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Large-scale studies on contribution of high strength composite geotextile reinforcing poor draining backfill

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ABSTRACT: In-plane drainage capability is important especially when geosynthetic reinforcement is used with poor draining soil as backfill in a geosynthetic reinforced soil system. Excessive pore pressure build-up due to water infiltration can undermine the stability of the reinforced soil system particularly one with no proper drainage. Both back drainage as well as internal drainage systems are important. Studies were carried out to evaluate the efficiency of drainage capabilities of high strength composite geotextiles in poor draining residual soil. Large-scale laboratory tests were conducted to evaluate the drainage contribution of permeable geotextiles compared to a geosynthetics with no in-plane drainage capability. The results were promising as the dissipation of pore pressures was rapid immediately after excess pore pressures were generated. Results obtained from a full-scale model wall constructed in the field also showed similar response.

1 INTRODUCTION

The use of geosynthetics to construct walls and slopes is common and has gained acceptance worldwide. In most cases free draining soil, like sand, is recommended as the construction backfill material. This is viable in areas where supply is in abundance and less expensive. However, in region where free draining backfill materials are scarce and have to be imported or hauled at long distance, the cost of construction with geosynthetics becomes economically unattractive. This is particularly true in Southeast Asia region where common locally available soils are those of poor draining. Thus, the use of poor draining soils, such as laterite (or residual soil as commonly known) as the construction material, is not a matter of choice but a requisite for economic viability. Soil contributed more than 60% of the overall construction material requirements in the construction of retaining structures. Laterite soil, however, is poor draining in nature and pore pressure build-up during the wet season is a major concern to engineers. In order for the geosynthetics reinforcement to be effectively used together with poor draining soil backfills, it must not only provide the necessary tensile strength but must also provide adequate in-plane drainage capability to prevent excessive build-up of pore pressure (Chew and Loke, 1996). The soil-geotextile interaction parameters must also not be severely affected by infiltration of water into the soil mass. This paper provides information on the contribution of high strength composite geotextile with respect to its ability to dissipate pore water pressure when reinforcing poor draining soil. Extensive tests have been carried out previously in the laboratory and recently at large scale testing facility to investigate and realistically identify the contribution of the composite geotextile in poor draining soil. The high strength composite geotextile investigated consists a continuous fiber polypropylene nonwoven component reinforced with grid network of polyester yarns. The nonwoven component provides in-plane drainage and the high tenacity polyester yarn provides tensile strength.

2 CURRENT FINDINGS

2.1 *Laboratory pull-out test*

The pullout capacity of high strength composite geotextile in residual soils had been investigated and the results have shown good pull-out resistance provided by the geotextile even at fully saturated soil condition compared to that at in-situ moisture content at compaction (Chew et al., 1998). The test result indicated that while the average strength of the soil reduced almost 75% at saturated condition, the reduction of peak pull-out strength recorded was only about 16% when tested in saturated soil condition.

The ability of the geotextile to maintain adequate pull-out resistance under saturated soil condition was attributed to its ability to drain water in the plane of the geotextile as shown by pore water pressure transducers placed at different locations during the pull-out test. At some 15cm away from the geotextile layer, excess pore water pressure was recorded while at the interface of the geotextile, pore water pressure was negligible.

