Influence of load type on filtration behaviour for two nonwoven geotextile-soil composites

Wu, C.S., Hong, Y.S. & Yang, H.H.
Department of Civil Engineering, Tamkang University, Taipei, Taiwan

Lee, W.F.
Office of Research and Development, National Taiwan University of Science and Technology, Taipei, Taiwan

Keywords: sustained load, pulsatory load, filtration test, nonwoven geotextile, permeability

ABSTRACT: The impact of load type on the filtration behaviour of soil-nonwoven geotextile composites has been studied through series of tests using an experimental apparatus designed specially for the laboratory tests. One of the three load types, namely sustained load, pulsatory load, and compound load of pulsatory and sustained load, was applied to the composite prior to each filtration test. The frequency of the pulsatory load was 0.1 Hz and a total of 5000 cycles of repeated load applied to the composite for each load type test. After applying specific type of load on a soil-geotextile composite, water was allowed to flow down through the composite from the soil into a drainage layer set at various hydraulic gradients. The flow rates corresponding to elapsed times were measured and the average permeability value was extracted by using Darcy's law to characterize the filtration performance of the entire soil-geotextile composite. Variations in the average permeability value with respect to the magnitude and type of normal load were examined.

1 INTRODUCTION

Geotextile serves as a filter or separator in roadway applications is frequently subjected to earth pressure and dynamic or impact load caused by highway vehicles, railroad trains or landing aircraft. Therefore, the success of these applications depends on the retention and seepage capabilities of geotextiles, and the prevention of undue clogging as the geotextile subjected to in-plane stress/strain and dynamic load. The current filter criteria may not be effective because the current filter criteria or the selection of suitable geotextiles is based on the pore size and permeability of plain geotextile. The clogging potential is also evaluated for an un-loaded soil-geotextile system.

Change in permeability for a soil-geotextile system subjected to dynamic load was studied and reported in literatures (Saxena and Hsu 1986; McMorrow 1990). McMorrow (1990) estimated that the fall in permeability for geotextile subjected to pulsatory load could be about one to two orders in magnitude.

For a soil-geotextile system subjected to dynamic loading, the filtration behaviour of the system depends on soil compactness, geotextile pore size, and pumping action. In this study we conducted laboratory tests to evaluate the performance of two non-woven geotextiles subjected to various load conditions. A special apparatus, capable of applying various types of normal load to a soil-geotextile-steel bead system with geotextile as filter, was built to simulate a drainage system for the study.

2 EXPERIMENTAL PROGRAM

The test apparatus consists of a pneumatic loading device and a permeameter chamber. Two 100-mm internal diameter and 125-mm outer diameter acrylic tube sections and a clamped specimen mounted between two tube sections constitute the permeameter chamber. The chamber is arranged by allowing the clamped geotextile specimen to be inserted between a 5-cm soil layer and a layer of steel beads.

The upper acrylic section, 100 mm in height, contains the test soil and a porous steel plate placed on the top of soil to disperse the applied load. A schematic diagram of experimental apparatus is presented in Fig. 1. A layer of steel beads, 15.85 mm in diameter, is placed beneath the geotextile sheet to provide support. The steel beads are arranged in a specific pattern such that the opening area for water flow is the same for each test. The contact area between the geotextile and drainage layer will not be a variable for the seepage flow (Wu et al. 2006).

Prior to a filtration test, different type of normal load could be applied to the soil-geotextile composite via a loading piston. There are three types of loads acting on the composite, namely sustained load, pulsatory load and compound load of pulsatory and sustained load. The frequency of the pulsatory load was 0.1 Hz with 5000 cycles of repeated load applied. Following the completion of normal loading, water was allowed to flow through the composite under test using hydraulic gradients of 1, 5 and 10. The flow rates at various elapsed times were meas ured and the corresponding permeability values, using Darcy's law for the entire composite length (5-cm soil and geotextile thickness), were calculated.

A series of wet sieving tests, using the apparatus described in Wu et al. (2008), was also conducted on the clamped geotextile samples to characterize the pore size distribution and mean flow rate. Gradient ratio tests (GR test) were also performed on similar soil-geotextile composites with a thicker soil layer (10-cm) and free of the normal load.

