

ANALYSIS OF FIELD APPLICABILITY PERFORMANCE OF PVD BY HYDRAULIC PROPERTY TEST

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ABSTRACT

For prefabricated horizontal drains, the water flow path must be provided to have drainage and filtration functions properly. It is permitted to flow from the soil mass under the surcharge to appropriate drainage and filtration points. Thus the drains can provide stability of embankment and traffic ability of equipment. Good quality of sands, however, is being exhausted. The problems such as low permeability of sand cause unstability of embankment and low consolidation rate. Expensive raw materials such as sand used for drains prevent cost effective construction. In this study, theoretical studies have been performed for drainage and filtration characteristics, low consolidation rate of sandmat and prefabricated horizontal and vertical drains. These prefabricated horizontal drains were adopted to substitute for sandmat in domestic highway construction sites and test instrumentation was installed to investigate the drainage and filtration capacities of these materials. Finally, discussion on quality control and methodology, cost analysis for sandmat and prefabricated horizontal drains were performed.

Keywords: Prefabricated horizontal drains, drainage and filtration, consolidation, sandmat

INTRODUCTION

As national land development grows, acquirement of nature material is felt constraint gradually in industry spot. We report methods to apply efficiently to soft ground improvement utilizing man-made prefabricated horizontal drains material theoretically and introduce application in several construction field. Sand drain, pack drain, sand compaction pile and plastic vertical drain have been used to improve soft ground. For vertical drains to function properly, a drainage path must be provided. It is to receive flow from the vertical drains installed in the soil mass under the surcharge in order to keep stability of embankment and to increase traffic ability of equipment. Good quality of sands, however, is being exhausted. The problems such as low permeability of sand and high cost cause unstability of embankment and low consolidation rate.

In this study, a theoretical study on the drainage characteristics and low consolidation rate of sand mat and prefabricated horizontal drains (PHDs) were performed. PHDs were adopted to substitute for sandmat at domestic highway construction sites. Instrumentation is conducted to investigate the drainage capacity and applicability of PHDs. In addition, a cost analysis for sandmat and PHDs was performed. A discussion on quality control and

construction method for PHDs is included. Various applications are presented. Finally, guidelines for the design and construction of PHDs are proposed.

THEORETICAL BACKGROUNDS

Use of horizontal drains such as sand mat with low permeability gives bad effects on stability of embankment and results in low consolidation rate. Yoshikuni proposed a model to define delay of consolidation rate related to mat resistance. Until, we have not handled seriously the effects of permeability in drain layer gets on consolidation delay, but Yoshikuni (1969) et al. effect that presented in the consolidation speed model to quantity resistance of sand mat and vertical drain exert (Fig. 1). Goughnour(1997) also discussed delay of consolidation process caused by low permeability of sandmat. He pointed out that excessive pore water pressure was developed in sand layer, causing low consolidation rate but was not in PHDs (Figs. 2 and 3)

