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Stability of punctured geotextile filter in large-scale physical model for coastal revetment

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ABSTRACT: Geotextile filters have been used in coastal revetment projects for many years. However, most research done so far concentrates on uni-directional flow condition. The stability of the soil-geotextile interface subjected to dynamic and cyclic wave action is different from that under uni-directional flow. Furthermore, geotextiles are likely to be punctured during installation in the field. Thus, there is a need to study the effect of punctured holes as well as the size and location of the holes on the soil-geotextile interface stability. In this study, large-scale physical flume model of revetment filter was conducted with modelled cyclic wave action. The results showed that erosion would occur only when there are punctured holes within the surf zone and cause instability. In addition, there exists a critical punctured hole size beyond which the stability is impaired.

1 INTRODUCTION

Geotextile filters have been used in coastal revetment projects for many years; however, the performance of the geotextile filter under cyclic wave action has not yet been clearly validated. Most experimental studies conducted to evaluate the performance of geotextile filters concentrated on uni-directional flow condition solely (Loke, 1992). However, the alternating flow through the geotextile filter in coastal revetment creates a cyclic flow regime quite different from the uni-directional flow. The design philosophy and methodology of the geotextile filter that was based on research conducted on the uni-directional flow may not adequately reflect cyclic flow of in-situ conditions.

Geotextiles are likely to be punctured during installation in the field conditions. The concern that the presence of punctured holes may lead to the failure of geotextile fillers calls for a need to carry out research to validate the effect of punctured holes as well as the size and location of the holes on the soil-geotextile interface stability.

At the National University of Singapore, a physical model of the revetment with geotextile filter has been established in a large-scale wave flume. In order to look into the stability of the soil-geotextile interface and the performance of the geotextile filter under the wave of designated number of cycles, measurements were taken to evaluate the deformation of the revetment model and the changes in soil particles size distribution near the filter after designated number of wave cycle.

The punctured holes were modelled by a series of pre-cut "V" shape holes of pre-determined size on the geotextile. These holes were exposed directly to the wave during testing in this series of test to evaluate whether the punctured hole location is critical for the soil-geotextile interface stability and how the erosion develops due to the presence of punctured holes. The ultimate concern is to evaluate whether the presence of those punctured holes would always imply the revetment failure. If not, it is thus useful to determine the critical hole size of which the erosion on geotextile initiated, as well as the significance of the location of these critical punctured holes.

2 EXPERIMENTAL SET-UP & PREPARATION

The large scale flume test model includes the assembled components of the large scale revetment model with the geotextile filters, the wave generation and control system and the instrumentation. The wave flume used is a ferrocement wave channel of 35.2 m long, 2.0 m wide and 1.3 m deep as shown in Figure 1. The wave generation system consists of a hydraulic servosystem, which gives the vertical wave paddle a horizontal translational movement. Different waves with the combination of different wave periods and different wave heights can be simulated by this wave generator. The parameters of wave used in this research are as follows: Wave Height = 30 cm, Wave Length

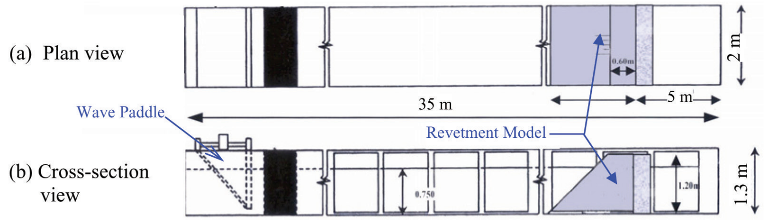
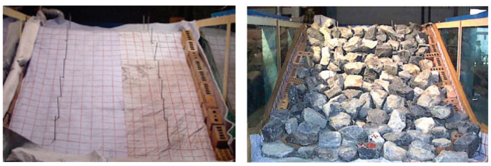


Figure 1. Schematic diagram of wave flume.

= 4.75 m, Wave Period = 2 second, Phase velocity = 2.375 m/s, Depth of Water = 0.75 m.

In the flume opposite the wave generation system, a revetment model was constructed. The model is having a slope of 1V:2H, with sand fill as the base soil (Figure 2), on which geotextile filter was placed. The properties of the geotextile used in this research are summarized in Table 1. Figure 3 presents the particle size distribution of the subsoil, together with the opening size of the geotextiles. Settlement plates with sharp stamp were placed above this geotextile layer at various locations along the slope, as shown in Figure 4. On top of this geotextile filter, layer of stones simulating riprap were placed.



(a) Laying geotextile during model construction

(b) Complete revetment model before wave action

Figure 2. Revetment model.

Table 1. Index properties of geotextiles tested.

