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COMPARISON OF NON-WOVEN AND WOVEN GEOTEXTILE AS PACKS FOR VERTICAL DRAIN METHOD

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ABSTRACT

In the conventional packed drain method, a drain column is constructed in compressible soil by driving a casing to a designed depth, placing a cylindrical woven fabric pack or bag inside the casing, filling the pack with sand, and pulling out the casing. Four different types of non-woven and woven fabric packs were made and their performance during the construction was studied through a field test. As filling materials, sand, scrap tire, rock powder, bottom ash were used. Their applicability with respect to the different packs was investigated. An innovative method was introduced which was aimed to prevent the pack from being twisted inside the casing and, thus assure the soundness of drainage column. This method employs a specially designed guiding plate and an anti-twisting rod attached on the inner surface of the casing. The effectiveness of this method was evaluated as compared to that of the conventional packed drain method.

INTRODUCTION

Vertical drains adopted in conjunction with a surcharge scheme is used to accelerate the consolidation of soft clay subsoil. The packed drain method (PDM) stemmed from the conventional sand drain method was first developed by Chioda Construction Co. in Japan in late 1980s. Changes have been made to the size of casing, air pressure for casing pull-out, etc. The PDM employs the installation of vertical sand drains of displacement type, 120 mm to 130 mm typical in diameter and drain spacing on centers in the order of 1 or 2 m. The installation of drainage columns includes: (1) driving simultaneously four closed end casings through drainage blanket into the ground; (2) placing cylindrical net bags inside the casings; (3) filling the bags with sand; and (4) pulling the casings out. Net bags made of woven monofilament mainly serve to maintain the continuity of drains when the drains undergo excessive horizontal and vertical displacements during consolidation settlement of the ground. The two sides of the bag in the direction parallel to the drain are melt-bonded for the bag to be thin plate shaped, which is aimed to prevent the bag from being twisted inside the casing.

In order to assure a successful installation of a drainage column, the upper part of the drain is constructed to stick out of horizontal drainage blanket by a predetermined length. In case where the protruding portion of the drain is excessive or non-existing, installation is considered unsatisfactory. Unsatisfactory installation can be caused by many reasons including use of poorly made bag, twisting of bag inside the casing before filling, construction flaws in filling, improper operation during extracting of the casing, and so forth (Chung et al. 1996 and Koh 1995). The PDM was introduced in Korea in early 1990s and has been applied in many projects. A new modified method to the PDM has been, in recent, developed in Korea to minimize the twisting of bag, thus leading to reduce chances of unsatisfactory installation. This consists of the use of a specially designed guiding plate and a thin anti-twisting rod welded on the inner surface of the casing as shown in Fig. 1.

In a field test, vertical drains were installed using the modified PDM to evaluate the performance of woven and non-woven geotextile bags, compared to that of the conventionally used net bags. The woven and non-woven geotextile bags as opposed to the net bag help reducing the clogging of drain during consolidation. Coal bottom ash, rock powder, and tire chips were used as drain materials and their applicability was evaluated in comparison with sand.

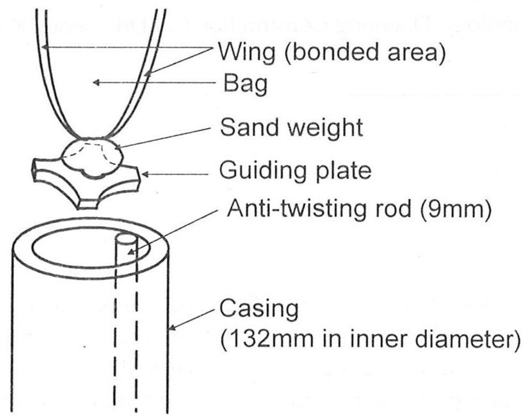

FIG. 1. A Schematic of Components of the Modified Packed Drain Method (MPDM)

FIELD TESTS

Woven and Non-Woven Bags

Four different types of bags manufactured by Serim Geotech Co. in Seoul, Korea were used for the test: a net bag of woven monofilament (W1); a closely woven geotextile bag (W2); two non-woven geotextile bags (NW1 and NW2). The properties of the bags used are summarized in Table 1. The side(s) of the bag in the direction parallel to the drain was bonded to 20 mm wide in such a way that the bonded side(s) appeared wing(s): two wings for W1 and one wing for W2, NW1, NW2. One hundred twenty six mm diameter bags were cut to 26.2 m long pieces at field. This 26.2 m consists of the design length of the bag 25 m to be placed in the ground and the rest approximately 1.2 m including protruding portion and some loss for the placement of weight.