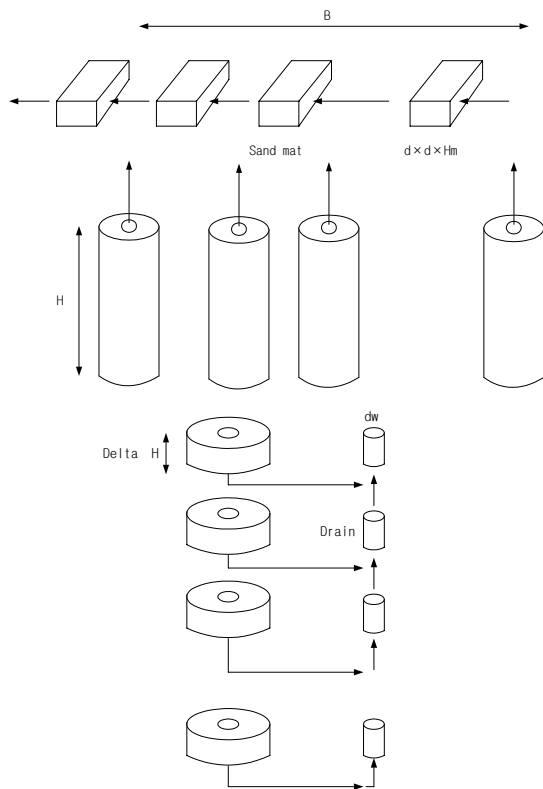


Fig. 1 Relationship of sand mat and sand drains

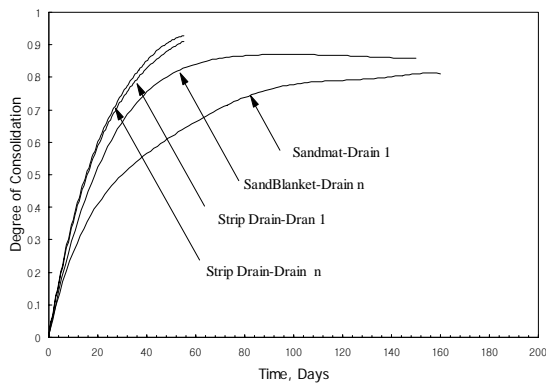


Fig. 2 Degree of consolidation versus time (Goughnour, 1977)

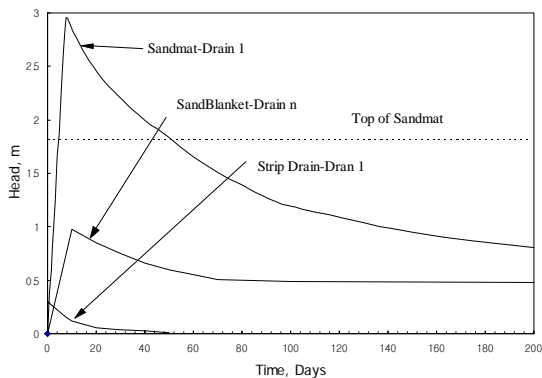


Fig. 3 Degree of pore water pressure versus time (Goughnour, 1977)

PREFABRICATED HORIZONTAL DRAINS (PHDs) METHOD

PHDs method is construction technology to use substitute material of drain layer which use existent sand or crushed rock. Therefore, PHDs method must decide establishment space of PHDs material to have drain ability of drain layer same as natural material of good quality and drain ability. PHDs are comprised of PVC core and polyester filter. Its dimension is 5 to 25mm of thickness and 30 to 100cm of width. Figure 4 shows typical shape of PHDs. Drainage mechanism is that water flow is introduced into PHDs through filter from the vertical drains or soft ground, and then conducted to appropriate drainage point.

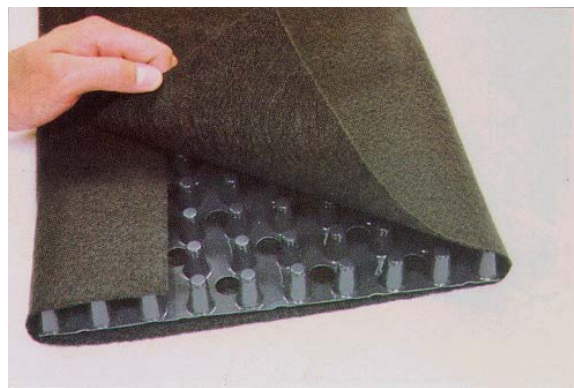


Fig. 4 Typical shape of PHDs

Figure 5 displays basic idea of PHDs material design by typification. We can calculate section of PHDs material that can secure horizontal direction drain ability (quantity of drainage after flow in the inner parts of drainage material interior) more than equality that use sand of good quality as follows. Figure 5 is mimetic diagram for equivalence drain ability comparison. Quantity of drainage per unit width by sand can be calculated (1).

$$q_s = (100 \times h) \times i \times k_s \quad (1)$$

where: i = hydraulic gradient,
 k_s = Permeability coefficient of sand

Also, displacement of PHDs material is written in Eq. 2.

$$q_d = (B \times t) \times i \times k_d \quad (2)$$

where: B = drainage material width,
 t = drainage material thickness
 k_d = drainage material's permeability coefficient

