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 area in many Southeast Asian 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; organic silty clay and a fill material, which is a sandy type of soil. Shear box tests were performed to determine the shear strength parameters of the soils and to investigate the shear frictional behavior of the soil/geotextile interfaces. It appears from the results of the shear box tests performed that there exists 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 increasing 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 area in many parts of the world in general and in Malaysia and South East Asia 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 control 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 asSoil 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 was carried out in the laboratory for this purpose. The experimental results will provide a better understanding of the shear behavior of reinforced unpaved roads and will add to the existing database of the shear frictional behavior of soil/geotextile interfaces.

Two types of soils were used in these tests; 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. MATERIALS

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, Mahmood, (1998).

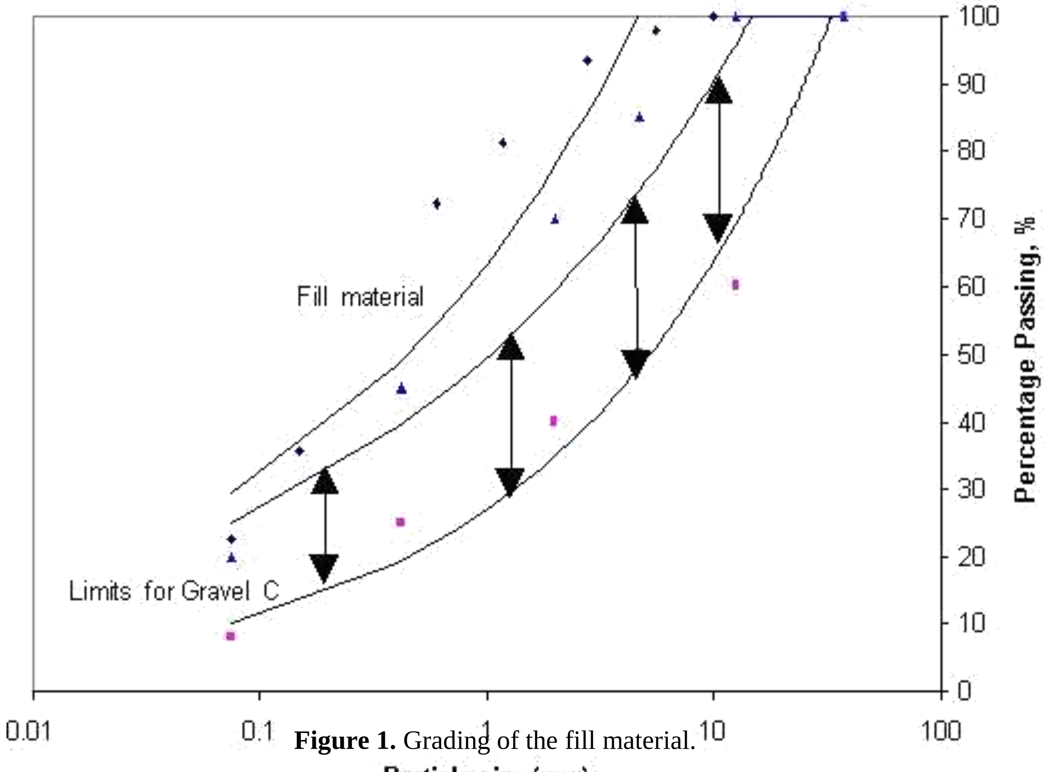

Figure 1. Grading of the fill material.

The gradation chosen for the fill was a scaled down version of material type C specified by the Malaysian Federal Works Department, (1988). The fill material was scaled down using a scale of 1:4 in order to account for the modeling requirements. Figure 1 details the gradation limits for material C and the gradation for the scaled fill material.

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 as can be seen from Figure 2 that details the particle size distributions for the organic clay. 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 interest lay in subgrade shear strengths in the range of 20-60 kN/m2 in the field, a range of subgrade undrained strengths of 5-15 kN/m2 was used in this study. To satisfy this modeling requirement strength of the soil was reduced by 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.

For a full description of the scaling procedures and more on the index properties of the two soils refer to Mahmood, (1998).

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, Toh et al., (1994). A description of their properties and specifications can be found in Table 1.

3. TEST APPARATUS

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. Figure 3 is a schematic showing the configuration of the test apparatus for geotextile-soil shear tests.

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), Somasundaram and Khilnani, (1991).

4. DESCRIPTION OF MATERIALS

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.* British Standardsfriction tests Bouazza and Khodja, (1994) and 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 details the index properties of the tested organic clay and fill specimens. The organic clay specimens were chosen from all parts of the subgrade material used to be representative of the whole amount of organic clay tested. 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 exercised 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 proceeded with.

5. TESTING PROCEDURE

Testing has been conducted in a standard, motorized shear box apparatus with the testing box having the dimensions of 100 by 100mm.

(i) The Soil-Alone Tests

When testing the organic clay alone, the soil was excavated using the soil sampler. After excavating the cohesive specimen, the sampler was put on top of the shear box in a manner that the sides of the sampler would be directly above the sides of the shear box. Then the metal cap of the shear box was put on top of the sampler and the clay specimen squeezed inside the shear box taking care not to disturb its laboratory-undisturbed state. Greasing the inside of the sampler before using it helped in achieving a smooth descent of the organic clay specimen inside the shear box.