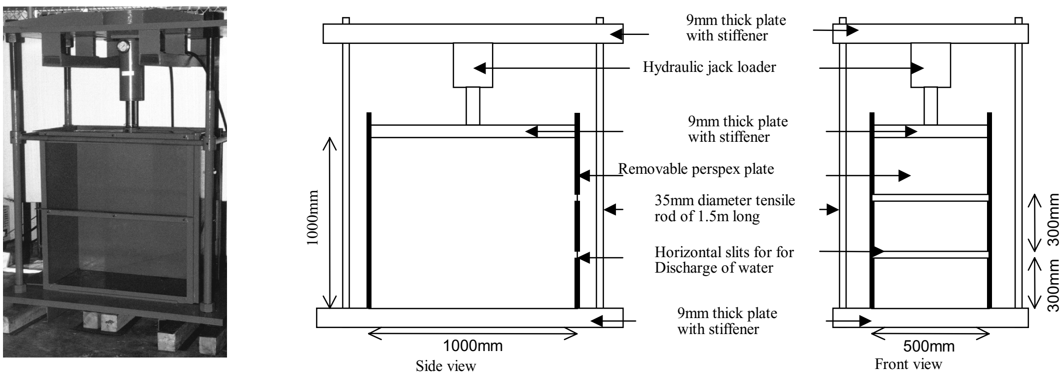
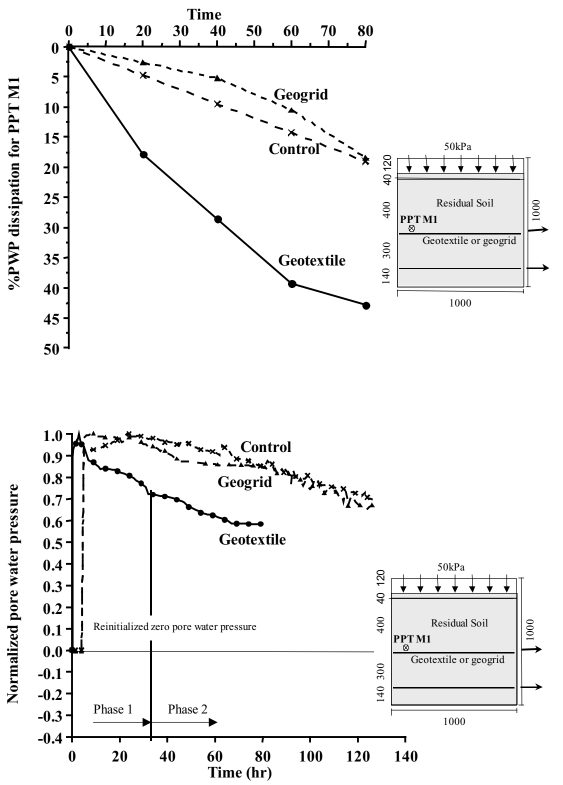


Figure 1. Test apparatus and schematic diagram.

2.2 *Laboratory drainage test*

Laboratory seepage flow and consolidation tests were carried out to evaluate the drainage capability of the high strength geotextiles embedded in residual soil. Figure 1 shows the set-up and the schematic diagram of the test apparatus. The set-up allowed uniform surcharge loading to be applied at the top by means of a hydraulic jack loader. The tests were conducted by first ponding the soil surface to allow infiltration of water into the soil and subsequently apply different surcharge loading in stages.



Figures 2. Dissipation of pore water pressure with time.

Figure 2 shows the dissipation of pore water pressure versus time of the test using soil alone (control test) and that with different geosynthetics reinforcement. The geosynthetics were placed horizontally at the level of the slit openings to allow drainage of water. Pore water pressure transducers were installed at different location to measure the pressure development in the test. The upper figure shows the pore water pressure dissipation at 50kPa surcharge load. The lower figure shows the normalized pore water pressure, which is the ratio of measured pore water pressure to the surcharge load increment.

The results clearly indicate that dissipation of pore water pressure was much faster when the soil was reinforced with the composite geotextile than without as in the control test. Dissipation of pore water pressure was similar to the control test when the soil was reinforced with geogrid. This clearly indicate the ability of the high strength composite geotextile to drain water in the plane of the geotextile and the advantage of in-plane permeability to reduce pore water pressure.

3 LARGE-SCALE FIELD MODEL WALL TESTS

A large scale experimental wall was constructed to further verify laboratory studies and also to simulate actual wall construction and conditions. The wall was about 3m high and 6m long, constructed using segmental modular blocks as the facing as shown in Figures 3 and 4. Six layers of high strength composite geotextile were used to reinforce the wall retaining laterite soil backfill. Six layers of geotextile with 50kN/m ultimate tensile strength were placed horizontally at vertical spacing of 0.4m. The base of the wall was filled with gravel to provide a bottom drainage layer. This drainage layer extended vertically at the back of the wall to form a vertical back drain.

The modular block used was hollow in the inside and the opening was filled with gravel. Connection of the geotextile to the modular blocks was achieved by placing the geotextile in between the modular blocks and filled with gravel in the hollow opening.

Figure 5 shows the particle size distribution of the laterite soil. The plastic limit of the soil was in the range of 22% to 24% while the liquid limit was 42% to 45%. The in-situ moisture content of the soil was about 20% to 28%. Compaction tests carried out on a few soil samples showed optimum moisture content of around 19% with a maximum dry density of around 1.73g/cm^3.

Figure 3. Top of large-scale wall with some instrumentation.

Figure 4. Portion of the front wall.

