Interpretation of clogging effects on the hydraulic behavior of ion treated geotextiles

Lee, K. W.
Department of Civil Engineering, Dongseo University, Busan, Korea
Jeon, H. Y.
Division of Nano-Systems Engineering, INHA University, Incheon, Korea
Zornberg, J.
Department of Civil, Architectural and Environmental Engineering, The University of Texas at Austin, Austin, USA

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ABSTRACT: Clogging retention improvement can be increased if the geosynthetic is treated by negative ion material in accordance to the knowledge that fine soil particle is negatively charged material. In this study, column tests were conducted to examine the effects of negative-ion treatment by using various types of ion-treated geotextiles filters. It was found that the negative ion treatment gave apparent increase of drainage capacity after long time as describe on this paper. Clogging effects of two non-woven geotextiles filters treated by negative ion (10%; NI-10 and 20%; NI-20) were compared to non-ion treated one (control) by long term filtration test. This study resulted in the highest drainage capacity obtained by NI-20 followed by NI-10 and control.

1 INTRODUCTION

Prefabricated vertical drains have been widely used for drainage and filtration to accelerate consolidation due to pre-loading and improvement to the soft ground. (Das 2002, Shukla 2002) During the primary consolidation phase, the drainage capacity of the vertical drain will decrease as the time goes by, which is affected by several factors such as; 1) magnitude of confining pressure in soil among vertical drains, 2) hydraulic gradient along vertical drain of which the well resistance is affected, 3) physical disturbances on the vertical drain (bending, folding, twisting, and crimping), 4) installation disturbance (smear zone), air bubbles stuck into vertical drain, and 5) permeability of vertical drain influenced by intrusion of fine particles termed as filtration and clogging. (Palmeria and Gardoni 2000) These effects, together with clogging and filtration, occur after long time using the vertical drains because the initial flow is controlled by the hydraulic gradient and properties of the soil, not by geotextile-soil system. (Gardoni and Palmeria 2002) The physical disturbance and other factors seem inevitable in the geotechnical field; however the clogging and filtration of the fine soil particles may be reduced if the geotextile is equipped with particular substance that may impede the fine soil particle into its fiber. The purpose of this paper is to examine the effectiveness of those three non-woven geotextile specimens on increasing the drainage capacity.

2 EXPERIMENTAL

Soil materials tested in this experiment is mainly clayey silt. Sand and gravel were functioning as water storage before the water is flowed through the drainage valves. Due to this role, sands were selected from parts retained by standard sieve #40 and gravel sizes were chosen retained by standard sieve #4. Clayey silt soil was remolded and determined to simulate marine clay with the high water content and compressibility. Negative ion materials contained in the specimens are extracted from a mountain stone in Japan called "E-stone". There are two kinds of stone distinguished by their colors. The colors of "E-stone" give different composition / component inside them as described in Table 1.

Table 1. Properties of e-stones.(unit: %)

Comp / E-stone	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	K_2O	Na_2O	Lg. loss
Red	77.20	12.49	0.70	0.03	0.18	0.06	4.65	3.51	0.43
White	66.09	19.55	0.19	0.03	0.40	0.11	6.48	6.58	0.26

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Two specimens (NI-10 and NI-20) were treated with this stone for a special purpose. These two specimens were compared to the control one The following Table 2 gives the properties of the specimens (geotextile) used.

Table 2. Properties of geotextile specimens.

Properties	Geo-0%	Geo-10%	Geo-20%	Remark
Mass (g/m^2)	177.8	220	195.3	KSK 0514
AOS (μm)	85.2	58.6	59.9	ASTM 6767
Tensile strength (kgf/m)	551	639	659	KSK 0520
Permeability (cm/sec)	2.5x10^{-1}	4.2x10^{-1}	2.8x10^{-1}	KSF 2322

Geo 0%: control, Geo-10%: NI-10, and Geo-20%: NI-20.

The clogging apparatus consists of two parts, they are flexi glass chamber and air pressure supplier (Fig. 1).

