Shear strength in the interface between compacted fine grained soil and nonwoven geotextile

L.A.Seraphim & M.J.A.Zagatto Penha
State University of Campinas, Unicamp, Campinas, SP, Brazil

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ABSTRACT: The paper discusses the variation of the shear strength in the interface between compacted fine grained soil and nonwoven geotextile, with the tests performed in a direct shear apparatus. The soil remoulded and compacted at optimum moisture water content and at Standard Proctor energy has its strength evaluated with and without saturation, with and without geotextile between the two halves of soil inside the box of shear apparatus. The variation of the shear strength will also be shown in saturated conditions of the soil with nonwoven geotextile put between the two halves of the soil, when exposed to the weather during a time length of 3, 7 and 14 months and the resultant variation in adhesion between the soil and the geotextile.

1 INTRODUCTION

The use of geotextile in civil engineering works, particularly in slope reinforcement, has been more frequent. The inclusion of geotextile between layers of compacted soil has been analyzed by many researchers but a few of them have worried about fine grained soils, where the influence of the adhesion between soil and geotextile can exert a great importance on the choice of other design parameters, mainly in slope reinforcement.

The obtained results shown in this paper and the relevant variations observed in the cohesion of the soil and particularly in the adhesion between soil and geotextile with saturation and weather exposure lead to some considerations about the pertinence of the use of the adhesion between fine grained soil and geotextile in the analysis of stability of soil strengthened with nonwoven geotextile.

2 SHEAR STRENGTH CHARACTERISTICS

According to Tupa and Palmeira (1995), the interaction between soil and geotextile depends on the characteristics of the soil and of the reinforcement material. The influence of this interaction implies in the definition of friction and adhesion parameters developed in the interface between soil and geotextile. The shear strength in the interface is performed as:

$$\tau = a + \sigma \,.\, \mathrm{tg}\, \delta \qquad (1)$$

where τ = shear strength in the interface between soil and geotextile; a = adhesion developed between soil and geotextile; σ = normal pressure applied in the interface; and δ = frictional angle developed in the interface soil-geotextile.

In sequence, it is possible to define the adhesion parameters as a function of the strength parameters of the soil, c and $\varnothing$, and of the interface soil-geotextile, a and δ, as:

$$\lambda = a/c \qquad (2)$$

$$f = \mathrm{tg}\, \delta / \mathrm{tg}\, \varnothing \qquad (3)$$

and the Equation 1 becomes:

$$\tau = \lambda \,.\, c \; + \; f \,.\, \sigma \,.\, tg\, \varnothing \tag{4}$$

The cohesion parameters, λ and f, can be expressed in terms of drained or undrained conditions, depending on the kind of load and of the characteristics of involved materials.

3 THE TESTS

The direct shear test apparatus used in the tests has a 10 x 10 cm square box, each half of it 1.5 cm high. The soil, remoulded and compacted at optimum moisture water content and at Proctor energy, has the characteristics listed in Table 1.

Table 1. Main characteristics of the soil

Sand (%)	20
Silt (%)	48
Clay (%)	32
Liquid Limit (%)	47
Plastic Limit (%)	32
Plastic Index (%)	15
Specific Gravity of Soil Solids	2.82
Maximum Dry Unit Weight (kN/m^3)	16.1
Optimum Moisture Water Content (%)	23.5
Frictional Angle (^{o})	27.3
Cohesion (kPa)	80.0

Bdim® OP-30 was the nonwoven geotextile used, composed of continuous filaments, needled punching bonding, with technical characteristics listed in Table 2.

Table 2. Technical characteristics of the geotextile OP-30

μ (g/m^2)	T_{max} (kN/m)	ε_{max} (%)	J (kN/m)	T_{GT} (mm)
300	22	35	71	2.7

where μ = mass per unit area; T_{max} = maximum tensile strength; ε_{max} = maximum elongation; J = tensile stiffness; and t_{GT} = thickness of the geotextile. The two halves of the shear box were apart by the geotextile thickness, which remained anchored in the shear apparatus.

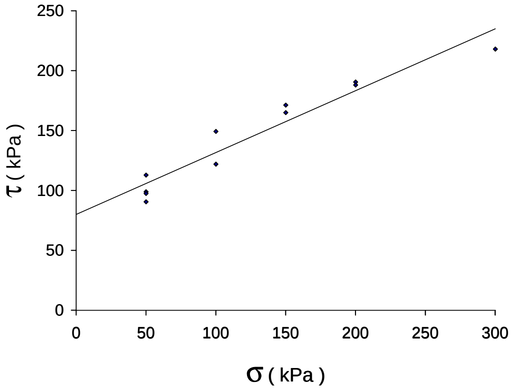
The soil had its strength evaluated in the compaction moisture water content without saturation as much as in saturated conditions, with interface soil-geotextile strength evaluated in saturated conditions.

