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Studies on geotextile/ soil interface shear behavior

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ABSTRACT: Shear frictional behavior of soil/geosynthetic interfaces plays a pivotal role in the overall performance of geotextile-reinforced roads. Since a substantial proportion of the total land areas in many Southern parts of Middle east countries is composed of organic soils, it was seen of particular importance to investigate the shear frictional behavior of such soils when subjected to loading with geotextiles used as reinforcement. Two types of soils were used; namely organic silty clay and a fill material, which is a sandy type of soil. From the results of the shear box tests performed it appears that there is a relationship between the tensile strength of the geotextile used and the shear strength of its interface with the organic clay, with the shear strength of the interface increases with the increasing tensile strength of the geotextile. The shear strength of geotextile/fill interfaces did not show a consistent relationship with the geotextile tensile strength.

1 INTRODUCTION

Organic soils are considered some of the most problematic types of soils for their compressibility and high moisture contents. However because they constitute a considerable proportion of the total land areas in many parts of the world in general and in Northern part of Iran in particular it is necessary to consider these soils as potential subgrades for the construction of reinforced unpaved roads, Hobbs, (1986).

One of the major factors that controls the performance of reinforced soil structures is the interaction between the soil and the reinforcement.

It is necessary to obtain accurate bond parameters for the design of these structures. It was desired to study the behavior of geotextiles as soil reinforcement materials for their availability in the local market and their wide-spread use all over the world for soil reinforcement applications.

Accordingly a test program was carried out to investigate the shear frictional behavior of geotextile/soil interfaces. A series of shear box tests were carried out in the laboratory for this purpose. The experimental results will provide a better understanding of the shear behavior of reinforced unpaved roads.

Two types of soils were used in these tests; namely sandy soil and organic clay along with non-woven needle punched geotextile with four different tensile strengths. It was desired to study the effect of the variation of the geotextile tensile strength on the behavior of this system. Such knowledge would provide a better understanding of the shear frictional mechanism of geotextile/ soil interfaces and the design of reinforced unpaved roads.

2 DESCRIPTION OF MATERIAL

A brief description is given of the materials used in this experimental study. The fill and the organic clay used were a scaled down version of the original site materials. However the type of scaling down of these two materials differs in that the fill was scaled in terms of its particle size distribution whereas the clay was scaled down in terms of its undrained shear strength.

The fill material was scaled down using a scale of 1:4 in order to account for the modeling requirements. The Particle Size Distribution curve revealed that more than 50% of the organic clay is in the clay fraction with the rest of the soil being in the silt fraction.

Liquid and plastic limits of this organic clay were found to be 83.5% and 48.1% respectively. This gives the Plasticity index of the soil as being equal to 35.4%. It has been found also that the soil had an organic matter content of 11.1% with an average specific gravity of 2.54.

Since our interest lie in subgrade shear strengths in the range of 20-60 kN/m^2 in the field, a range of subgrade undrained strengths of 5-15 kN/m^2 was used in this study.

To satisfy this modeling requirement adding measured amounts of water and by mixing it to reduce its density until the undrained strength of the soil being used was ¼ that of the same soil in the field reduced strength of the soil.

The geotextiles used are non-woven needle-punched geotextiles. These types of geotextiles were found to be most effective when filling over very soft cohesive soils. It was proven to be able in reducing settlements and providing a platform for sewing and rolling for site applications.

A description of their properties and specifications are shown in Table 1.

A square shear box 100mm by 100mm, split horizontally at mid-height was used for direct shear testing.

For testing soil only, whether organic clay or fill, two porous plates were used one at the bottom of the sample and the other on the top. All tests were strain controlled under the same constant rate of shear loading.

The range of normal stresses applied was (29-98.7) kN/m^2, which was similar for all tests conducted in this study with and without a geotextile to simulate the site stresses. It was found earlier that using lower normal stresses would render the test results for these types of soils inconclusive. High normal stresses were used by other investigators when performing direct shear tests, Fishman and Pal, (1994).

The geotextiles were cut to square pieces of 100 by 100mm and then each piece was glued using epoxy glue to the top of a piece of hard wood having the same dimensions (100 by 100mm). This procedure was used previously by other investigators when conducting their soil/geosynthetic Friction tests, Fishman and Pal (1994).

After each shear box test the geotextile piece was removed and replaced with another one with the same dimensions to account for the damages in the geotextile texture that might have occurred as a result of the previous test.

Table 2 shows the index properties of the tested organic clay and fill specimens. The organic clay specimens were chosen from all parts of the sub-grade material.