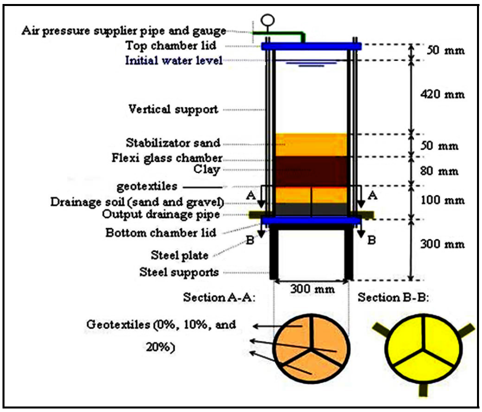


Figure 1. Schematic diagram of clogging test apparatus

Non-woven geotextile (as separation material) was installed to suspend and keep the bottom surface of all specimens. The clayey silt was then mixed until it got higher water content. Before the last sand layer was poured, full-circle-shape of non-woven geotextile had had to be put again as separation to prevent the intrusion of sand layer that would disturb the drainage length of the water through the clayey silt. Sand, gravel, geotextile specimens, and separation materials were made wet to accelerate the saturation of the chamber. Having finished the saturation, air pressure was applied until 40 kPa (this is more or less equal to generate excess pore pressure under common embankment surcharge of 2.0 to 2.5 m high with soil density of 16 to 18 kN/m^3. The volume of water flowing out from the drainage valves was being collected and recorded together with elapsed time. Having finished the test, clogging mass and cross plane permeability of the specimens was analyzed.

3 RESULTS AND DISCUSSION

3.1 *Drainage capacity and efficiency*

The record of accumulated volume of water drained during the test is shown in Fig. 2 and the one of discharge is in Fig. 3. According to Fig. 3, the effect of soil clogged was greatly influenced the system at 96 hours after the test and almost becoming constant after 504 hours until the end of the test. After a certain constant discharge undergoes by each specimen, the distinction of drainage capacity among them become evident (Fig. 3). In this case the discharge of the water was not influenced by the hydraulic gradient applied during the test, but it was merely taken by the soil-geotextile system (counted the clogging factor).

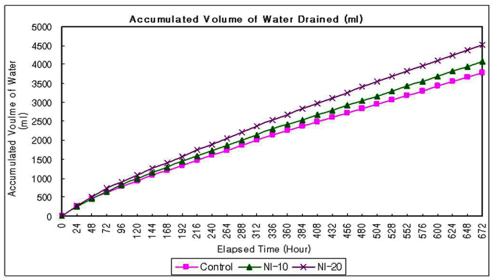


Figure 2. Accumulated volume of water drained

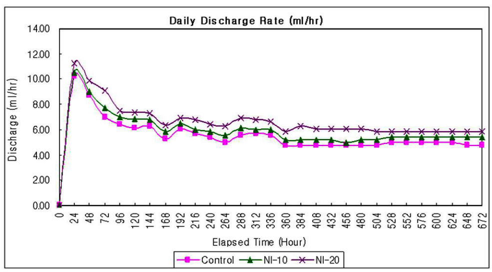


Figure 3. Discharge rate for time passing

It has been proved that specimens (geotextile) used during the test show some different abilities to flow the water when they were partially clogged by soil particles. Fig. 4 and 5 give comparison among the specimen results in the following order form the highest NI-20, NI-10, and the control specimen in respect to drainage capacity.