The interface soil-geotextile strength was also evaluated over soil samples and geotextile exposed to the weather during time length of 3, 7 and 14 months. These samples were only tested in saturated conditions since the shear strength is dependent on the moisture water content in partially saturated soil.

The applied vertical stress ranged from 50 to 250 kPa and the shearing speed was the same in all tests and equal to 0.133 mm/min.

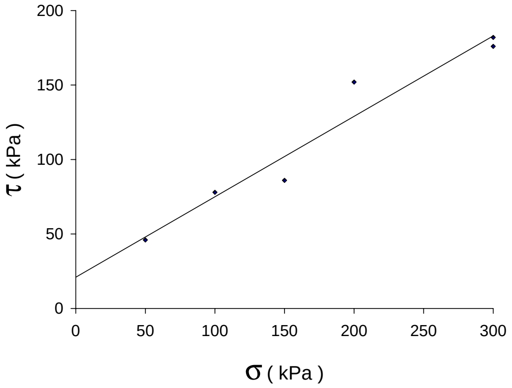
4 RESULTS

Figures 1 to 7 show the envelope shear strength for the tests performed on samples with and without geotextile between the soil, in saturated and non-saturated conditions and with soil and geotextile exposed to the weather, with the tests performed in saturated conditions. In the figures, $\varnothing$ is the frictional angle of compacted soil at failure, δ is the frictional angle between soil and geotextile, c is the cohesion, a is the adhesion between soil and geotextile, σ is the normal stress at the shear failure plane, τ is the shear stress at the shear failure plane, λ and f are the adhesion parameters and R^2 is the coefficient of correlation of the envelope through the pairs (σ,τ).



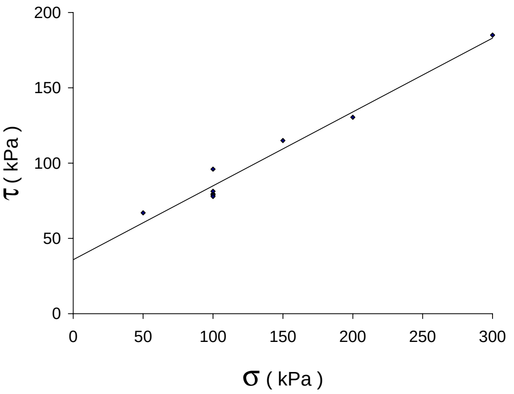
$\phi = 27.3^o$; $c = 80$ kPa; $R^2 = 0.9267$

Figure 1. Soil strength envelope without saturation



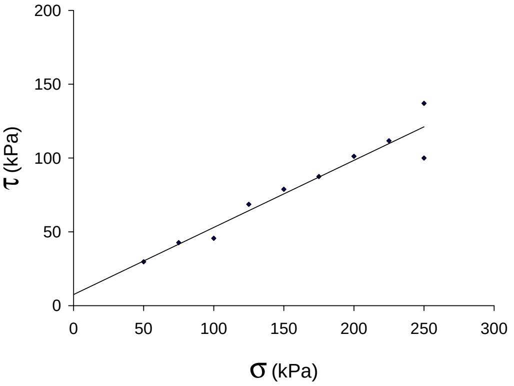
$\delta = 28.4^o$; $a = 21$ kPa; $\lambda = 0.26$; $f = 1.05$; $R^2 = 0.9483$

Figure 2. Interface soil-geotextile strength envelope without saturation



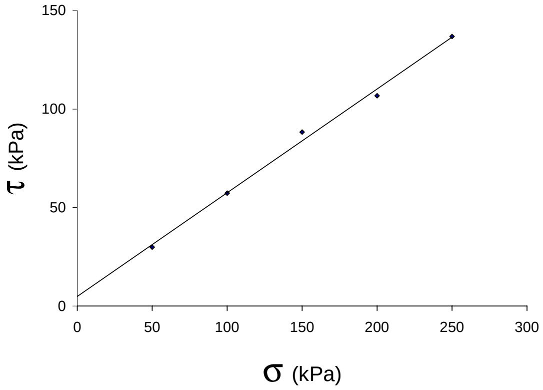
$\phi = 26.1^o$; $c = 35.8$ kPa; $R^2 = 0.9694$