Properties	Test Standard	Geotextiles
Name		NW1
Type		Nonwoven
Polymer type		Polypropylene
Mass per unit area (g/m^2)	EN 965	400
Thickness (mm)	EN 964-1	3.5
No. of Constrictions	*	25
Opening size O_{90} (mm)	EN ISO 12956	0.08
AOS O_{95} (mm)	ASTM D 4751	0.1
Cone drop test (mm)	EN 918	12
Tensile strength (kN/m). MD/CD	EN ISO 10319	23/23
Elongation at max. load (%). MD/CD	EN ISO 10319	85/85
Max. absorbed energy (J/m)	EN ISO 10319	10,000

Holes were cut in the geotextiles to simulate punctured holes in geotextiles in the field. All of punctured holes are cut in "V" shape with 120° in this test, as shown in Figure 5, based on the field observation by Wong et al. (2000). The test was conducted starting from a small hole at these "V"s,

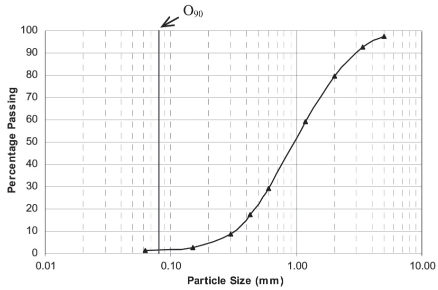


Figure 3. Particle size distribution and geotextile opening size.

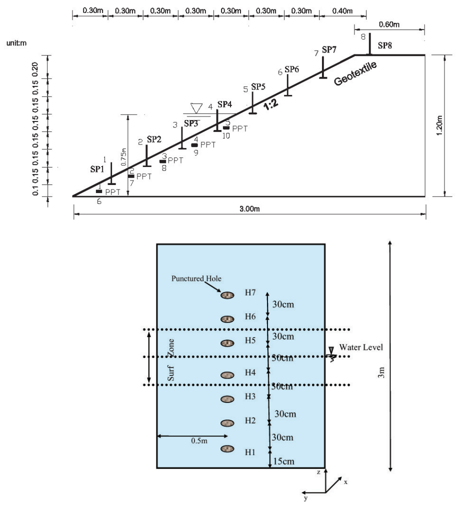


Figure 4. Revetment model with locations of settlement plates.

and the punctured holes were subsequently enlarged by cutting along the "V" lines centimeter by centimeter until serious erosion occurred. Punctured hole was positioned near the settlement plates, therefore if erosion occurred, the settlement plates would move drastically and be able to be identified.

3 EXPERIMENTAL RESULTS

As shown in Figure 6 (phase A), at the beginning, a small "V"-shaped cutting of size 20 mm was cut at

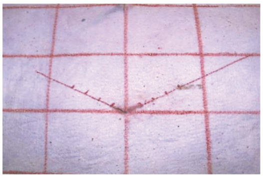


Figure 5. Punctured holes in the geotextile filter.

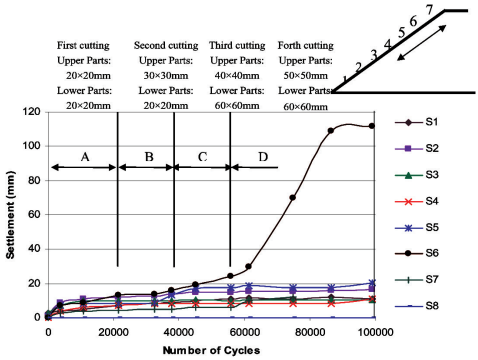


Figure 6. Vertical deformation of the revetment model.

both upper and lower parts of the slope of NW1 geotextile. During this phase, no serious erosion occurred. Subsequently, the hole at the upper parts was increased to 30 mm while the lower part remained at 20 mm (in phase B). Within this phase, the deformation remained very small. The hole at the lower part of the slope was increased from 20 mm to 60 mm, while the upper part was increased from 30 mm to 40 mm (phase C). The settlement at this phase was still very small, indicating that the holes at lower part may not be critical at all. The holes at the upper part were continued to enlarge until 50 mm (phase D). At this time, the erosion occurred and lots of sand was eroded from the punctured hole. Within the erosion zone, the settlement plates settled very rapidly at this phase at settlement location S6. However, erosion occurred only within the surf zone; and no serious erosion and settlement was observed beyond the surf zone. This explains the observation that larger holes at lower part of the slope have no effect on the erosion.

The erosion took place near the top punctured holes and formed a distinct deformed pattern near each of these pre-cut holes. It is noticed that serious deformation near the punctured holes occurs at the erosion zone only. For punctured hole outside the surf zone, no erosion is observed; even when the size of these punctured holes are larger than the size of punctured holes in the erosion zone.