The organic clay specimen was placed inside the upper half of the shear box with the geotextile-wooden block assembly occupying the lower half. Care was taken in excavating the organic clay and any organic components that were to coincide with this soil specimen where cut using a sharp knife to the dimensions of the sampler.

After placing the organic clay specimen inside the upper half of the shear box, a cheese wire was used to cut it to proper dimensions to fit inside the shear box. Then normal load was applied and the test was carried out.

Fill material was used as the second type of soil in contact with the geotextile. For testing fill/geotextile assembly, the geotextile-wooden block assembly was fitted inside the lower half of the shear box occupying it first, then the upper half would be screwed on top of the lower and the fill material compacted above the geotextile-wooden block assembly.

The rate of shearing applied was 1.27 mm/min., which was chosen to ensure undrained conditions when testing the organic clay. It was proven through previous studies that this rate of loading was fast enough to cause undrained conditions in the clay, Fishman and Pal, (1994). The same rate of loading was applied to all tests using the two types of soils.

Table 1. The geotextile specifications.

Characteristic	Test Standard	Unit	A	B	C	D
Nominal Mass/m^2	ASTM D 3776	g/m^2	180	200	280	350
Tensile strength	B.S 6906/1*	kN/m	12.5	13.9	19.3	24
Elongation at break	B.S 6906/1*	%	45	45	45	45
Thickness under Pressure						
2 kN/m^2	ASTM D 1777	mm	1.80	2.00	2.50	3.00
200 kN/m^2		mm	0.80	0.90	1.20	1.40

- British Standards

3 RESULTS OF TESTS

Figure 1 shows failure envelopes for soil/geotextile interfaces and soil-alone interfaces. Shear stress is plotted against the normal stress both expressed in kN/m^2.

Figure 2 details the shear strength parameters of the interfaces versus the tensile strength. of the geotextiles used. The parameters are expressed in kN/m^2 and the tensile strength is in kN/m.

Table 2. Index properties of the sshear box tests performed.

Type of Test	Density (g/cm^3)	Moisture Content %	Organic Content %
Peaty clay-Only	1.36	115.4	14.7
Peaty clay-A	1.54	110.6	13.9
Peaty clay-B	1.58	97.9	14.7
Peaty clay-C	1.59	111.9	15.4
Peaty clay-D	1.54	112.5	14.7
Fill-Only	1.61	0.7	
Fill-A	1.61	0.7	
Fill-B	1.61	0.8	
Fill-C	1.61	1.6	
Fill-D	1.61	0.8	