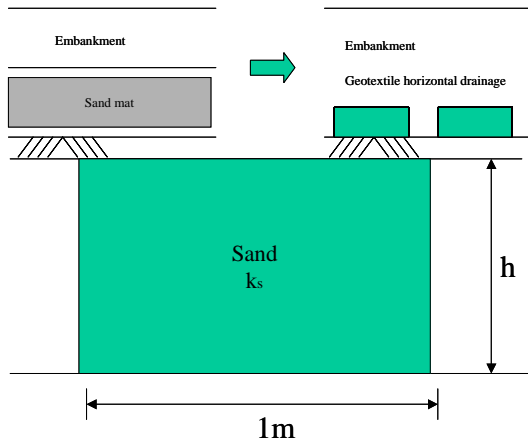


Fig. 5 Schematic view of conceptual design of PHDs for horizontal drainage

If we calculate sand stratum thickness h , permeability coefficient k_s by upper, width of necessary PHDs material per 1.0m to be equal to which drain ability per unit width of drain layer which use sand of good quality can be calculated by Eq. 3.

$$B = (100 \times h \times k_s / k_d) / t \quad (3)$$

Required drainage material width calculated from Eq. 3 can be described, as shown in Fig. 6.

Portion that appear in solid line in picture examines ED drainage material and PD drainage material that is used in this research. ED drainage material drain natural calamity has $1000 \times 5 \text{ mm}^2$ section and section of PD drainage material is $300 \times 10 \text{ mm}^2$. When we assume permeability coefficient of general sand as $1 \times 10^{-2} \text{ cm/s}$ as shown in Fig. 6, need drainage material's width per 1m and equality become by 10~35 cm to secure drain ability more than sand and width of established product is enough to secure the drain ability.

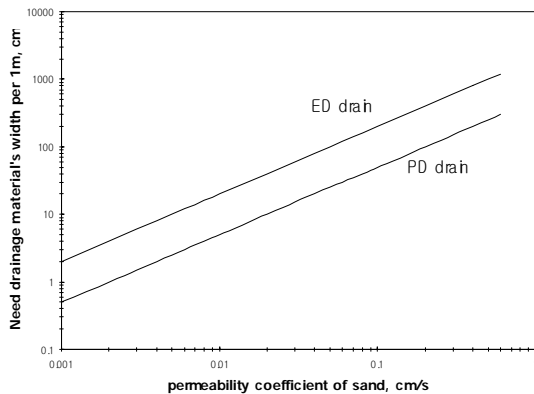


Fig. 6 Relationship between permeability of sand and required width of PHDs

Based on Darcian flow, a relationship between permeability of sand and required width of PHDs used in this study is presented in Fig. 6.

TEST CONSTRUCTION

Various types of PHDs were used at two highway construction sites, MM26-CW and NKJ R-D to investigate drainage capacity and filed applicability. Monitoring with piezometers, settlement gauges and inclinometers were performed. Figures 7 and 8 present instrumentation plans, cross-section of construction sites and plane view of test construction sites.

