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Clogging evaluation on cross-plane flow performance of geotextile filter

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ABSTRACT: The objectives in this study are to consider the cross-plane flow performance required as filter and separation materials and to establish a test method for estimating a clogging phenomenon of geotextile filter adequately. A series of constant head permeability test on two kinds of geotextile filter which thickness differs was performed. A geotextile filter was put in between a fine-grained sand layer and a sand layer. The geotextile filters used tothe test were 3 mm and 4 mm in thickness, which were spunbonded nonwoven fabric made of polypropylene resin. Based on the test results, the following results were obtained. It was confirmed that the coefficient of permeability, k, became small as amount of clogging increases in the geotextile independent with the thickness of the geotextile. It was found that the cross-plane flow performance of the geotextile filters of 3 mm and 4 mm in thickness was almost the same.

1 INTRODUCTION

Recently, a geotextile filter has been used as separator and filter material between the surrounding ground and crushed gravel layer around underground pipe or roadbed and subgrade of road. In the design of these cases, a consideration of permeability is important. Clogging is closely related to permeability and flow capacity (Christopher et al. 1992). When a geotextile filter is used as a drainage layer in an embankment, the in-plane flow performance of geotextile filter decreases due to a clogging by infiltration of soil particle and effect of confining pressure by an embankment load (e.g., Giroud 1996, Miyata et al. 1996, Gardoni et al. 2000). Since an in-plane and a cross-plane flow performance depend on each other, the cross-plane flow performance decreases due to a clogging arised in an in-plane direction (e.g., Makiuchi et al. 2002). In the cross-plane flow performance, the adequate opening size to various soil conditions is not proposed. In addition, a flow performance for a long term is not clear on a geotextile filter.

In this study, a series of constant head permeability test on two kinds of geotextile filter was performed. Based on the test results, this paper discusses a clogging evaluation on the cross-plane flow performance of geotextile filter.

2 TEST PROCEDURE

2.1 *Test materials*

The geomaterials used for tests were Toyoura sand and fine-grained sand obtained in the campus of Muroran Institute of Technology. Fig. 1 shows the grain size distributions of Toyoura sand and fine-grained sand. Each physical property is shown in Fig. 1. In the fine-grained sand, the liquid limit is 36.39 % and the plastic limit is 31.42 %.

The geotextile filters of 3 mm (GT1) and 4 mm (GT2) in thickness, which were spunbonded nonwoven fabric made of polypropylene resin, were used. Table 1 shows the properties of GT1 and GT2.

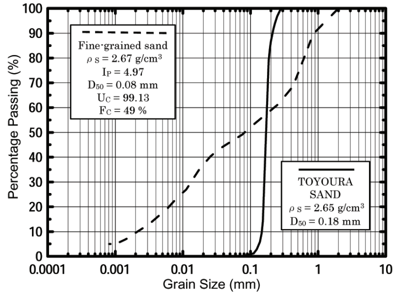

Figure 1. Grain size distribution of testing materials.

Table 1. Properties of GT1 and GT2.

Geotextile filter		GT1	GT2
Mass per unit area (g/m^2)		300	400
Thickness (mm)		3.0	4.0
Opening size O_{95} (mm)		0.22	0.19
Coefficient of	cross-plane	1×10^{-1}	1×10^{-1}
permeability (cm/sec)	in-plane	1×10^{0}	1×10^{0}

2.2 *Testing methods*

The schematic figure of apparatus used for the constant head permeability test is shown in Fig. 2. The specimen was prepared as Toyoura sand in upper mold and fine-grained sand in lower mold. The sand layer was prepared by the water-pluviation method as relative density of D_r = 80%. The fine-grained sand layer was preconsolidated from slurry stage under a consolidation pressure of 147 kPa.

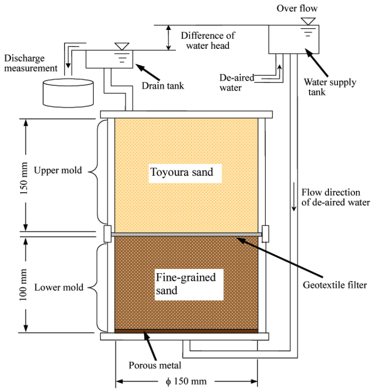

Figure 2. Schematic figure of testing apparatus.

The constant head permeability tests were performed by supplied with de-aired water from bottom side of apparatus. The hydraulic gradient of i = 4 was selected in order to accelerate a clogging arising in the geotextile filter.

3 TEST RESULTS AND DISCUSSION

3.1 *Verification of permeability test method*

Before conducting the constant head permeability test to evaluate a clogging of a geotextile filter, the verification tests were performed in order to investigate the influence on the test result by using of tap water or de-aired water.

