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Shear behaviour of geocomposites for landfill capping

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ABSTRACT : Geocomposite drains are increasingly being used as an alternative to traditional mineral drainage layers in the construction of various geotechnical structures. It is common practice to use them in landfill capping systems. At present, there is limited information on the interaction of geocomposites in shear with other capping system members at the associated low normal stresses. The frictional resistance of a given geocomposite interface varies with the orientation of its core grid in relation to the direction of shear. Core grid-geotextile interaction is crucial to the overall stability. Close attention must be paid to the on-site geocomposite orientation in relation to the slope. Methods of measuring geocomposite interface shear strength are considered. Two designs of shear box are compared, and the measurement of the normal stress on the interface during shear discussed. It is shown that the shear box design controls the measured shear strength and that unconservative (i.e. high) values can be obtained if fixed top box shear devices are used.

1 INTRODUCTION

The drainage layer is a key component of the final cover (Figure 1) in non-arid climates, as in the process of reducing the head of water on the hydraulic barrier layer, it drains the overlying cover soil and reduces/controls the pore water pressures therein. Incorporating geocomposites in various geotechnical structures instead of the traditional mineral drainage layers e.g. sand and gravel, provides a way of combining the best features of different materials to solve specific geotechnical problems, with cost and time benefits. Geocomposite drains constitute a central core such as a geonet, sandwiched between two geotextiles. The geonet often has a major (thicker) and minor (thinner) grid to form a high flow capacity conduit. The filtration, separation and protection functions of the geotextile are combined with the high hydraulic conductivity functions of the more rigid plastic core.

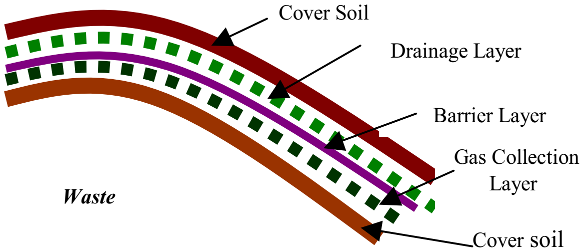

Figure 1. Schematic of a typical capping system

Potential construction generated damages to the individial components of the cover system have been discussed by Paruvakat & Richardson (1999) who identify good placement practice as key to long term stability. The presence of liquids generating pore water pressures above, below or within the failure surfaces is a triggering mechanism and contributing cause of failure in most landfill slope failures (Koerner & Soong (2000).

Stresses acting normal to the interfaces in capping systems are low i.e. between 5 and 35 kPa. This in turn results in low shear strengths at the interfaces between geocomposites and adjacent materials. Geocomposite placement on caps is typically down slope in the direction of the roll. However, geocomposites used for patching in corners and confined areas are not necessarily oriented in the same direction. The influence of the orientation of the geonet on its frictional properties has also been observed by De & Zimmie (1998). Effective and efficient capping design requires a thorough understanding of the various factors that can influence shear strength of the various interfaces, geosynthetic placement being one of them.

This paper considers the influence of the structure and orientation of the geonet ribs in the geocomposite core on the interface shear strength. The shear behaviour of one geocomposite interface is presented. Two different designs of large direct shear box have been used. The shear boxes differ in their kinematic degrees of freedom of the top box. The influence of the test device is discussed.

2 MATERIAL DESCRIPTION

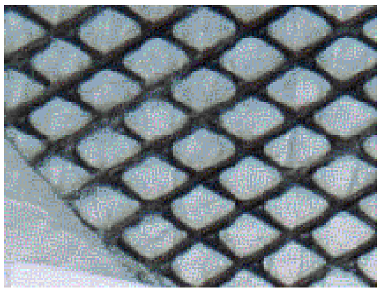

Figure 2. Geocomposite T (upper geotextile layer has been peeled back to reveal the core grid)

The type of geocomposite chosen for this study, Terram 1B1, shown in Figure 2, is commonly used in North America and Europe. It is denoted as geocomposite T, in this paper. It was sheared against Leighton Buzzard sand, a standard sand commonly used in the United Kingdom for laboratory studies.