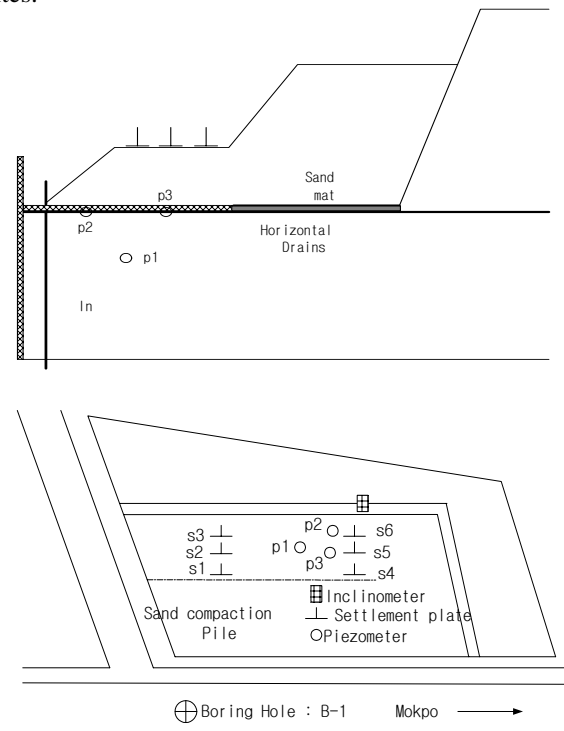


Fig. 7 Instrumentation plan and cross-section/plane view of MM26-CW

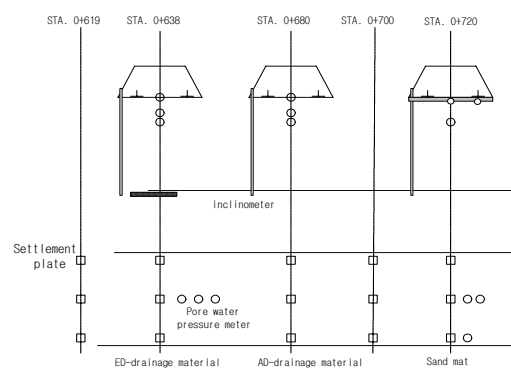


Fig. 8 Instrumentation plan and cross-section/plane view of NKJ R-D

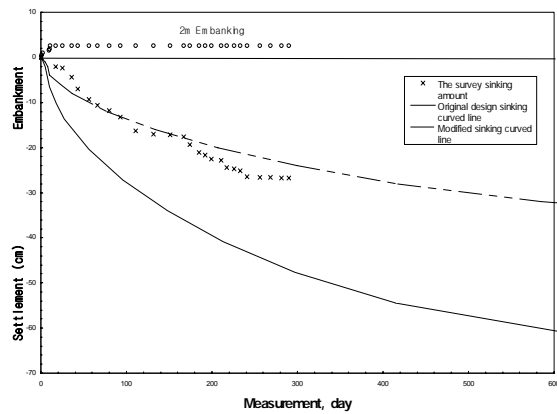


Fig. 9 Monitored and back analyzed settlement at MM26-CW

MM26-CW Site

Figures 9 to 11 show monitored results of settlements, pore water pressure, and lateral displacements at MM26-CW. Common type of consolidation settlement took place. It is thought that additional settlement after 180day of construction is due to lowering of water table. 90~95% of peak water head at ground surface was dissipated. Sudden displacement took place as soon as finishing banking, but additional displacement was not found. Therefore Embankment is thought to be stable.

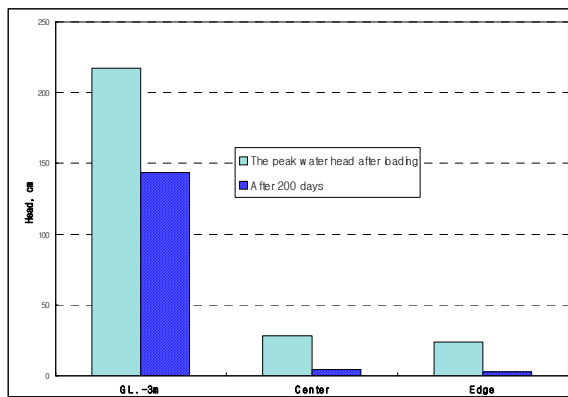


Fig. 10 Changes in water head of test construction site.

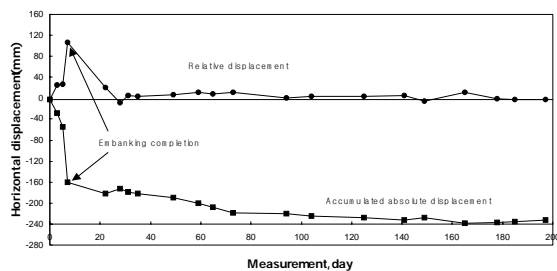


Fig. 11 Lateral displacement measurements

at MM26-CW

NKJ R-D Site

Figures 12 to 14 show measured settlements. The summaries of long-term settlements estimated by ASAOKA method are shown in Table1. The results show that degree of consolidation with PHDs is larger than sandmat.