Figure 3 shows the relationship between coefficient of permeability, k, and elapsed time obtained from the constant head permeability test by using of tap water under the hydraulic gradient of i = 1. In the case of sand only filled in a mold without geotextile filter, the value of k tends to decrease slightly with

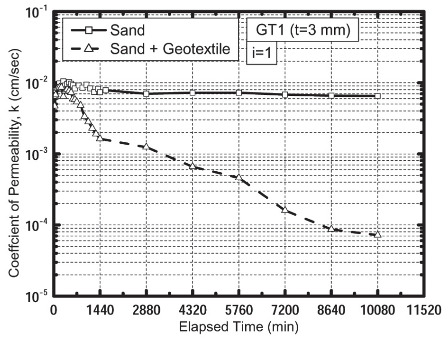

Figure 3. Relationship between k and elasped time (tap water).

an increase of elapsed time. On the other hand, in the case of a geotextile filter installed between upper mold and lower mold filled up sand, k decreases noticeably from 600 minutes.

Figure 4 shows a comparison of degree of saturation, S_r. In the case of sand only, the value of S_r decreases noticeably with an increase of elapsed time, whereas the value of S_r in the case of geotextile filter installed in a mold tends to decrease up to 1440 min., after that, S_r indicates almost constant value. Then, the constant head permeability tests were performed by filling only tap water in a mold. As shown in Fig. 5, air bubbles are adhering to an inner surface of mold and air clump is seen at a top of mold. It is considered that an air contained in a tap water affects the result of constant head permeability test.

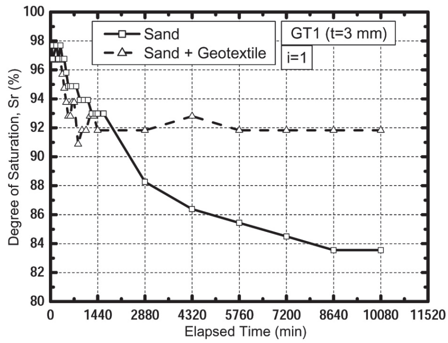

Figure 4. Relationship between S_r and elasped time (tap water).

Figure 6 shows the relationship between coefficient of permeability and elapsed time obtained from the constant head permeability test by using of de-aired water under i = 1. The values of k in the case of sand only and geotextile filter installed indicate almost constant values, and both value of k is consistent with each other.

Figure 7 shows a comparison of degree of saturation in the case of sand only and geotextile filter installed

Figure 5. Generation of air bubbles and air clump.

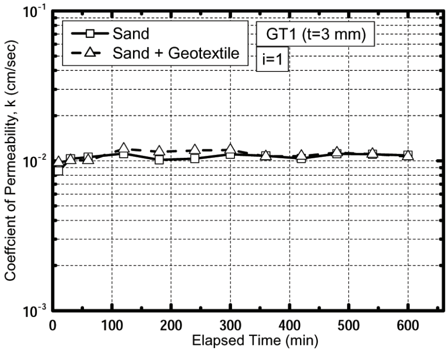

Figure 6. Relationship between k and elapsed time (de-aired).

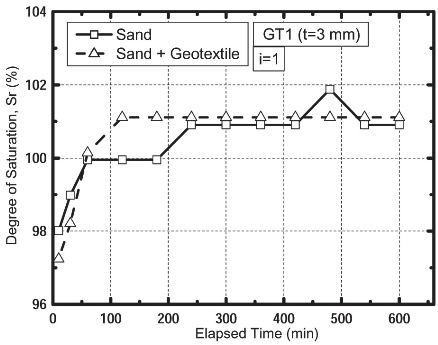

Figure 7. Relationship between S_r and elapsed time (de-aired).

in a mold. In either case, the degree of saturation reaches 100% in about 60 minutes and indicates almost constant value independent of elapsed time.

Judging from the above, it is found that the use of de-aired water lead to the adequate evaluation for cross-plane flow performance on the permeability test.

3.2 *Clogging evaluation on flow performance*

To investigate a relationship between a permeability of geotextile filter and the amount of clogging, a series of the constant head permeability test under i = 4 were performed by using of clogged geotextile filter without soil in the mold. In this paper, the amount of clogging was defined as follows;

(amount of clogging) = (mass of geotextile filter after the permeability test) – (mass of geotextile filter before the permeability test) (1)

Figure 8 on the clogged GT1 and Fig. 9 on the clogged GT2 show the relationship between coefficient of permeability and elapsed time, respectively. In these figures, the results of virgin geotextile filters are compared with the results of clogged filters. The values of k on the clogged geotextile filters indicate a trend to increase with the increase of elapsed time. It is considered that this is caused by the outflow of soil particles in the clogged geotextile filter since amount of clogging after the test was decreasing compared with amount of clogging before the test. Therefore, the values of k on the elapsed time at 10 minutes are compared when the outflow of soil particle is smallest. In Figs 8 and 9, the values of k of clogged geotextile filters are smaller than the k of virgin geotextile filters on elapsed time at 10 minutes for all cases. The coefficient of permeability becomes small as the amount of clogging is large independent of the thickness of geotextile filter.