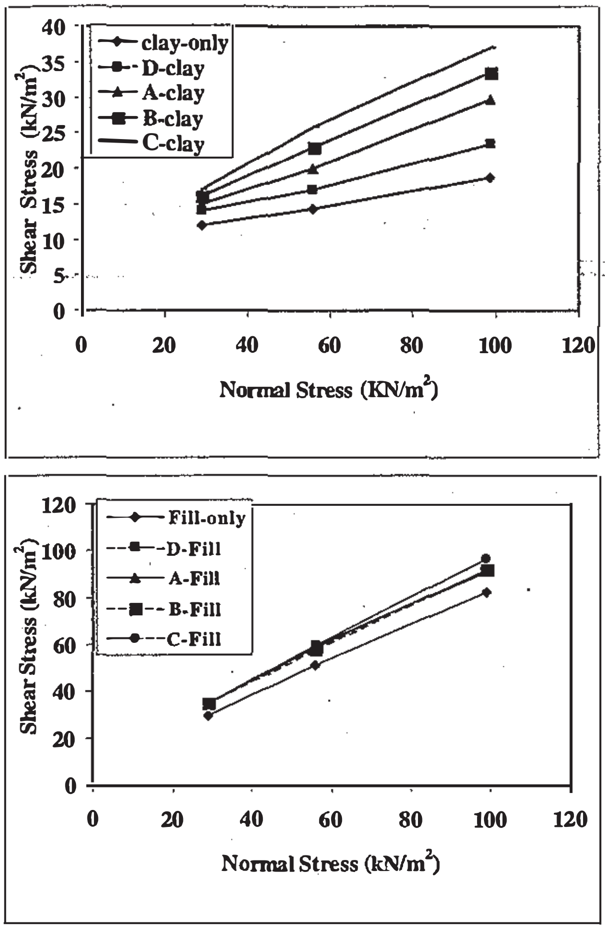

Figure 1. Failure envelopes of the soil/geotextile interface

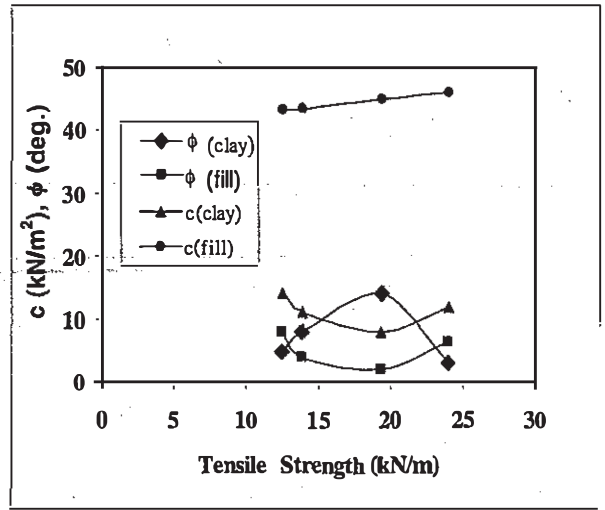

Figure 2. Shear strength versus tensile strength for the soil/geotextile interface.

4 DISCUSSION AND CONCLUSION

As a result of shear box tests, the following is an attempt to discuss and interpret the results of these tests. Examining the organic clay failure envelopes in Figure 1 reveals a behavior that differs according to the tensile strength of the geotextile used in contact with the soil.

By examining the organic clay-geotextile curves a trend appears to dominate these curves associated with the increase of the geotextile strength. It can be seen clearly from Figure 2 that increasing the tensile strength of the geoetextile in contact with soil increases, in return, the shear strength tolerated by the soil-geotextile interface.

This can be seen clearly by observing the increase in the shear strength angle, (ø), and the cohesion or adhesion, c, for the range of tensile strengths used, Figure 2.

There is a significant increase of shear strength associated with the increase of geotextile strength. It can be seen that the highest shear strength in terms of both ø and c was gained by the C-organic clay interface.

Using a geotextile with a lower strength resulted in lower shear strength for the B-soil interface followed by lower shear strength for the lightest geotextile used (A).

Organic clay-only test gained a shear strength lower than all of its interfaces with the geotextiles. The only abnormal behavior was exercised by D, which, although having the highest strength, achieved an interface shear strength lower than all other geotextiles.

This is thought to be due to its complete interlocking with the organic soil. A result of which failure might have occurred inside the organic clay near the joint soil-geotextile interface.

Another reason might be the high pore water pressures on the soil-geotextile interface reducing the active stresses in that region causing a reduction in the shear strength of the interface.

This observation is consistent with that of Koerner et al., (1986) who conducted tests on a variety of cohesive soils in contact with various geomembranes.

He noticed lower friction coefficients for the harder PVC and HDPE geomembranes.

Examining fill-geotextile interfaces reveals a behavior that differs completely from that of the organic clay-geotextile interfaces discussed above.

Fill-geotextile interfaces seem to be relatively close in terms of both Angle of Shear Friction (ø) and Cohesion (c). Although on average they exhibited angles of shear strength much higher than those of the clay-reinforcement interfaces, it seems that the effect of the variation of the geotextile strength has no significant effect on the magnitude of their angle of shear friction.

The only-fill envelope had shear strength consistently lower than all its interfaces with the other geotextiles.

As for the rest of the shear envelopes that represents the behavior of the interfaces of the four geotextiles in contact with the sandy fill material, all envelopes seem to share approximately the same angle of friction and the same cohesion.

By examining Figure 1 that shows failure envelopes of the soil-geotextile interfaces and soil-only tests, it can be observed, in general, that fill geotextile interfaces gained higher angles of shear strength with lower cohesion.

This in comparison with the organic clay-geotextile interfaces that on the contrary had higher cohesion values with significantly lower angles of shear friction.

This increase in cohesion of the organic clay-geotextile interfaces associated with the increase of the geotextile strength can be attributed to the fact that as the thickness of the geotextile increases, its capacity for performing drained cohesion increases.

In other words when the geotextile thickness increases, a corresponding increase in its capacity as a drainage media occurs. This in turn gives space for more water to be drained from the interface with the soil. The result of which is higher interlocking with the organic soil.

It should be pointed out that high cohesion values were obtained for the organic soil in contact with the geotextiles and that these values are plotted in Figure 2 that shows their magnitude versus the tensile strength of the geotextiles used.

It can be observed that cohesion plays a very important part of the bond resistance in organic clays. It contributes to the overall shear resistance of the organic soil more than its angle of shear friction.

Therefore cohesion in organic soils is an important part of the bond resistance that should be taken into account when designing reinforced unpaved roads.

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