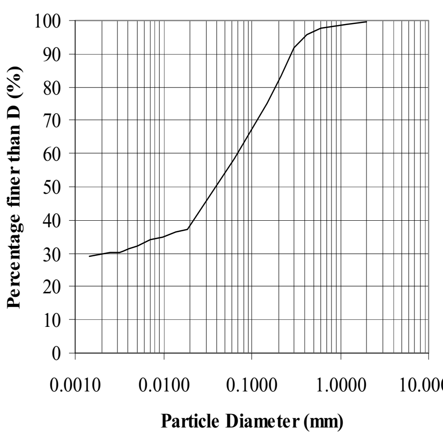


Figure 5. Particle size distribution of laterite soil.

3.1 *Pore pressure measurements and analysis*

Various instrumentation was installed to monitor the performance of the wall. The locations of piezometers in the wall are as shown in Figure 6.

Figure 7 shows some of the pore water pressure measurements recorded by the piezometers from the time of construction (July 2000) until the end of the monitoring period (July 2001) in the soil between two layers of geotextiles at the bottom of the wall (Layer 1A). In general, the pore pressures were fairly low till the end of construction in September 2000. Upon the completion of the construction, the wall was left exposed to natural weather with the intention of allowing the soil to be saturated during the rainy season. Pore water pressure at L1A-C-PZ1 increased gradually to about 2kPa from the end of construction (September 2000) to March 2001. This result corresponded well to the rainfall data shown in Figure 9 where heavy rainfall was recorded. Negative pore water pressure was recorded at L1-C-PZ1. This was due to its location near the bottom drainage layer. It was also noted that pore water pressures recorded near the top of the wall (L4A readings) was also low. These readings were realistic as rainwater was quickly drained via the back drainage layer provided. Infiltration of water from the top of the wall into the backfill was minimized due to the compact and poor draining nature of the backfill.

However, it can be noted that the pore water pressure was even lower at the soil-geotextile interface as recorded at L1-C-PZ2 in Figure 8, while L1A-C-PZ2 showed similar result as that of L1A-C-PZ1. This result was attributed to the in-plane drainage provided by the composite geotextile. Both PZ3s at layer L1 and layer L1A show almost zero pressure owning to its proximity to the front drainage wall face during this period (till March 2001).

In March 2001 the bottom drainage layer was closed. To accelerate full saturation of the backfill, continuous and gradual filling of water was allowed at the surface of the wall. This procedure was to simulate clogging of the back drain. The standpipe installed in the back drain recorded water level at 0.8m from the base. Water seeped into the soil mass horizontally from the back drainage layer and intercepted the geotextiles near the bottom of the wall. The soil was fully saturated for the bottom portion of the wall. At L1A level, the pore water pressure recorded in the soil was about 5kPa as shown in Figure 7, which was in agreement with the hydrostatic pressure calculated. However, near the geotextile interface L1A, the pore water pressure remained low (Figure 8). This can be explained by the presence of the composite geotextile providing in-plane drainage.

At end of May, the entire wall, both at the front and in the back, was filled with water to its surface rapidly. It can be noticed that the pore water pressures in the soil mass was significantly increased and corresponded to the hydrostatic pressure calculated. Again pore water pressure at the geotextile interface showed low value.

After ponding for about one week water was pumped out rapidly in front of the wall to simulate a rapid draw-down condition. Dissipation of pore water pressure in the soil backfill was rapid with no indication of instability of the wall. It was observed that water was draining out of the backfill via the geotextiles at the facing where the geotextiles were located. A similar exercise carried out 2 weeks later drew a similar response as shown by the second peak in the pore pressure measurements in Figures 7 and 8.

3.2 *Pull-out tests and analysis*

Several pullout tests were carried out to evaluate the interface friction between the soil and the composite geotextile, under different surcharge and saturation conditions. The pull-out tests were carried out on small strips 0.3m wide laid in the soil during construction. Figure 10 shows the pull-out test setup. A modified compression machine with a pulling capacity of 20kN and constant displacement rate of 1.25mm/min was used for the tests. A steel structure was fabricated to support the compression machine and to align the machine to the level of the geotextile strips. Potentiometers were used to capture the real-time displacement of the tell-tales as well as the clamp.