The soil used has a specific gravity of $G_s = 2.60$, mean diameter $d_{50} = 0.19$ mm, with the particle size distribution curve shown in Fig. 2. The soil specimen filled in the permeameter was controlled to a unit weight of $\gamma = 15.70$ kN/m^3. Two chemical bonded non-woven geotextiles made of polypropylene were employed in this study and designated as GT1 and GT2 geotextiles. The mass per unit area and thickness of the test geotextiles are 210 g/m^2 and 337 g/m^2, and 1.0 mm and 2.6 mm respectively. The pore size distributions of the test geotextiles are presented in Fig. 2. The apparent opening sizes (AOS) for the geotextiles determined from the distribution curves are 0.112 mm and 0.122 mm, respectively. The mean flow rates for the plain geotextiles are 15.1 cm/sec and 15.3 cm/sec for GT1 and GT2, respectively. The tensile force-strain relations of both geotextiles were obtained using a wide-width tensile test with the results depicted in Fig. 3. Geotextile GT2 is thicker and stronger than GT1 but with a similar pore size distribution, apparent opening size and mean flow rate.

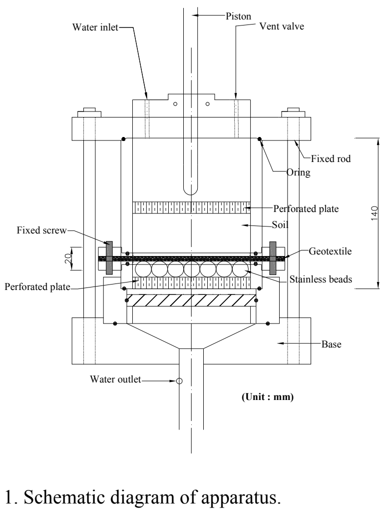


Figure 1. Schematic diagram of apparatus.

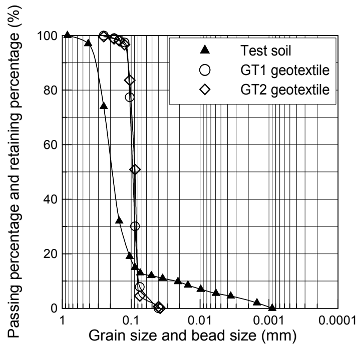


Figure 2. Particle size distribution of the test soil and pore size distributions of the test geotextiles.

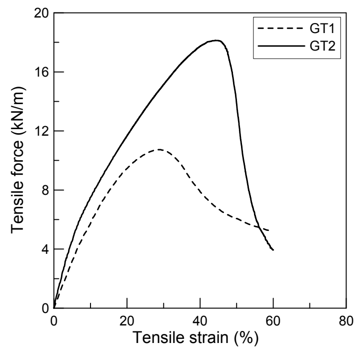
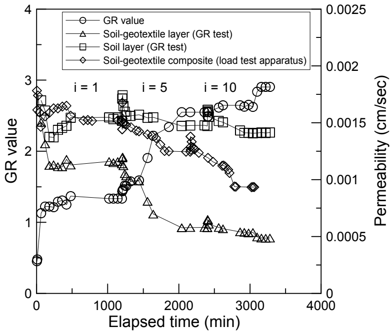


Figure 3. Tensile force-strain relations for test geotextiles.

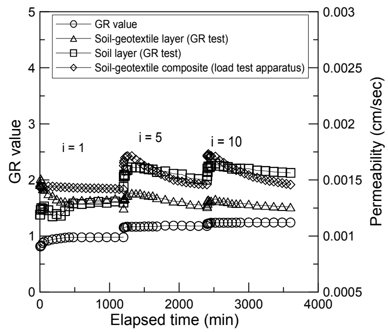
3 EXPERIMENTAL RESULTS

3.1 *Permeability of the pure soil and soil-geotextile layers using GR test apparatus*

The test soil permeability was evaluated using a gradient ratio (GR) test apparatus. Figure 4 depicts the GR test results for composites composed of each geotextile and the test soil.



(a)



(b)

Figure 4. GR value and permeability of soil layer and soil-geotextile composites: (a) soil-GT1 composite; (b) soil-GT2 composite.

In the GR test using the GT1 geotextile, the permeability value of the soil-geotextile layer decreases from 0.0011 cm/sec for the low hydraulic gradient (i =1) to 0.0005 cm/sec for the high hydraulic gradient (i =10). This indicates that clogging or blinding might have occurred in the soil-geotextile layer when the system was subjected to higher hydraulic gradient as shown in Fig. 4(a). For the composite using GT2 geotextile, the soil-geotextile layer permeability value decreases from 0.0014 cm/sec for the low hydraulic gradient (i =1) to 0.0013 cm/sec for the high hydraulic gradient (i =10). This result shows only an insignificant increase in the GR value, as shown in Fig. 4(b).

