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Filtration behavior of geotextile under overburden pressure and bi-directional cyclic flow

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ABSTRACT: To prevent scouring problem of riverbanks, concrete structures such as RC walls have commonly been used. From aesthetic and ecological points of view, however, concrete structures have adverse impacts to the environment. In addition, they are apt to suffer from long-term scouring problem. Therefore, it would be beneficial to seek alternative structures that are safe, economic, as well as having more environmental amenity. One solution is to construct revetments or embankments using geotextiles as filters. These structures consist of a geotextile layer placed on a soil slope, then covered with armor stones. The main function the geotextile performs is filtration. The geotextile must be permeable enough to allow water move freely through the fabric, whilst it also can retain soil particles. Hence, the stability of the structure is ensured. In this research, a series of laboratory tests are conducted with the apparatus which can simulate the geotextiles in the revetments under bi-directional flow. Influencing factors considered are the vertical loading and the period of bi-directional flow that have a definite effect on the stability of revetments. The behaviors of non-woven geotextile with soils of various fine particle contents are studied. The settlement of the soil and the pore water pressures at various depths are recorded. Specimens and the grain size distribution of the soil before and after the test are examined to study the effect of erosion. The purpose is to obtain the load-displacement mechanism of the specimen, thereby to establish appropriate analytical models and design criteria accordingly.

1 INTRODUCTION

Scouring has been a severe problem to the stability of riverbanks in Taiwan. Thus, measures should be taken to enhance their stability. Currently, building high embankments is often adopted as a viable measure for this purpose. These concrete structures, however, may cause considerable environmental impacts and are not reliable under long-term scouring. Therefore, it is urgent to seek substitute structures that are safer and more environmentally friendly for revetments.

Reinforced revetments using geosynthetics not only easily fit in with the environment but also have better long-term stability compared with conventional concrete structures. Yet, the design parameters for chronically submerged geosynthetics-reinforced revetments subjected to bi-directional cyclic flow, however, have not been studied.

In this project, a series of laboratory tests are performed with the equipment that is able to simulate the behavior of geosynthetics-reinforced revetments under bi-directional flow. Specimens are prepared from a combination of geosynthetic material with soils. Stress and settlement of the specimens under various wave periods of bi-directional flows and overburden pressures are measured in order to understand the filtration behavior of the specimens, thereby to develope appropriate analytical models and design criteria accordingly.

2 FILTRATION/DRAINAGE MECHANISM

Due to the fluctuation of water table, a geosynthetics-reinforced revetment has a zone subject to bi-directional flow. The infiltration rate of water through the soil-geotextile system is a function of the hydraulic gradient between the water levels within and outside of the revetment. Under this condition, soil particles may migrate from the soil into the geotextile thus to make this zone to have different properties from those of the soil. The study of this zone and its hydraulic characteristics are essential to understand the filtration mechanism.

The water infiltrates through the pores of this zone may change the soil structure and affect intrinsic permeability. As the soil particles migrate into this zone, the permeability of the system decreases. To prevent this phenomenon, a suitable geotextile should be selected to impede sufficiently the movement of coarse particles and to build a natural filter layer at the up-flow face. In turn, this layer will stop the smaller particles migrate until a stabilization is established. The faster a natural filter established, the smaller amount of soil particles will migrate (Mlynark et al., 1991).

3 BI-DIRECTIONAL CYCLIC FLOW TEST

Bi-directional cyclic flow apparatus was built at National Taiwan University (Figure 1). It was developed with some modifications of the perpendicular cyclic flow model of ENEL, Italy. This apparatus is capable of simulating cyclic flow normal to the soil-geotextile interface.

Figure 1. Front view of bi-directional cyclic flow apparatus.

The bi-direction cyclic flow apparatus consists of a cyclic wave generator, a water reservoir and washed-out collecting tank, and acrylic sample chamber. The cyclic wave generator activated by the piston action simulates the cyclic wave loadings applied on a revetment. The specimen cylinders consist of two acrylic chambers: the top and the bottom chambers. The bottom chamber contains marbles simulating the secondary armor layer in a revetment. The soil specimen is in the top chamber, while in between the top and the bottom layers is the geotextile filter. Figure 2 shows the detailed schematic view of the internal setup of the chambers. A pneumatic loading device placed on the top of the chamber is activated by a hydraulic jack to apply an overburden load on the soil specimen. There are four pore pressure transducers (P01, P02, P03 and P04) placed at different positions to monitor fluctuation of pore pressure. In addition, two strain gauges (S01 and S02) are mounted on the top of porous steel plate.