The embedded area of the pullout strip was 1.85m by 0.3m and the overburden pressure on the geotextile was 7.5kPa during the pullout test. The soil condition was saturated. Figures 11 and 12 show the results from one of the pullout tests. Pullout resistance attained was rather high even at low overburden pressure and wet soil condition. The peak pullout strength achieved was 8.74kN per 0.3m width or 29.15kN/m as shown in Figure 12. Back calculations were carried out to evaluate the effective interface parameters. With an assumed adhesion value

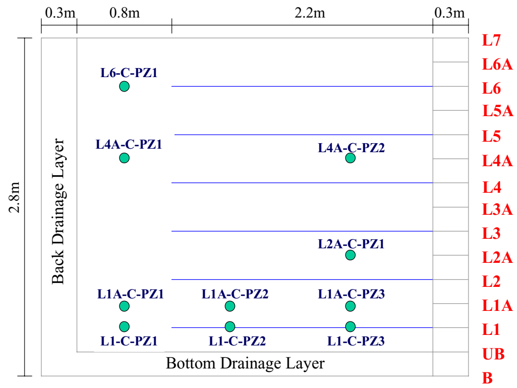


Figure 6. Location of piezometers in large-scale wall

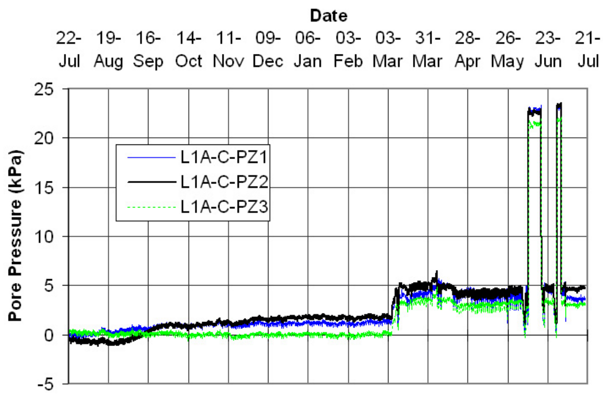


Figure 7. Pore water pressure measurements at various locations between two geotextiles layers - Layer L1A.

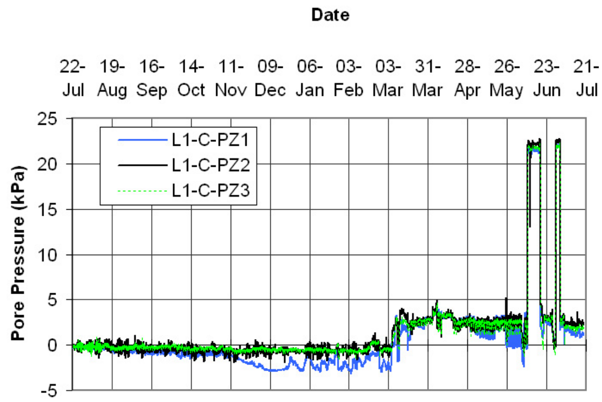


Figure 8. Pore water pressure measurements at the interface of high strength composite geotextile. – Layer L1

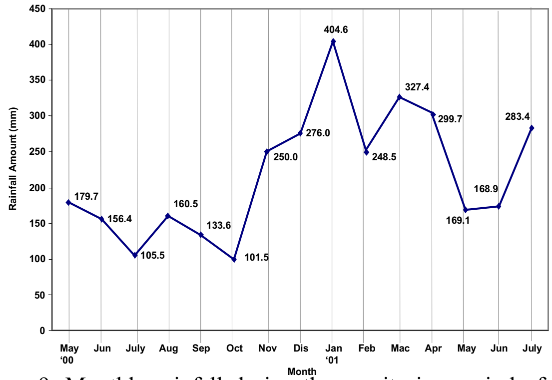


Figure 9. Monthly rainfall during the monitoring period of the test.

(a)

(b)

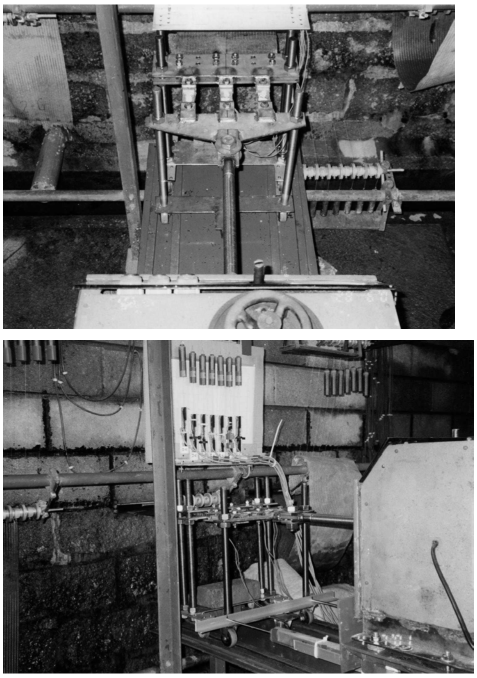


Figure 10. Pull-out test setup in front of large-scale wall.