3.2 *Averaged permeability of the un-loaded soil-geotextile composites using the load test apparatus*

The combination of 5-cm soil layer and a geotextile sheet is treated as a soil-geotextile composite unit. The test results obtained from the GR test and the load test apparatus were compared to assess the validity of the load test apparatus. The variations in averaged permeability value for soil-geotextile composites tested by using the load test apparatus for different elapsed time are plotted in Fig. 4. It shows that averaged permeability values decrease with the elapsed time and they reach stable values for each different hydraulic gradient.

By averaging the permeability values for the soil-geotextile layer (the combination of 2.5-cm soil length and the geotextile thickness) and the soil layer (2.5 cm soil length) from the GR test, the averaged values for the soil-GT1 system are 0.00133, 0.00103, and 0.00095 cm/sec for low, medium and high hydraulic gradients respectively. For the soil-GT2 system, the averaged values are 0.00131, 0.00139 and 0.00141 cm/sec. for low, medium and high hydraulic gradients respectively. These values are close to those permeability results for the soil-geotextile composite made of 5-cm thick soil layer and a geotextile sheet collected by using the load test apparatus.

3.3 *Permeability of soil-geotextile composites subjected to various sustained loads*

Variations in the averaged permeability value against the elapsed time for soil-geotextile composites subjected to various sustained loads are presented in Fig. 5. The results for the same soil-geotextile composites free of load were used as a reference. While water flows through the composites with a low hydraulic gradient, the permeability values for all composites tend to decrease with the elapsed time for a very short period of time at first. After that, the permeability value trend varies depending on the magnitude of the sustained load.

For a soil-GT1 composite subjected to high normal load (98 and 196 kPa) at i = 1, the permeability value increases with the elapsed time and reaches a stable value close to or higher than the initial permeability value. For the composite subjected to low (24.5 kPa) or free of normal load, the permeability value continued to decrease with elapsed time and reached a stable value. For all soil-GT1 composites subjected to sustained load only, the averaged permeability value decreases with the increase in hydraulic gradient. At a specific hydraulic gradient, the averaged permeability value of soil-geotextile composite increases with an increase in sustained load.

At low hydraulic gradient, the soil-GT2 composite exhibits a greater variation in averaged permeability while subjected to high sustained load. In contrast with the soil-GT1 composite, at a specific hydraulic gradient the averaged permeability value of soil-GT2 composite decreases with an increase in sustained load.

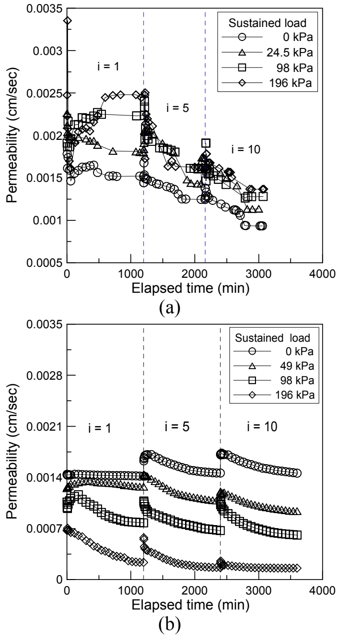


Figure 5. Variations in averaged permeability with elapsed time for soil-geotextile composites subjected to various sustained loads: (a) soil-GT1 composites; (b) soil-GT2 composites.

3.4 *Permeability for the soil-geotextile composites subjected to various pulsatory loads*

Pulsatory loads of 24.5 kPa, 98 kPa and 196 kPa were applied to soil-GT1 composite samples free of sustained load. Pulsatory loads of 24.5 kPa and 98 kPa were also applied to composite samples subjected to a 98 kPa sustained load. The variations in averaged permeability value with the elapsed time for composites under different load combinations are shown in Fig. 6. These test results indicate that a greater hydraulic gradient tends to produce a lower averaged permeability value. For a composite subjected to a specific sustained load and hydraulic gradient, the averaged permeability value increases with the increase of pulsatory load.

Pulsatory loads of 49 kPa, 98 kPa and 196 kPa were applied to soil-GT2 composite samples subjected to 0 kPa, 49 kPa and 98 kPa sustained loads. For the composite samples free of sustained load, the averaged permeability value decreases with the increase in pulsatory load (Fig. 7(a)). For composites subjected to 49 kPa sustained load, the averaged permeability value decreases with an increase in pulsatory load up to 98 kPa. The composite subjected to 196 kPa pulsatory load shows higher averaged permeability than the composite subjected to 98 kPa pulsatory load (Fig. 7(b)). The 196 kPa pulsatory load introduces a greater variation in the averaged permeability against the elapsed time for a given hydraulic gradient. For the composite samples subjected to 98 kPa sustained load, a composite subjected to an additional 49 kPa pulsatory load produces a lower averaged permeability value than the composite free of sustained load. Nevertheless, the averaged permeability value increases with an increase in pulsatory load for the composites subjected to higher additional pulsatory loads (98 kPa and 196 kPa) (Fig. 7(c)).