Figure 3. Soil strength envelope in saturated conditions



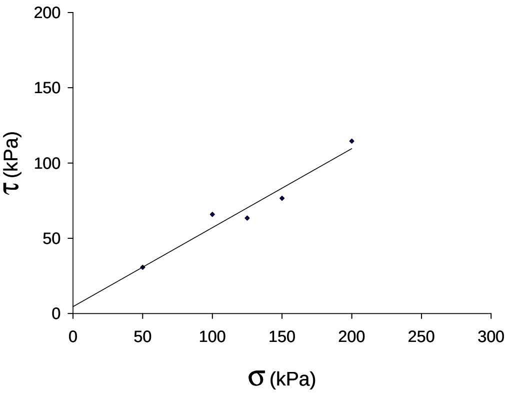
$\delta = 24.4^o$; $a = 7.6$ kPa; $\lambda = 0.21$; $f = 0.93$; $R^2 = 0.9233$

Figure 4. Interface soil-geotextile strength envelope in saturated conditions



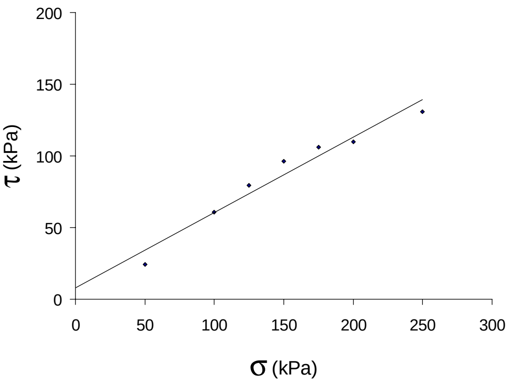
$\delta = 27.6^o$; $a = 5.2$ kPa; $\lambda = 0.15$; $f = 1.07$; $R^2 = 0.9952$

Figure 5. Interface soil-geotextile strength envelope in saturated conditions and weather exposition of 3 months



$\delta = 27.7^{o}$; a = 4.6 kPa; $\lambda = 0.13$; f = 1.07; $R^2 = 0.9471$

Figure 6. Interface soil-geotextile strength envelope in saturated conditions and weather exposition of 7 months



$\delta = 27.7^{o}$; a = 8 kPa; $\lambda = 0.22$; f = 1.07; $R^2 = 0.9537$

Figure 7. Interface soil-geotextile strength envelope in saturated conditions and weather exposition of 14 months

5 COMMENTS

Tests performed with geotextile between the two halves of soil in the direct shear apparatus, in saturated and non-saturated conditions, showed the cohesion parameter *f* higher than 1, meaning that the geotextile drains the soil adjacent to it, increasing the interface soil-geotextile strength, while the parameter λ remained very low.

The insertion of geotextile between the two halves of soil showed no significant increase in frictional angle (from 27.3^{o} to 28.4^{o}), but a significant decrease in adhesion (from 80 to 21 kPa), when the tests were run in non-saturated conditions. In saturated conditions the tests showed a decrease in frictional angle (from 26.1^{o} to 24.4^{o}) and a great significant reduction in adhesion (from 35.8 to 7.6 kPa).

The direct shear tests performed with samples, which remained exposed to the weather and with geotextile inserted between the two halves of soil showed that:

for the set soil-geotextile that remained exposed to the weather during a time length of 3 months, the frictional angle increased from 24.4^o to 27.6^o and the adhesion decreased from 7.6 to 5.2 kPa,

for the set soil-geotextile that remained exposed to the weather during a time length of 7 months, the frictional angle increased from 24.4^o to 27.7^o and the adhesion decreased from 7.6 to 4.6 kPa, and,

for the set soil-geotextile that remained exposed to the weather during a time length of 14 months, the frictional angle increased the same as from an exposure time of 7 months e no change had been observed in adhesion.

A lixiviation process in the soil exposed to the weather was observed. Table 3 shows the variation of grain size distribution at the top of soil sample that remained in the weather exposure and the natural soil, not exposed to the weather. This occurrence has been observed in a very range of lateritic soils in Brazil (Seraphim, 1996).

Table 3 – Variation in the percent of grain size

	Natural Soil	Weather exposed soil
Clay (%)	45	32
Silt (%)	35	48
Sand (%)	20	20

6 CONCLUSIONS

The adopted repetitive methodology clearly show that the saturation affects the shear resistance of the compacted soil without the insertion of geotextile, mainly the cohesion, and does not affect the frictional angle so much.

With the insertion of geotextile between the two halves of soil in the shear box of the direct shear apparatus there was no great variation in frictional angle but a great decrease in adhesion between the soil and geotextile, approaching to zero.

Tests performed on samples that remained in the weather exposure also showed the drop in adhesion, which approached to zero, but an increase in frictional angle. It is probably due to the lixiviation observed in the samples that remained in the weather exposure, in which there was an increase in the coarse fraction of soil solids (see Table 3).

Finally, in the design of earth slope straightened with geotextile, it is recommended to observe the outline conditions, that is, whether the soil can be flooded or not, making the choice of the resistance parameters more suitable to the local conditions, mainly the cohesion and adhesion between soil and geotextile, the resistance parameters in which the observed variations were appreciable.

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