After the specimen was put inside the shear box, cheese wire was used to cut the extra part of the clay specimen in order to make its surface flush with the top surface of the shear box. Then the second porous plate was put on top and squeezed gently inside the shear box so that its top surface comes in level with the top surface of the shear box. Finally the top cap would be fitted above the shear box and the test carried out.

The same arrangement was made when testing the fill material alone, in which case the first porous stone was laid, then fill material was compacted on top of it in three equal layers, using a small wooden compactor. After compaction was finished the other porous stone would be put on top of the fill material so that its top surface be at the same level as the shear box's top surface. Finally, the whole loading assembly would be fitted in place.

Tests utilizing fill material were all performed using the same relative density of compaction inside the shear box. This was done to enable comparisons to be made after completion of tests.

(ii) The Soil-Geotextile Tests

When testing the soil/geotextile interfaces, a procedure used by previous investigators, Bouazza and Khodja, (1994) was used here, in which a wooden block was cut to the same dimensions of the shear box; 100 by 100mm. Then a piece of geotextile cut to the same dimensions was glued on top of the block using epoxy glue. Epoxy glue was thought to be strong enough to resist any sliding of the geotextile during the test that would affect test results. The block was adjusted so that the surface of the geotextile was flush with the top edge of the bottom half of the shear box, in order to ensure shearing would occur only at the interface. Care was taken to replace the geotextile piece with another one after each test was finalized to account for the damage that might have occurred as a result of shearing of the geotextile/ soil interface. In this case the soil would be placed in the upper half of the shear box. Specimens of organic clay were taken in the same procedure described above to fit inside the upper half of the shear box and when fill material was tested it was compacted in two layers, also in the upper half of the box. All tests; with and without reinforcement were carried out using the same rate of loading, to ensure undrained conditions, this had to be taken into account since model tests are going to be performed in an undrained manner, Mahmood, (1998). Dial gauges measured the horizontal stresses and strains acting on each specimen. Vertical strain was measured by another dial gauge.

6. RESULTS OF TESTS

Figure 4 shows failure envelopes for soil/geotextile interfaces and soil-alone interfaces. Shear stress is plotted against the normal stress both expressed in kN/m2.

Figure 5 details the shear strength parameters of the interfaces versus the tensile strength of the geotextiles used. The parameters are expressed in kN/m2 and the tensile strengths are in kN/m. In the context of the results obtained from the shear box tests, the following is an attempt to discuss and interpret the results of these tests

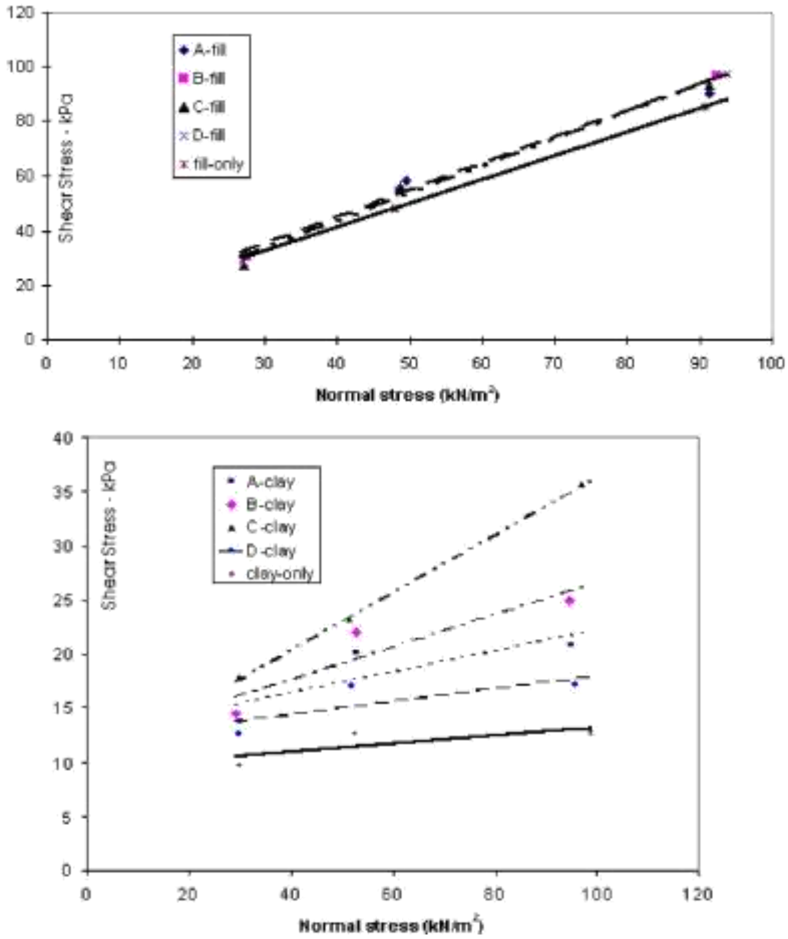

Figure 4. Failure envelopes of the soil/geotextile interfaces.