of 5kPa, the friction angle between the soil and the geotextile was calculated to be around 21°. The internal friction angle of the soil was about 27°. Hence, the efficiency of 0.80 was achieved. The measured tensiometer readings also indicated that the effective stress at the geotextile interface was not significantly affected by the saturation of the soil carried out prior to the test.

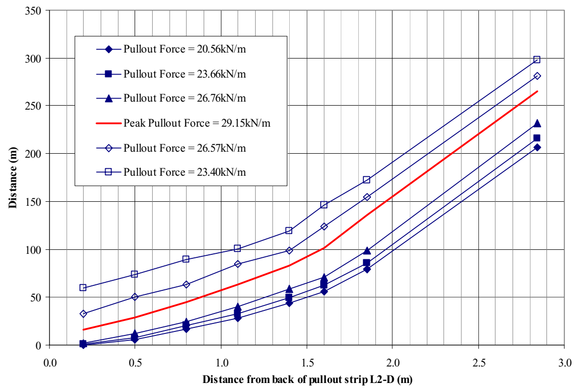


Figure 11. Geotextile displacement at various stages of pull-out test.

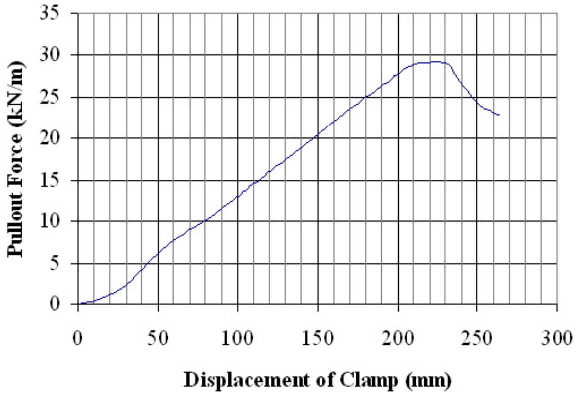


Figure 12. Force versus front displacement for the pullout test.

4 SUMMARY AND CONCLUSIONS

Extensive tests have been carried out both in the laboratory and at large scale testing facility to investigate the drainage capability of reinforcement geotextile used in association with poor draining soil and its pull-out resistance under saturated soil condition.

For a geotextile to provide both reinforcement function and drainage capability, a composite geotextile is required. Research has shown that geotextile composite with nonwoven component reinforced with high tenacity polyester yarn is suitable for use with poor draining soil in providing both in-plane drainage and reinforcement functions.

Under saturated soil condition, while full hydrostatic water pressure was exerted on the soil backfill, minimum pore water pressure was obtained at the interface of the composite geotextile. In some instances, zero or negative pore water pressure was obtained.

For the soil investigated under fully saturated condition, the reduction in soil strength was more than 70% compared to that at optimum moisture content. However, the reduction in pull-out resistance of the composite geotextile, from optimum moisture content to saturated soil condition, was less than 20%.

High strength composite geotextile effectively reinforced poor draining soil used in the construction of walls without affecting its stability. It provided addition factors of safety under conditions of poor back drainage system and rapid draw down.

The large-scale experimental wall showed that the combination of high strength composite geotextile with segmental blocks as facing is an ideal and viable system for wall construction, especially in areas where poor draining soil is abundant and can be economically used as the backfill material.

5 REFERENCES

Chew, S.H. & Loke, K.H. 1996. Design criteria for reinforced soil structures using poor draianing backfills. Proc. of 12th Southeast Asian Geotechnical Conference, Kuala Lumper, Malaysia, Vol 2. pp.137-145

Chew, S.H., Tan, S.A., Loke, K.H., Delmas Ph. & Ho, C.T. 1998. Large scale pullout tests of geotextiles in poorly drainage soils. Proc. of 6th International Geosynthetics Conference, Atlanta, USA. Vol. 2: 821-824.