Geocomposite T comprises a fairly uniform HDPE 3-D net structure laminated to and between two layers of a thermallly bonded non-woven geotextile (Terram 1000) of 729 g/m^2 mass per area. The product is approximately 5mm thick under no load.

Leighton Buzzard sand is a uniformly graded sand of an average particle size of 1.2 mm. D_{10} = 1.18mm, D_{20} = 1.40mm and D_{60} = 1.6mm. It has a minimum density of 1493 kg/m^3, a maximum density of 1667 kg/m^3 and a critical φ value in the order of 35^o.

2.1 *Material Preparation*

Geocomposite T was cut in three different directions of the main grid, to fit the 300 mm x 400 mm dimension of the bottom box of the large direct shear device. The main grid members were orientated in relation to the direction of shearing namely; 60^o (roll direction), 90^o (grid perpendicular to direction of shear) and 180^o (grid parallel to direction of shear), as shown in Figure 3.

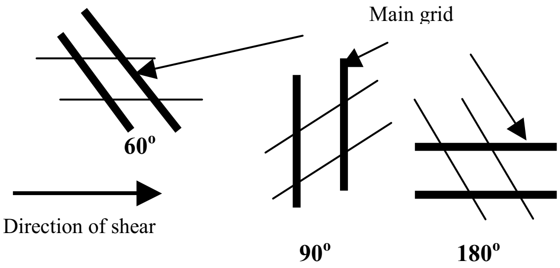

Figure 3. Grid orientation in relation to direction of shear

2.2 *Apparatus*

The large direct shear device (top box 300mm x 300mm, bottom box 300 mm x 400 mm) is widely accepted for use in the measurement of geosynthetic interface shear strengths. The two shear boxes used for this study differed in the degree of freedom of movement of the top box. The fixed top box was used at Loughborough University, and the vertically movable top box was used at Hanover University, Germany. In the latter device the top box is free to move vertically but cannot rotate. A 100mm x 100 mm shear box was used for direct shear tests on sand. The top box in this device is able to move vertically and can rotate.

A rigid low load system capable of applying controlled low normal stresses was used with the fixed box device. The applied normal stress on top of the sample is kept constant for the duration of the test. As in the 100mm x 100mm shear box, the stress distribution on the interface is unknown and is usually taken as equal to the applied normal stress on top of the sample.

For this test programme, it was necessary to measure the normal stress acting on the geocomposite/sand interface during shearing in the fixed top box device. Three load cells connected to a data logger were placed in a triangular configuration in the bottom box. A schematic of the fixed shear box experimental set up is shown in Figure 4. This method of measuring the normal stress at the interface using load cells is an accepted approach and has been reported by Zanzinger & Alexiew (2000).

The design of the vertically movable box is such that the average normal stress acting on the shear plane during shear is determinable by measuring the vertical support forces at the four corners of the upper box. The applied pressure at the top of the sample is regulated automatically during horizontal movement of the lower box, in order to keep the normal stress on the shear plane constant (Stoewahse, 2001).

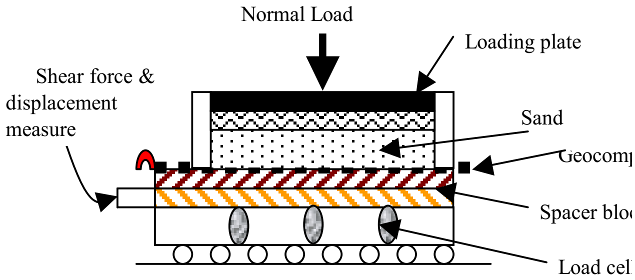

Figure 4. Schematic of fixed top box shear device

3 TEST PROCEDURE

The bottom box of the shear box was filled with plastic spacer blocks. The top most spacer was covered with sandpaper in order to prevent slippage and hence stretching of the geocomposite. The geocomposite was then clamped to the leading edge of the bottom box. The top box was lined with Teflon tape and lowered onto the geocomposite, clamped onto the main frame and a 50 mm layer of sand compacted to its maximum dry density in the top box. The loading system was then attached to the top box and the top box unclamped and raised approximately 1mm above the interface. The normal load was applied for 10 - 15 minutes before shearing at 1mm/min. The testing programme is shown in Table 1.