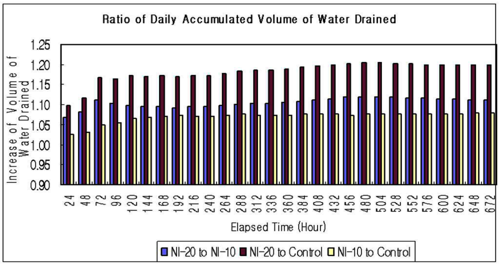


Figure 4. Ratio of daily accumulated volume of water drained

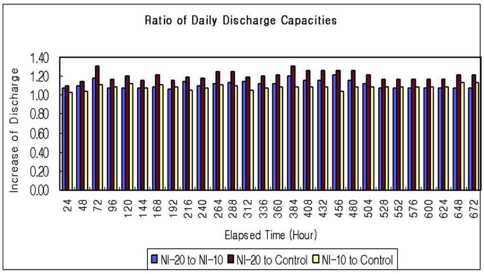


Figure 5. Ratio of daily discharge capacity

The drainage capacities of two negative ion treated geotextiles (NI-10 and NI-20) are apparently above the control one. During the test, the clay was consolidated until its void ratio became 1.75 from the initial void ratio of 3.0 (Fig. 6). The final void ratio almost remained constant after 120 hours. This clay was experienced high compression at the beginning of the test so that after, for example, 24 hours the void ratio reached 2.3 from 3.0. Furthermore, the cross plane permeability tests were conducted to all specimens. The cross plane permeability tests were falling head mechanism as ever suggested to approach its value. There was no certain test machine standard used for this test in respect to cover all area of the specimens. Falling head tests were conducted at the bottom part of the apparatus with 5.2 cm de-aired water head and 0.5 cm grease sealing to the perimeter of the specimens and the adjacent flexi glass walls to prevent water flows through the perimeter of the specimens. Fig. 7 (a) shows the decreasing of specimen cross plane permeability due to clogging. Week 0 (Fig. 7 (a)) refers to the initial cross plane permeability of the specimens. Decreasing of specimen cross plane permeability are about hundred times (Fig. 7 (b)). Although the decreases of the cross plane permeability are very high, the final cross plane permeability values are still acceptable to prevent excessive clogging regarding to the minimum cross plane permeability value for geotextile (without clogging) is 8×10^{-4} cm/s.

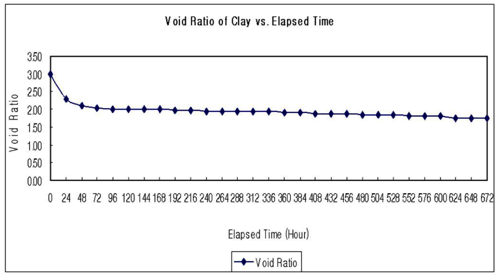
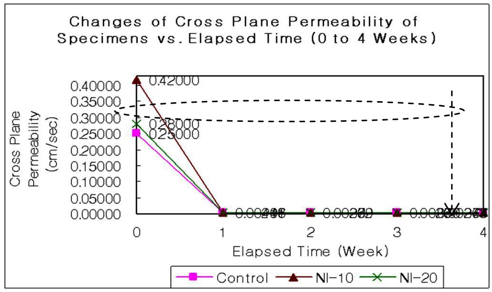
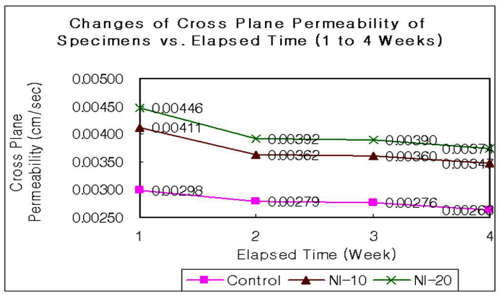


Figure 6. Decrease of void ratio.



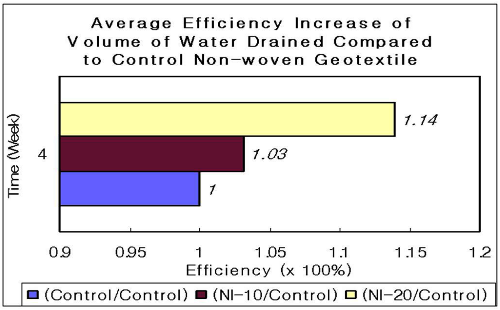
(a)



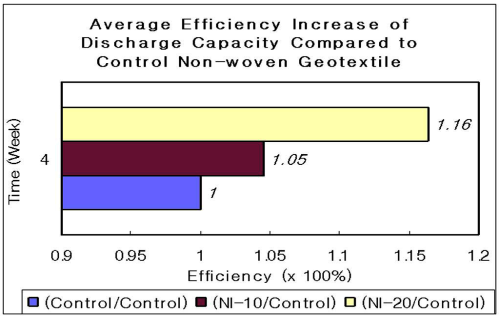
(b)

Figure 7. Changes of cross plane permeability of the specimens during 0 to 4 weeks (a) and 1 to 4 weeks (b)

By using specimen NI-20, the average efficiency increases are about 14% for volume of water drained (Fig. 8 (a)), 16% for discharge capacity (Fig. 8 (b)) compared to those of control specimen. The average efficiency increases, by using NI-10, are 3% for volume of water drained (Fig. 8 (a)) and 5% for discharge capacity (Fig. 8 (b)) compared to those of control specimen.