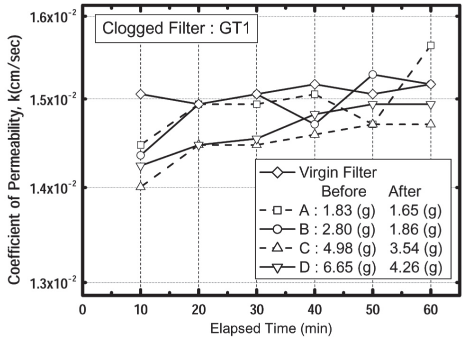

Figure 8. Relationship between k and elapsed time (Clogged GT1).

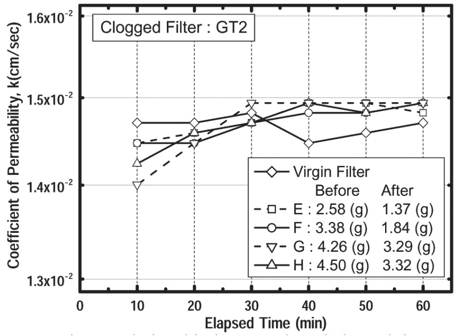

Figure 9. Relationship between k and elapsed time (Clogged GT2).

Figure 10 shows a comparison of coefficient of permeability obtained from constant head permeability tests on virgin GT1 and GT2 without geomterials in the mold. The values of k of GT1 and GT2 are almost constant independent of elapsed time. Then, it is considered that both cross-plane permeability performances are similar.

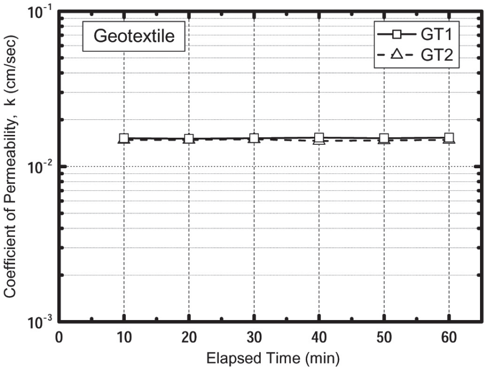

Figure 10. Relationship between k and elapsed time (GT1 and GT2).

Figure 11 shows the results of constant head permeability tests under i = 4, which a virgin geotextile filter was installed between upper mold filled up Toyoura sand and lower mold filled up fine-grained sand. The difference between a value of k of GT1 and GT2 is relatively large to 40 hours. However, both coefficient of permeability degrease in a similar way subsequently, both value indicate the constant value of about 5×10^{-6} cm/sec in more than 140 hours. Therefore, it seems that the cross-plane flow performance of GT1 and GT2 was almost the same for a long term.

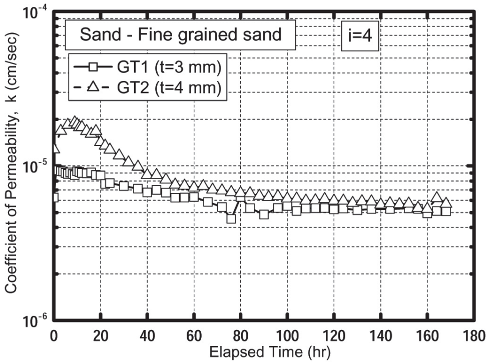

Figure 11. Relationship between k and elapsed time (Sand – Fine granied sand).

Amount of clogging of GT1 and GT2 calculated by equation (1) after permeability test is shown in Table 2. The both amount of clogging is equal. If the vertical stress acting on GT1 and GT2 are same, it is assumed that both amount of compression is same. When amount of compression is ignored, a clogging per unit volume is defined as amount of clogging divided by volume of geotextile filter used as test specimen, which is calculated by using of thickness as product specification. Amount of clogging per unit volume of GT1 and GT2 is shown in Table 2. The value of GT1 is about 1.4 times of GT2. According to Fig. 11, the coefficient of permeability of GT1 tends to smaller than GT2. This is consistent with amount of clogging per unit volume of GT1 larger than that of GT2.

Table 2. Amount of clogging of GT1 and GT2.

Geotextile filter	GT1	GT2
Mass before test (g)	7.36	10.49
Mass after test (g)	8.24	11.38
Amount of clogging (g)	0.88	0.87
Amount of clogging per unit volume (g/cm^3)	0.0122	0.0090

4 CONCLUSIONS

The following conclusions were derived from the results of a series of permeability tests on geotextile filters.

(1) It was confirmed that the use of de-aired water lead to the adequate evaluation for cross-plane flow performance on the permeability test.
(2) The coefficient of permeability becomes small as the amount of clogging is large independent of the thickness of geotextile filter.
(3) It seems that the cross-plane flow performances of geotextile filters used in this study are almost the same for a long term.
(4) Proposed amount of clogging per unit volume is available to clogging evaluation on cross-plane flow performance of geotextile filter.

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