For each of the three grid directions, shearing was undertaken at normal stresses of 10, 20 & 30 kPa. These stresses are within the range for typical capping systems.

Table 1. Geocomposite testing program

Interface	Top box design	Loading system
T/Sand	Fixed	Low load*
T/Sand	Vertically movable	Pneumatic bag
Sand/sand	Floating	Loading yoke

* = Load cells in bottom box
T = Geocomposite

4 RESULTS

4.1 *Geocomposite T - Fixed top box with load cells*

The shear stress-displacement plots for geocomposite T are shown in Figure 5. The three directions are represented by T_{60}, T_{90} and T_{180} respectively. As expected, the shear stress for T_{90} (grid perpendicular to direction of shear) is the highest of the three directions, with a peak shear stress of 41 kPa compared to 34 kPa and 31kPa for T_{60} and T_{180} respectively. Figure 6 shows the measured normal stress-displacement relationship for each of the tests in Figure 5.

A large-scale plot showing both the normal stress and shear stress during the first 10 mm of shearing is shown in Figure 7. Normal stress starts to increase in the first 2 mm of shearing. Although peak shear stress is in all cases obtained the in the first 10 mm of shearing, it does not necessarily coincide with the highest normal stress. Figure 8 shows the stress paths for the T_{60} tests.

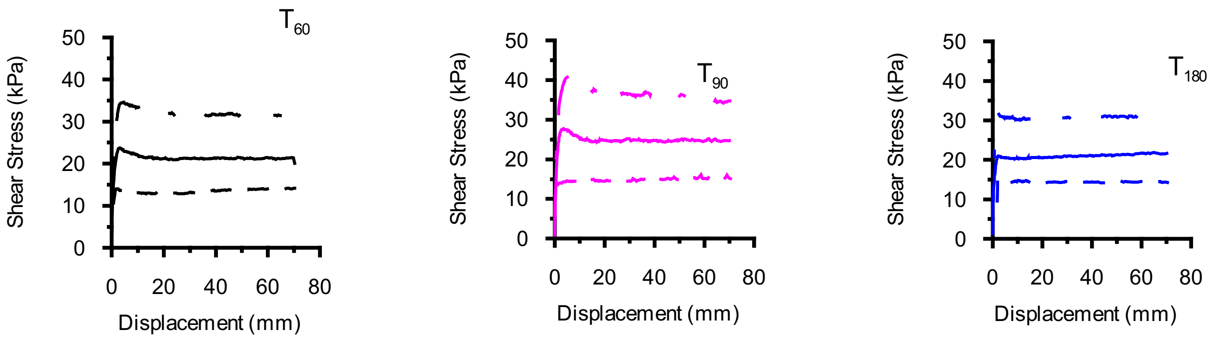

Figure 5. Shear stress-displacement plots for geocompoite T - fixed shear device.