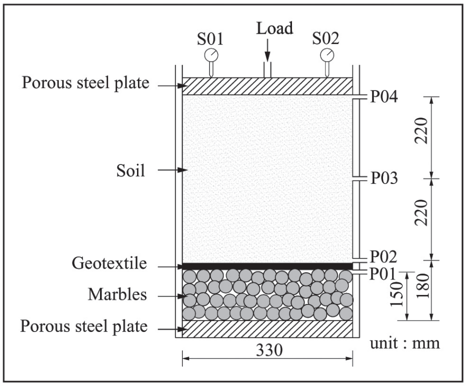


Figure 2. Detailed schematic view of the internal setup of chambers.

4 TEST MATERIALS

A. Soils
The soil used in this test is composed of various weight proportions of two different soils. The primary soil is Vietnam sand having particle size greater than 0.074 mm (sieve #200). The secondary soil is silt. Their grain size distributions are shown in Figure 3.

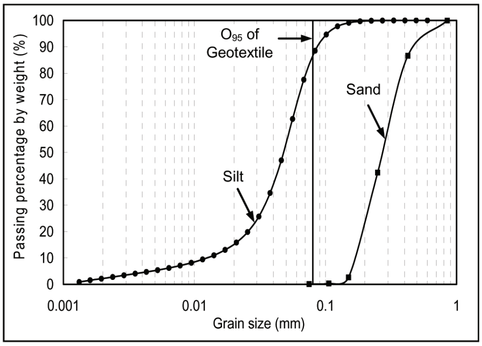


Figure 3. Particle distribution curves of the two soils.

The first group of specimen contains 100% sand of 58.16 kg. The second group is the mixture of 10% silt and 90% sand by weight. The third group has 20% of silt and 80% of sand.

B. Geotextile
This experiment employs a geotextile (F60) for a series of tests. Table 1 shows the properties of the geotextile.

5 TEST RESULTS AND DISCUSSION

In order to understand the effect of loading on the filter, overburden pressure is applied at 70 kPa and

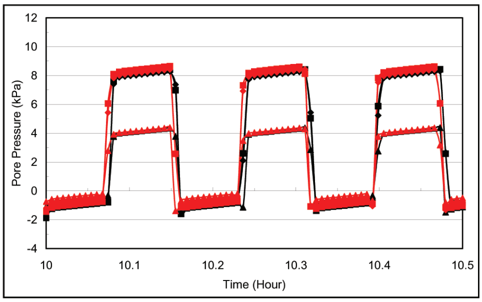
Table 1. The properties of the geotextile.

	Unit	Symbol	F60
Characteristic opening size	μm	$O_{90,w}$	80
Permeability normal to the plane	m/s	VI_{H50}	0.06
Elongation	%	ε_{max}	85
CBR puncture resistance	kN	P_s	2
Dynamic perforation (cone drop test)	mm	P_d	13
Tensile strength	kN/m	T_{max}	23
Water flow capacity in the plane (20 kPa)	m^2/s	Q/I	7.0×10^{-6}
Water flow capacity in the plane (100 kPa)	m^2/s	Q/I	2.3×10^{-6}
Mass	g/m^2	μ_{GT}	400
Thickness (2 kPa)	mm	t_{GT}	3.5

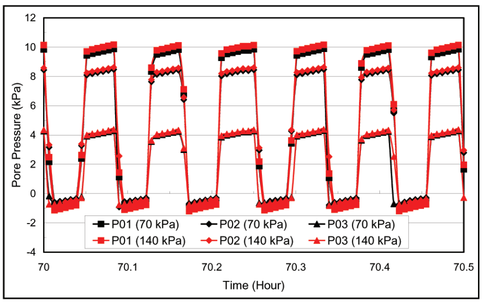
140 kPa, respectively. The wave period applied is at 600, 300, 150, and 75 seconds, respectively.

