used. Soil A is classified as a silt by ASTM to which 5% bentonite was added to increase its plasticity. Soil B is a uniform silt. Soils C and D are fine and medium to coarse uniform sands, respectively and soil E is a fine gravel. Tables 1 and 2 present the main characteristics of these soils. Dense samples of soils B to D were obtained by pluviation. For soil A compaction was used under optimum water content to reach a maximum dry density under Proctor conditions.

Tensile tests with the geotextile confined between rubber membranes were also performed for comparison. The membranes were installed under natural condition (with 33° interface friction angle between the membrane and the geotextile) and lubricated (plastic films and grease) to allow the investigation of the effect of friction between the geotextile and the confining membranes in this type of arrangement.

Two types of non woven needle punched geotextiles made of polyester were used in the tests. These materials are commercially available under the names of Bidim OP20 (geotextile A) and Bidim OP30 (geotextile B). Table 3 summarises the main characteristics of these materials.

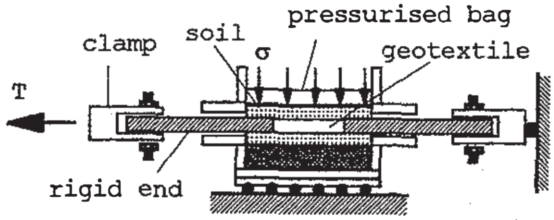

Fig.1. View of the apparatus.

Additional information on the equipment and materials is given in Gomes (1993) and in Tupa (1994).

3 RESULTS OBTAINED AND DISCUSSION

Figure 2 shows typical results of tensile load per unit width of the reinforcement versus tensile strain for the combination geotextile B - soil A, under different vertical stresses. The result of a tensile tests in isolation with geotextile B is also presented for comparison. It can be observed the marked influence of the confinement even in the case of a fine grained soil.

From curves similar to the ones presented in Figure 2 it is possible to obtain reinforcement secant stiffness at stabilised strains. Doing so, one can obtain the results shown in Figure 3, where the secant stiffness versus the correspondent strain is presented for all the tests with geotextile B under 50kPa vertical stress. The result of a test with geotextile B confined by lubricated (grease) rubber membranes is also presented for comparison. The results in Figure 3 suggest that the effect of confinement is greater for the fine grained soils in comparison with the results for the coarser materials. This may have been caused in part by the impregnation of the geotextile voids with fine soil particles during sample preparation. The comparison between results also suggests that the larger the soil particles the smaller the influence of the confinement. Despite the lubrication of the membranes, zero friction between them and the geotextile is impossible to achieve. Nevertheless, the result of this test may have provided a lower bound for the effect of confinement in tests with geotextile B.

Figure 4 shows the variation of secant stiffness with confining vertical stress for tests with soil A and geotextile B for different values of strain. This figure shows that the data can be reasonably fitted by straight lines. Similar results

Table 1. Properties of fine soils.

Property	Soil A	Soil B
w_L (%)	77	25
PI (%)	40	11
G	2.82	2.88
w_{opt} (%)	28.3	-
γ_d (kN/m^3)	14.4	17.1
ϕ' (deg.)	22	32
c' (kPa)	22	0

where: w_L = liquid limit, PI = plasticity index, G = specific gravity, w_{opt} = optimum moisture content, γ_d = max. dry density, ϕ' = effective friction angle and c' = effective cohesion.

Table 2. Properties of coarse soils

Property	Soil C	Soil D	Soil E
D_{50} (mm)	0.17	1.2	3.1
CU	2.1	1.6	1.7
G	2.62	2.63	2.70
γ_d(kN/m^3)	14.9	16.0	15.5
ϕ'(deg.)	38-46*	42-56*	37

where: D_{50} = mean particle diameter, CU = coefficient of uniformity, others as in Table 1; (*) range of values depending on stress level.

Table 3. Characteristics of the geotextiles used.

Characteristic	Geot. A	Geot. B
μ (g/m^2)	200	300
T_{max} (kN/m)	15	22
ε_{max} (%)	35	35
J (kN/m)	47	71
t_{GT} (mm)	1.9	2.7

where: μ = mass per unit area, T_{max} and J = tensile strenght and stiffness from in-isolation tests, ε_{max} = tensile strain at failure (isolation), t_{GT} = thickness.