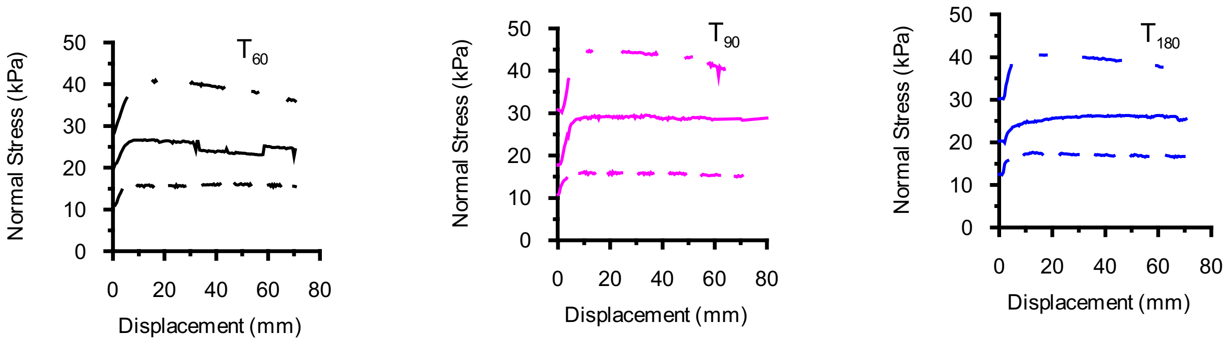

Figure 6. Normal stress-displacement plots for geocomposite T - fixed top box.

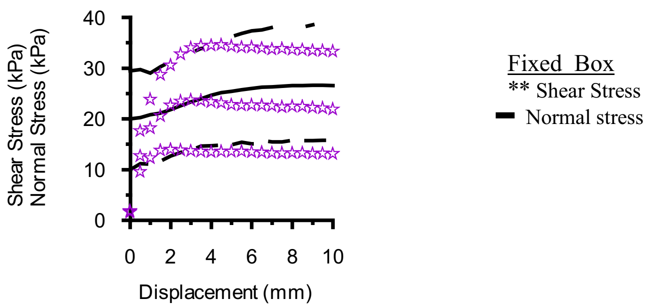

Figure 7. Shear stress & normal stress-displacement plots for T_{60}

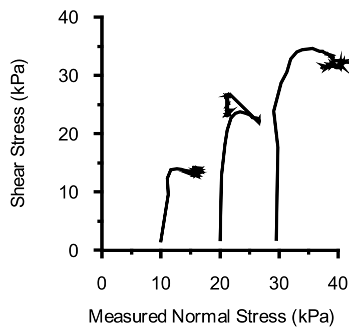

Figure 8. Shear stress path for geocomposite T_{60}

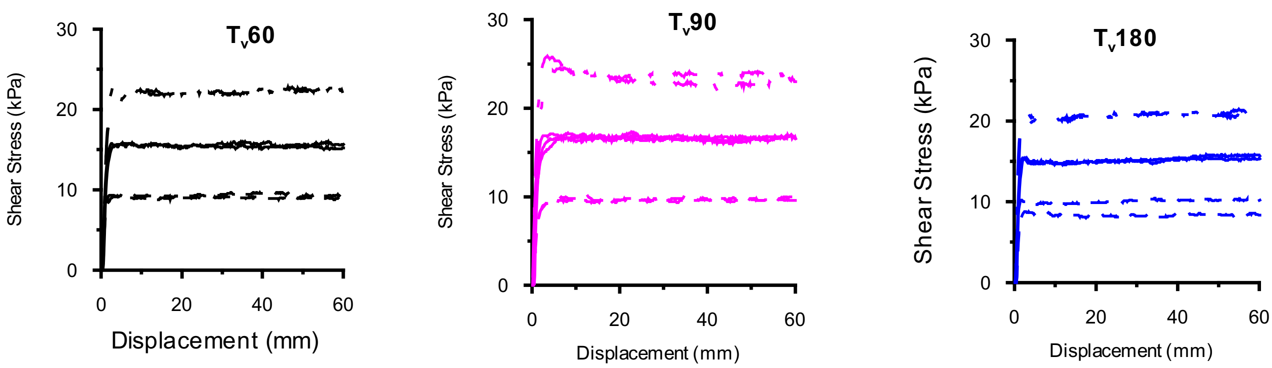

Figure 9. Shear stress-displacement plots - vertically movable top box.