A. Pore water pressure

Figure 4 and Figure 5 show the results of the first and the third groups, respectively. They illustrate the pore water pressure response under various wave periods for specimens of different amount of silts. In general, the peak value of pore pressure increases as the wave period decreases when the amount of silt keeps constant. This is due to the pore water pressure has not dissipated completely when the next cycle of flow comes up in the case of smaller period of flows. Besides, the peak pore water pressure also increases

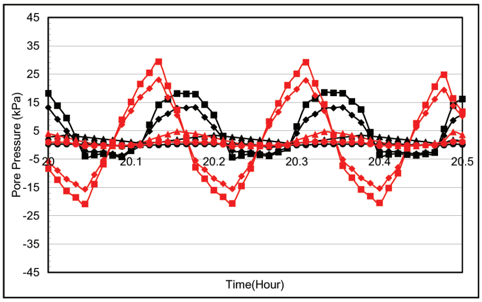


(a) Wave period at 600 s

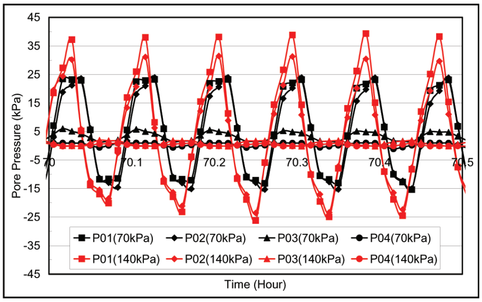


(b) Wave period at 300 s

Figure 4. Pore water pressure of the first group (pure sand).



(a) Wave period at 600 s



(b) Wave period at 300 s

Figure 5. Pore water pressure of the third group (20% silt).

with increasing amount of silt. It is apparent that the silt affects the dissipation of pore water pressure.

Figure 4 also shows that for pure sand under different overburden pressure, the difference in pore water pressure is negligible. But for silty sand under higher overburden pressure (140 kPa compared to 70 kPa) the peak value of pore water pressure is higher (Figure 5). This illustrates that the structure of the sand is quite stable irrespective of the overburden pressure. However, for silty sand, the silt is more compressible and susceptible to overburden pressure to form a denser structure when higher load is applied. Thus a denser structure tends to produce a higher response of pore water pressure.

B Amount of soil washed out

After the test, the soil that is washed out into the water tank is collected. The result is shown in Table 2. For pure sand, only very small amount of soil is collected. For silty sand, the amount of washed out increases with increasing amount of silt. Moreover, more amount of washed out is collected at higher overburden pressure.

Table 2. The amount of soil washed out.

Silt content \ Pressure	70 kPa	140 kPa
Pure sand	32.47 g	39.62 g
10% of silt	41.96 g	435.87 g
20% of silt	505.11 g	696.43 g

C. Settlements

The effect of overburden pressure and the amount of silt on settlement is shown in Figure 6. For all the cases, settlements are very small for longer wave periods. But the settlement increases as the wave period becomes short.

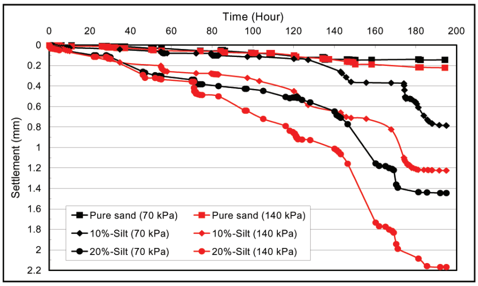


Figure 6. Settlement curves under various amount of silts.

For pure sand, the settlement is nearly the same under different overburden pressures. For silty sand, more fine particles have been washed out that result in particle rearrangement; therefore the settlement is larger than that of pure sand.

Table 3 shows the maximum settlements under different wave periods and overburden pressures. Under high overburden pressure, higher pore water pressure is produced and the soil is more easily to be washed out resulting in more settlement to occur.

Table 3. The maximum settlement of all cases.

	Wave period (sec)	Duration (hr)	Max. settlement (mm)	
			70 kPa	140 kPa
Pure sand	600	0~48	0.015	0.031
	300	48~100	0.058	0.072
	150	100~134	0.120	0.113
	75	134~194	0.145	0.222
10% silt	600	0~54	0.025	0.055
	300	54~120	0.136	0.450
	150	120~174	0.440	1.121
	75	174~195	0.787	1.226
20% silt	600	0~70	0.306	0.335
	300	70~125	0.537	0.924
	150	125~170	1.221	1.832
	75	170~195	1.446	2.169

6 CONCLUSIONS

A The peak value of pore water pressure increases as the wave period decreases when the amount of silt keeps constant. Moreover, increasing the amount of silt will also increase the peak value of pore water pressure.

B For pure sand under different overburden pressure, the difference in pore water pressure is insignificant. But silty sand under higher overburden pressure will have higher response of peak pore water pressure.

C The amount of soil washed out increases with increasing amount of silt. Additionally, more amount of washed out is collected at higher overburden pressure.

D For pure sand, the settlement is negligible irrespective of the overburden pressure. On the other hand, for silty sand, higher overburden pressure causes more settlement to occur. Furthermore, the settlement increases as the wave period decreases.

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