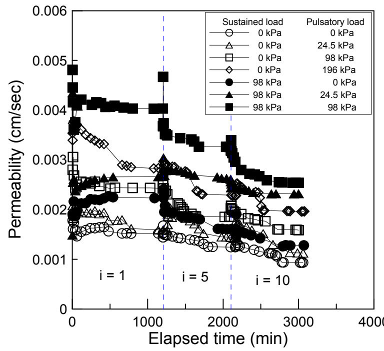


Figure 6. Variations in averaged permeability with elapsed time for soil-GT1 composites subjected to various pulsa tory loads.

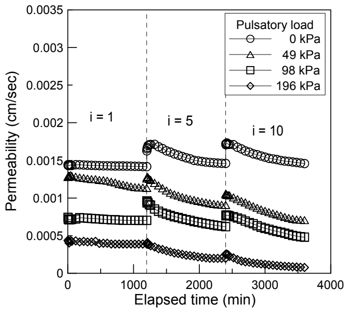
4 CONCLUSIONS

A new experimental apparatus was designed and built to conduct the filtration tests on soil-geotextile composites with various types of normal load applied on the composite under test. The experimental results show:

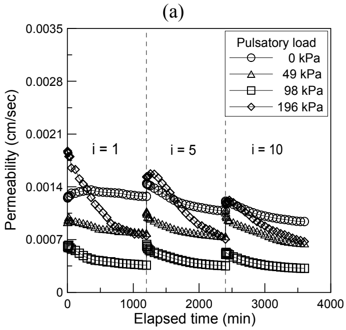
1. By averaging the permeability values for the soil-geotextile layer and the soil alone layer from the GR test, this averaged value is close to the permeability value of 5-cm thick soil and geotextile composite obtained from a new load test apparatus reported in this paper.
2. For a soil-geotextile composite subjected to sustained load alone, the averaged permeability value increases with increase in sustained load for the soil-GT1 composite. The soil-GT2 composite exhibits an opposite response to a sustained load; it means a higher sustained load produces a lower averaged permeability value instead.
3. For the soil-GT1 composites free of sustained load or subjected to 98 kPa sustained load, their averaged permeability values increase with an increase in pulsatory load.
4. For the soil-GT2 composites tested free of sustained load, the averaged permeability value decreases with an increase in pulsatory load.

ACKNOWLEDGEMENTS

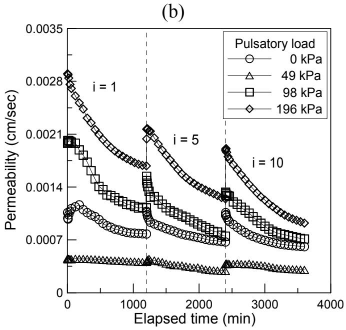
The authors would like to thank the National Science Council of the Republic of China for financially supporting this research under Contract no. NSC96-2221-E-032-039-MY3.



(a)



(b)



(c)

Figure 7. Variations in averaged permeability with elapsed time for soil-GT2 composites subjected to various pulsatory loads: (a) sustained load = 0; (b) sustained load = 49 kPa; (c) sustained load = 98 kPa.

REFERENCES

McMorrow, J. 1990. Filtering action of non-woven geotextiles under dynamic loading. *Proceedings of the 4th International Conference on Geotextiles, Geomembranes and Related Products*, Hague, Netherlands, Vol. 1, pp. 233-238.

Saxena, S.K. & Hsu, T.S. 1986. Permeability of geotextile-included railroad bed under repeated load. *Geotextiles and Geomembranes*, Vol. 4 (1), pp. 31-51.

Wu, C.S., Hong, Y.S. & Wang, R.H. 2008. The influence of uniaxial tensile strain on the pore size and filtration characteristics of geotextiles. *Geotextiles and Geomembranes*, Vol. 26 (3), pp. 250-262.

Wu, C.S., Hong, Y.S., Yan, Y.W. & Chang, B.S. 2006. Soil-nonwoven geotextile filtration behavior under contact with drainage materials. *Geotextiles and Geomembranes*, Vol. 24 (1), pp. 1-10.