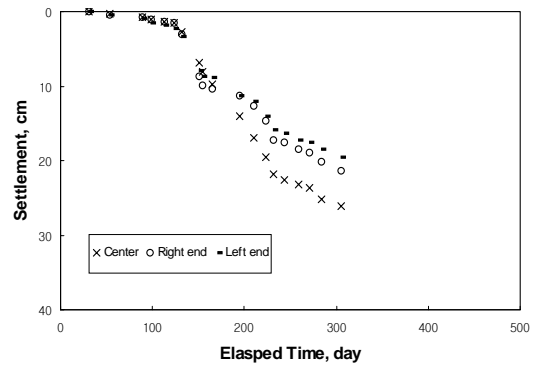


Fig. 12 Monitored settlements at Sta. 0+680 AD- Drains

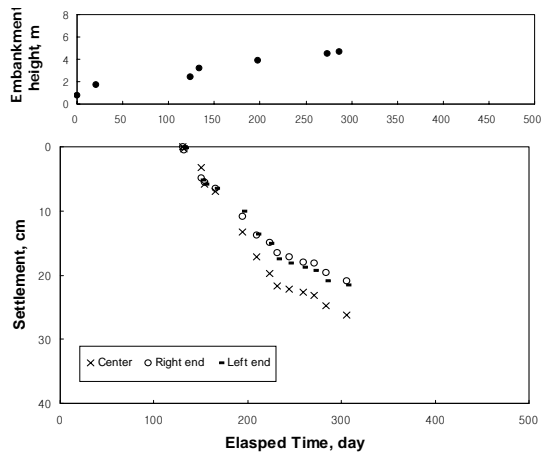


Fig. 13 Monitored settlements at Sta. 0+720 (Sandmat)

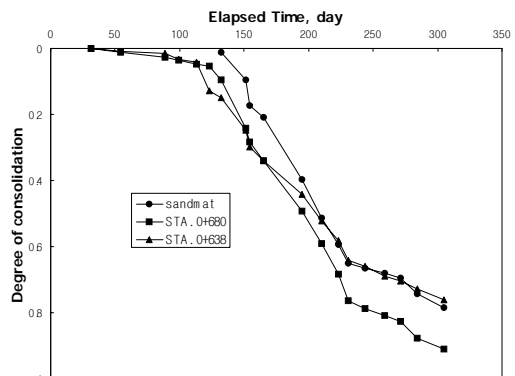


Fig. 14 Degree of consolidation between PHDs and sandmat.

Table 1 Summary of long-term settlements estimated

ta. No.	Asaoka method	Current Settlement (cm)	Avg. U. %	Remarks
0+619	23.4	19.5	83	U.D
0+638	31.4	22.9	73	E.D
0+680	28.7	25.2	88	A.D
0+700	24.4	23.9	97	-
0+720	33.3	24.8	74	Sand Mat

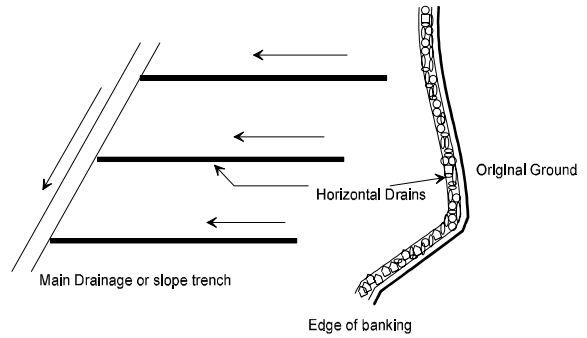


Fig. 17 Application to drainage for expansion section of mountainous area

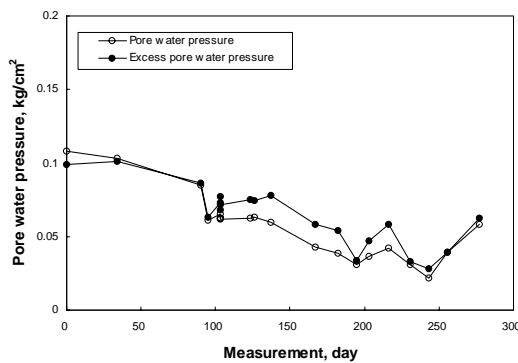


Fig. 15 Pore water pressure measure result (STA . 0+680)

Figure 15 gives pore water pressure measure result in drainage material establishment showing smooth pore water pressure. Pore water pressure rise in last measure work is considered to be due to final bank that happened recently.

APPLICATIONS AND CASE HISTORIES OF PHDS

Horizontal drainage material has various practical use such as drainage hole for bank stability, mountain district extension part's drainage hole, construction drainage hole as well as soft ground width drainage hole is possible and it has construction examples for methods of constructions widely used in international scale and it will be presented next.