(a)



(b)

Figure 8. Increases of efficiency by using negative ion treated non-woven geotextiles in respect to volume of water drained (a) and discharge capacity (b)

3.2 *Effect of negative ion on clogging*

The intrusion of soil particles into the non-woven geotextile specimens causes the increase of one's weights. Fig. 9 shows the final weight of the specimens after every one week (Weights at week 0 refer to initial ones).

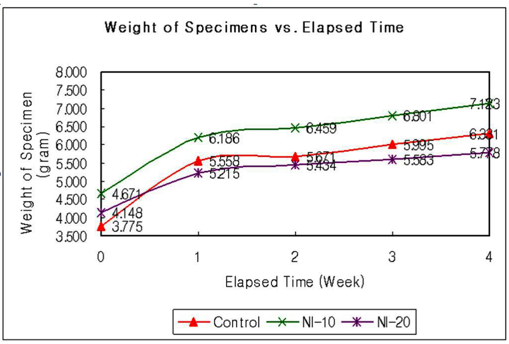


Figure 9. Final weights of specimen every week.

Fig. 10 shows the increase ratio of specimen weights. Although NI-10 has higher initial and final weights, control specimen has the highest increase ratio of weight after every one week followed by NI-10 and NI-20. In addition Fig. 11 describes the ability of each special treated non-woven geotextiles (NI-10 and NI-20) on reducing clogging compared to the control one. That figure shows the average of clogging decrease by NI-20 is 33.75% and 7.50% by NI-10. NI-10 seems not to give significant results to reduce the intrusion of soil particles.

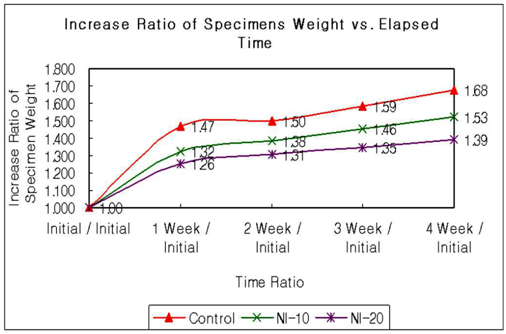


Figure 10. Increase ratio of specimen weights

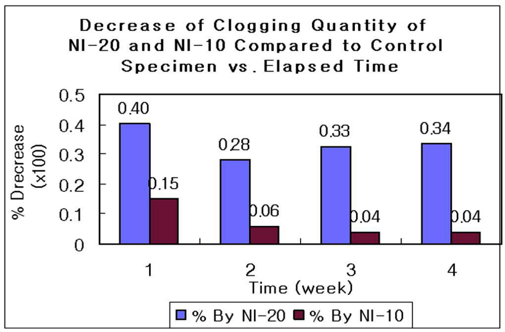


Figure 11. Clogging decrease after every week

4 CONCLUSION

The discharge rate increases about 16% for NI-20 (20% negative ion treated geotextile) and 5% for NI-10 (10% negative ion treated geotextile) compared to the control geotextile (no ion treated). The volume of water drained increases about 14% for NI-20 (20% negative ion treated geotextile) and 3% for NI-10 (10% negative ion treated geotextile) compared to the control geotextile (no ion treated). The average decreases of clogging quantity are 33.75% by NI-20 and 7.50% by NI-10 compared to the control geotextile (no ion treated). The cross plane permeability values reduce about hundred times due to clogging; however, they are still acceptable to prevent excessive clogging.

Some full scale tests are still needed in the future for the development of using E-stone as a part of geosynthetic materials and field test scale involving external water flow boundary (smear effect) and internal one (well resistance and clogging) to compare the results of laboratory test. Furthermore demanding of negative ion materials may lead to the new inventions of stone material and how to treat them properly as parts of geosynthetics. A new provision can be composed as a technical note to standardize the processing and handling of negative ion materials.

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