The effect of wave action on the sand particles movement is shown in Figure 7. This figure shows the particle size distribution curves for soil sample taken directly under the punctured hole outside the

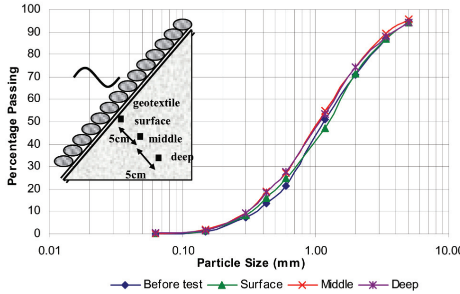


Figure 7. Subsoil particles distribution outside the surf zone.

surf zone. The particles size distribution curves almost coincide with pre-test curves, which indicates that if the punctured hole size is smaller than the critical hole size, there is no serious erosion occurs there and the punctured holes in the geotextile filter do not influence the soil particles movement.

It should be stressed that due to limited dimension of the flume used, the surf zone is located near the upper part of the revetment model. Therefore the erosion zone is also near the top of the slope, thus there is no stability problem even if the erosion occurred (Fig. 8 (a)). However, in the real revetment slope, the tidal variation may be much larger, such that the surf zone might be a certain depth below the top of the slope. Hence, if erosion occurred and there was significant soil mass above this erosion zone, then slope instability may occur, as shown in Figure 8 (b).

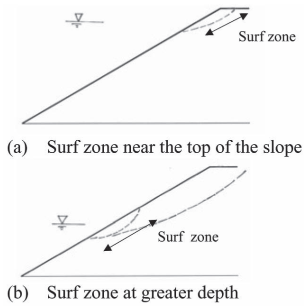


Figure 8. Effect of erosion on the slope stability.

4 DISCUSSIONS

4.1 *Effect of punctured holes position*

It is well-known that the wave dynamic energy applied onto a revetment slope is the largest at the surf zone. Therefore, the drag force in the surf zone is larger than that of other area of the revetment model. During wave action, the punctured holes in the surf zone are subjected to the greatest wave drag force, especially when the undertow occurs. Under some condition, the punctured hole in the geotextile would become a potential draining path so that sand particles are eroded from these holes.

The wave action will have a different effect if the punctured hole is located at different positions. Given the same punctured hole size, erosion would occur only on the punctured holes within the surf zone under severe conditions. For punctured holes present outside of the surf zone, no erosion was observed.

To further ascertain that only the surf zone is critical in erosion if there are punctured holes in it, the punctured holes sizes outside of the surf zone were increased to be larger than that of the hole within the surf zone. The result of the stability of the soil-geotextile interface is also summarized in Figure 9. In subsequent tests, the holes at the bottom were cut to be much bigger to start with, as it was observed that they do not affect the stability at all. Although there was a much larger punctured hole at the bottom of the slope, this did not result in any form of erosion or excessive settlement near the punctured holes at these locations. Figure 9 shows that there was no severe erosion occurring in punctured holes outside the surf zone in all cases. Erosion took place near the punctured holes in the surf zone, when their punctured hole sizes reach certain critical sizes. Hence it can be concluded that the punctured hole location has a significant effect on the stability of the soil-geotextile interface.

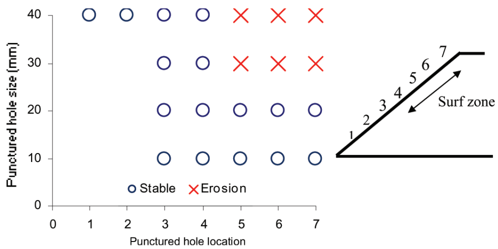


Figure 9. The stability of soil-geotextile interface under wave action.

4.2 *Effects of punctured hole size*

Referring to Figure 9, it was observed that at certain hole size, the soil-geotextile interface starts to be unstable, and erosion occurs. A limiting punctured hole size can be defined as the critical punctured hole size under this condition.

The critical punctured hole size is a function of the position as discussed earlier. It should be noted that the hole size outside of surf zone can be larger than this critical hole size, and yet no erosion occurs. It is expected that the critical punctured hole size far away from the surf zone could be very large. It can be envisioned that along the slope, the critical punctured hole size increases with increasing depth. Beyond a certain depth, the critical punctured hole size would even be infinity. It means that beyond the surf zone the geotextile protection becomes unnecessary.

5 CONCLUSIONS

In this research, the large-scale flume model is capable of simulating the cyclic wave regime at the geotextile filter in coastal revetment application successfully. The simulation of the cyclic flow is necessary for a better understanding of the performance of geotextile filter in coastal revetment structure.

The results showed that soil-geotextile interface can still be stable, even if there are punctured holes on geotextile, as long as they do not exceed certain critical hole size.

It was found that the critical punctured hole size is a function of the position and the most critical location for the punctured hole is at the surf zone. The critical size of punctured holes outside of the surf zone could be very much larger than that in the surf zone and yet no erosion occurs.

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