Examining the organic clay failure envelopes in Figure 4 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 5 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 witnessed clearly by observing the

Increase in the shear strength angle, □. and the cohesion or adhesion, *c*, for the range of tensile strengths used, Figure 5. 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.

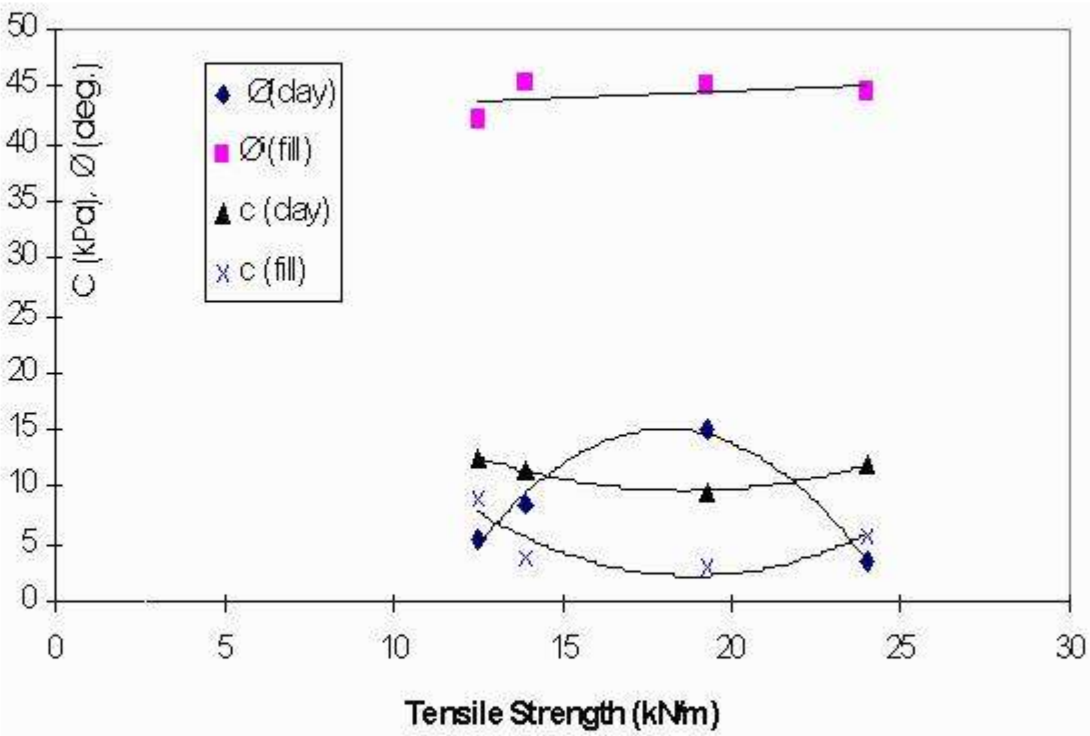

Figure 5. Shear strength versus tensile strength for the soil/geotextile interfaces.

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.

These findings are also consistent with the finite element works of Burd and Brocklehurst whoperformed analytical studies on geotextile/soil interfaces and who concluded that the shear strength of soil-geotextile interfaces increases with the increase of the fabrics tensile strength, Burd and Brocklehurst (1990) and (1992). However more work needs to be done in this direction to further validate their conclusion.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 theeffect 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 represent 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 4 that details 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 cohesions. 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 5 that details 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.

7. CONCLUSIONS

It can be concluded from the above that cohesion plays an important part of the bond resistance of organic clayey soils and that its contribution should be taken into account when designing an unpaved road.

It also 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 increasing with the increasing strength of the geotextile. This is thought to be due to the increasing role of the geotextile as a drainage media associated with the increase of its thickness.

There doesn't seem to be a consistent relationship between fill-geotextile interface shear strengths and geotextile strength.

From the failure envelopes constructed for the two soils in connection with the four types of geotextiles used, it was seen that fill-geotextile interfaces exhibited higher angles of shear friction associated with low cohesions, on the contrary organic clay-geotextile interfaces showed higher cohesions and significantly lower angles of shear friction.

The shear strengths of the organic clay-geotextile interfaces were increasing with the increase of the geotextile tensile strength. Similar findings were obtained by Burd and Brocklehurst who performed finite element analysis on the frictional shear behavior of soil/geotextile interfaces. They found that shear strength of these interfaces increases with the increase of the geotextile tensile strength.

It was proven through the construction of graphs that cohesion of the organic clay is an important part of the bond resistance, contributing to the overall bond resistance more than the angle of shear friction.

The stiffest geotextile used (D) had the lowest interface shear strength. This might have been due to increased pore water pressure on the soil-geotextile interface causing an accompanying reduction in the active stresses in the soil, which ultimately resulted in lower shear strength. It might also be due to the complete interlocking of the soil particles with the geotextile. This interlocking might have prompted the shear failure plane to be inside the soil close to the interface rather than at the interface itself.

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