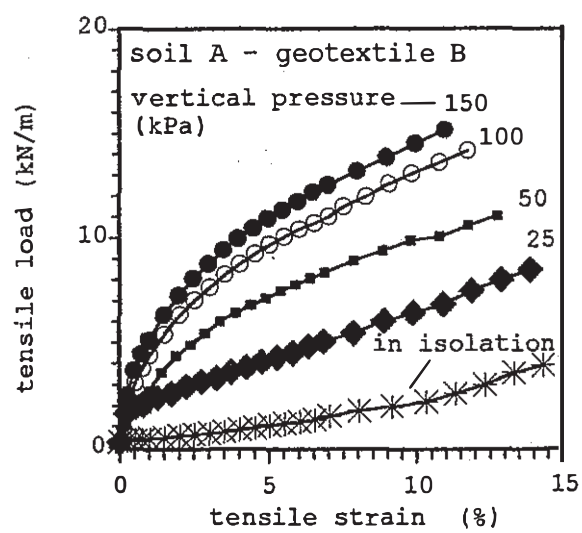

Fig. 2. Load-strain curves.

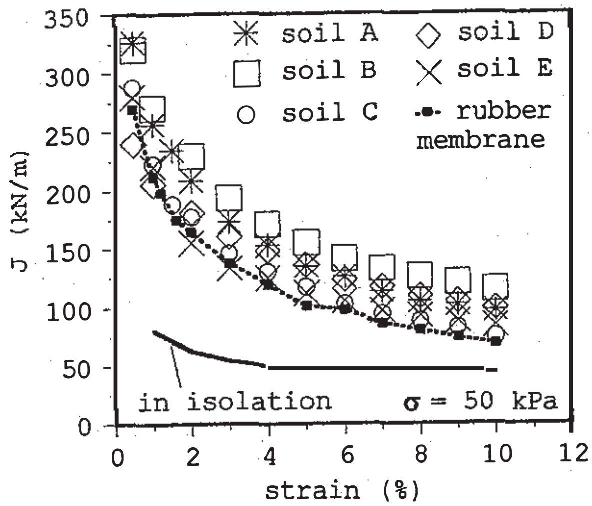

Fig. 3. Secant stiffness vs. strain.

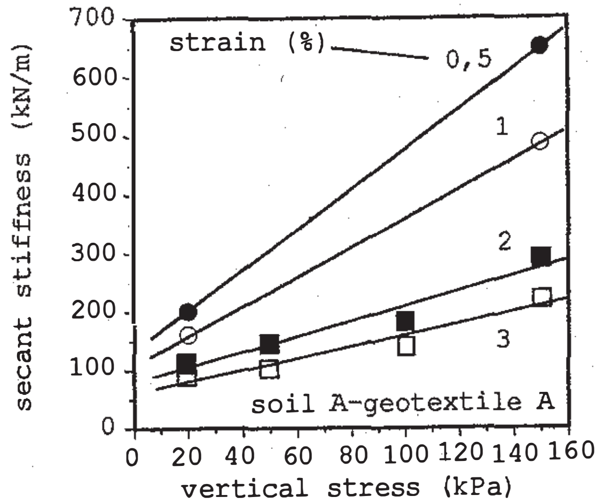

Fig. 5. Siffness vs. vertical stress.

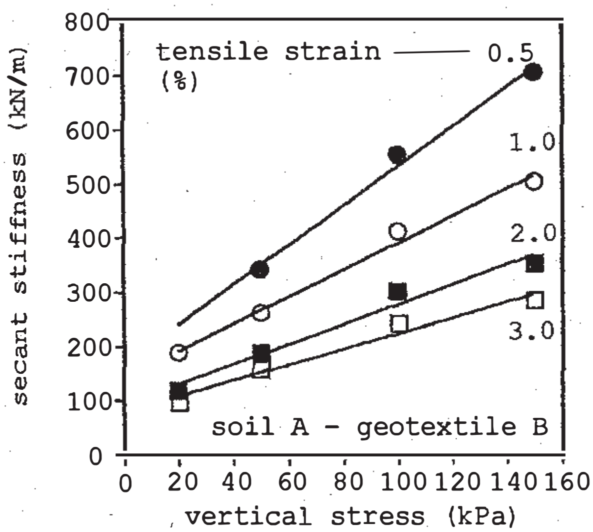

Fig. 4. Stiffness vs. vertical stress.

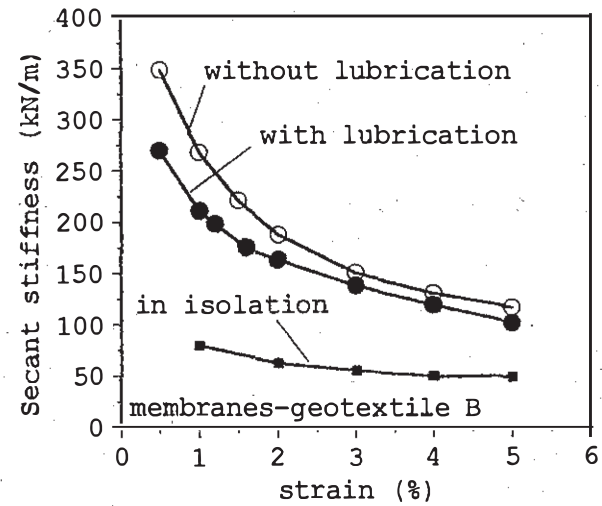

Fig. 6. Results of tests using membranes for confinement.

were obtained for tests with geotextile A (Figure 5).