4.2 *Geocomposite T - vertically movable top box*

Figure 9 shows shear stress displacement plots for geocomposite T tested in the vertically movable top box device. Good repeatability of test results is shown. The peak shear stresses are consistently lower than those obtained using the fixed top box. Mohr-Coulomb plots for geocomposite T in the direction of the roll (T_{60}) are shown in Figure 10.

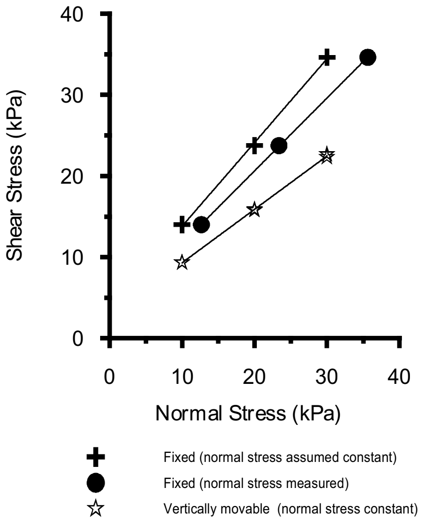

Figure 10. Shear stress-normal stress plots for T_{60}

The fixed top box significantly over estimates the derived peak interface shear strength parameters, especially when the normal stress on the interface during shear is assumed to be equal to that applied at the top of the sample. Measuring the normal stress on the interface results in lower strength parameters, but these are still larger than those measured in the vertically moveable top box device. Of concern is the fact that the fixed top box design is the most common device used in much of Europe and North America.

The sets of shear strength parameters for all three directions are shown in Table 2. For comparison, the tests conducted on Leighton Buzzard sand at maximum dry density and low normal stresses gave a friction angle of 41°.

Table 2. Interface shear strength parameters for geocomposite T

Shear box design (Normal Stress)	T_{60}	T_{90}	T_{180}
	Angle of friction (deg), apparent adhesion (kPa)		
Fixed(assumed const)	39°,8.4	38°, 3.5	34, 6.5
Fixed (measured)	42°, 2.7	46°, -0.6	42°, 1.6
Vertically movable (constant)	33°, 2.9	35°, 2.8	31°, 3.6

5 INTERPRETATION & SUMMARY

Shear strength parameters obtained using the fixed top box device (with normal stress on the interface assumed) are consistently higher than for the vertically moveable top box device. This trend is consistent with that found by Stoewahse (2001) from tests on sand/geotextile interfaces at higher normal stresses. Stoewahse (2001) has shown that the vertically moveable top box design gives correct interface shear strengths, while the fixed top box design consistently over estimates the shear strength.

Measurement of the normal stress on the interface enables a corrected failure envelope to be produced, thus providing lower shear strengths for a given normal stress. The importance of measuring rather than assuming the normal stress on the interface is demonstrated by the significant changes that occur during shearing (Figure 6). However, even using measured normal stresses, the fixed top box design still gives significantly higher shear strengths compared to the vertically moveable top box. This is believed to be caused by the fixed top box constraining the position and hence formation of the shear surface. Penetration of sand into the troughs between the grid ribs (i.e. by deformation of the overlying geotextile) causes the formation of a corrugated and hence complex shear surface. A planar shear surface is unable to form at a higher level (i.e. entirely in the sand) due to the constraint applied by the fixed top box. This results in higher and therefore unconservative shear strengths being measured.

Interface shear strength between a geocomposite drain and adjacent soil is clearly dependent on the orientation of the primary grid forming the core. The tests conducted in this study indicate that at low normal stresses the angle of friction can vary by up to 4° depending on the direction of shearing in relation to the core orientation. The designer must specify the orientation of geocomposites on site to ensure that the design strengths are available so that stability is not compromised. Detailed guidance on test set up is given by Dixon *et al.*(2000) and Stoewahse *et al.* (2002).

4 ACKNOWLEDGEMENTS

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