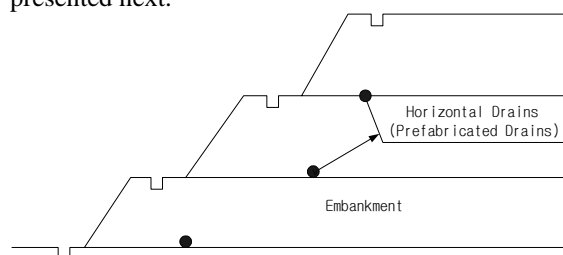


Fig. 16 Application to drainage for stabilizing of embankment using clay soil

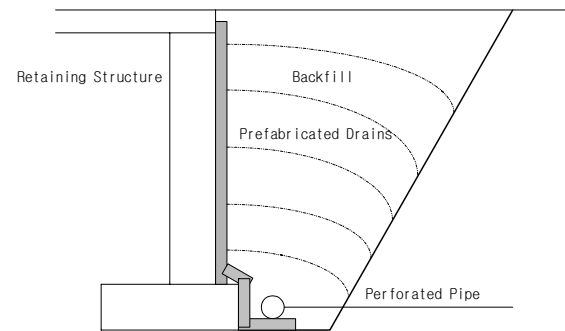


Fig. 18 Drainage behind retaining wall and abutment backfill

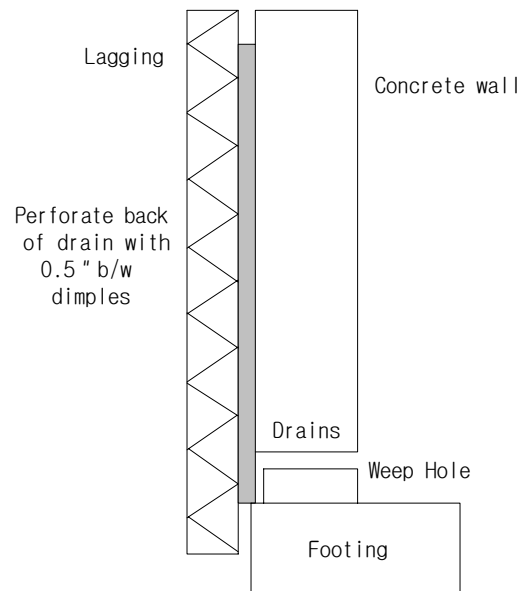


Fig. 19 Drainage at the lagging Wall

CONCLUSIONS

PHDs are used as substitutes for sandmats. Instrumentation monitoring, laboratory tests and cost analysis are performed. The results are as the followings;

1) PHDs have a good constructibility without quality control and construction management, and are very economical.

2) Results of nage capacity analysis show that PHDs have enough drainage capacity in comparison with sand, even though surcharge is present. They, however, show reduction of drainage capacity by surcharge due to decrease on sectional area. Thus compressive strength and decrease on sectional area should be considered in design step.

3) Results found on instrumentation monitoring show that a common type of consolidation takes place without instability of embankment and water dissipate out rapidly. Especially about 80~90% of peak value in total water head was dissipated. It is concluded that PHDs have enough drainage capacity.

4) PHDs material can be used for a substitute of sand mat principal parts in soft ground processing method.

5) PHDs material has various practical use such as drainage hole for bank stability, mountain district

extension department's drainage hole, construction drainage hole as well as soft ground width drainage hole.

REFERENCES

- Barron, R.A. (1948). Consolidation of fine grained soils by drain well, Trans. ASCE., 113: 718-754
- FHWA. (1989). Geotextile Engineering Manual, NHI Course No. 132213
- Ingold, T.S., (1994). Geotextile and Geomembrane Manual. 1st Ed. Elsevier.
- Korea Highway Corporation. (1995).PBD Method, HRC, Annual Report
- Korea Highway Corporation. (1995).Settlement Estimations of Soft Ground, HRC, Annual Report
- Lee, S.H., Kwun, M.N. (1996), A Study on drainage characteristics of geotextile by model test, Journal of KGS, 12(5).
- Yoshikuni, H. and Nakanodo, H., (1995). Consolidation of soil by vertical drain wells with finite permeability, Soils and Foundations, 14(2):35.