Figure 6 presents the variation of secant stiffness with strain for the tests with the confinement provided by membranes. It can be observed that the influence of friction between the geotextile and the membranes is significant for small strains (below 2%), which are the relevant ones in geotextile reinforced structures.

4 PRELIMINARY NUMERICAL ANALYSIS

The influence of scale and boundaries on the results of tests for the measurement of interaction between soil and reinforcement has been discussed in the literature (Palmeira 1987 and Palmeira and Milligan 1989). To assess the influence of the in-soil tensile test arrangement on its results a preliminary linear elastic plane strain finite element analysis was conducted. Figure 7 shows the finite element mesh used. Very extensible elements were used at interfaces where friction might be a problem. Stiffness of the materials (soil and reinforcement) were varied to study their influence on the results.

Figure 8 shows typical stress distributions on the surface of the geotextile (central region) as predicted by the finite element analysis for a total geotextile strain of 1%. Despite the simplicity of the procedure adopted at this stage it can be observed that the compressibility of the geotextile caused a re-distribution of stresses on the

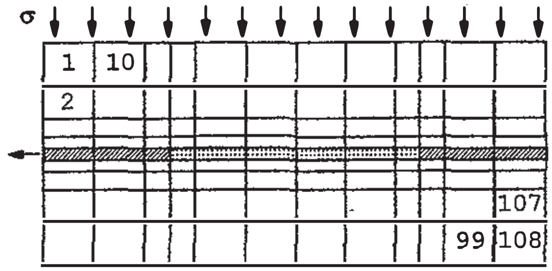

Fig. 7. Finite element mesh.

geotextile surface increasing the vertical stresses on the rigid extremities and reducing it along the central compressible region ("arching"). The result of the arching of the soil may lead to vertical stresses on the geotextile considerably smaller than the value applied at the top of the sample.

The numerical analysis also addresses the influence of the arrangement of the test on the results and pattern of deformation mechanisms in the soil-geotextile system. The analysis suggests that different results may be obtained depending on how the tensile load is applied to the geotextile and on boundary conditions.

5 CONCLUSIONS

The main conclusions of the present study are summarised below:

. Construction problems and pore pressure generation can occur when fine grained soils are used in real works. Nevertheless, regarding the effect of confinement and bearing in mind the limited amount of data still available, the silty soils tested in this work presented greater confined stiffnesses than the coarser materials, probably due to a better impregnation of the geotextile by the fine particles during sample preparation. The results of tests with confinement provided by membranes can be affected by the friction between the geotextile and the membranes.

. The results from the preliminary numerical analysis suggest that soil arching can occur during the test, reducing the vertical stress on the geotextile sample. The arrangement of the test and its boundary conditions can also affect the results.

. The standardization of the in-soil tensile test is needed since different test arrangements will certainly lead to different results. Additional research is required for a better understanding on the in-soil tensile test, particularly when fine grained soils are used.

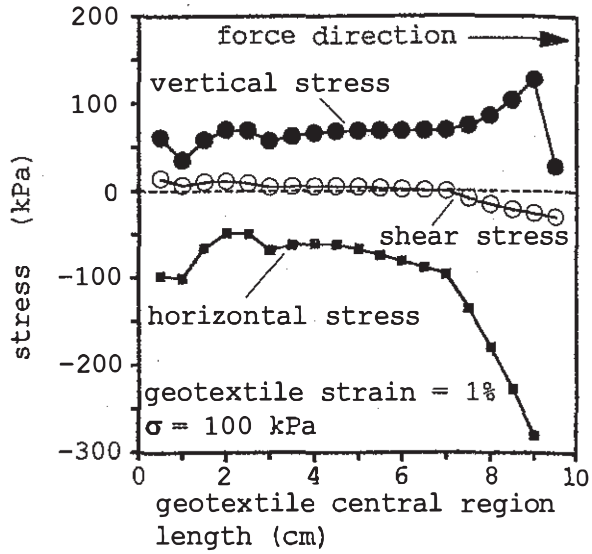

Fig. 8. Stress distributions on the geotextile.

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