Drain Materials

Bottom ash, rock powder, tire chips as well as sand were used as drain materials. Figs. 2 and 3 show the compaction curves and the size distribution of the drain materials, respectively. The bottom ash used is coarse residue resulting from the combustion of sub-bituminous coal in power plants in Taegu, Korea. Specific gravity is 2.36, maximum dry density is 1.51 g/cm^3, and maximum particle size is 10 mm. The bottom ash is classified as SW by the unified classification method. Park et al. (1996) reported the results of their study on the properties of the material. The rock powder used has maximum size of 10 mm and is classified as SP. Uniformly distributed tire chips were used: 2.0 mm < diameter ≤ 2.8 mm for 75 % and 1.4 mm < diameter ≤ 2.0 for 25 %. Specific gravity is 2.6 and maximum dry density is 0.6 g/cm^3 when compacted in mold. The geotechnical properties of tire chips can be found elsewhere (KICT 1996).

TABLE 1. Properties of the Packs (Serim Geotech Co. 1996)

W1 (Net Bag of Woven monofilament)	Polymer Type	Polyethylene	W2 (Woven Multifilament: Trade Name GT1000)	Polymer Type	Polyethylene
	No. of Meshes	≈ 60 EA/cm^2		Tensile Strength	98.1 kN/m
	Longitudinal Tensile Strength	22.6 kN/m		Elongation	18 (10~30) %
				Seam Strength	98.1 kN/m
	Lateral Tensile Strength	17.7 kN/m		Specific Gravity	1.1
				Weight	2.9 N/m^2
	Thick of Wing	20 mm (2 sides)		Thick. Of Wing	20 mm (1 side)
NW1 (Non-Woven Geotextile: Trade Name G150)	Polymer Type	Polyester	NW2 (Non-Woven Geotextile: Trade Name G200)	Polymer Type	Polyester
	Tensile Strength	15.1 kN/m		Tensile Strength	19.7 kN/m
	Elongation	80 (60~100) %		Elongation	80 (60~100) %
	Weight	1.5 N/m^2		Weight	2.0 N/m^2
	Permeability	$\alpha \times 10^{-3}$ m/s (α=1~9)		Permeability	$\alpha \times 10^{-3}$ m/s (α=1~9)
	Tear Strength	98.1 N		Tear Strength	147.2 N
	Seam Strength	382.6 N		Seam Strength	500.3 N
	Thick. of Wing	20 mm (1 side)		Thick of Wing	20 mm (1side)

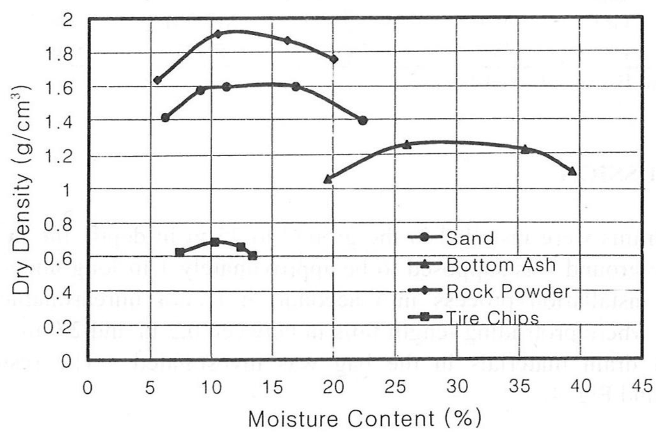

FIG. 2. Compaction Curves of Drain Materials

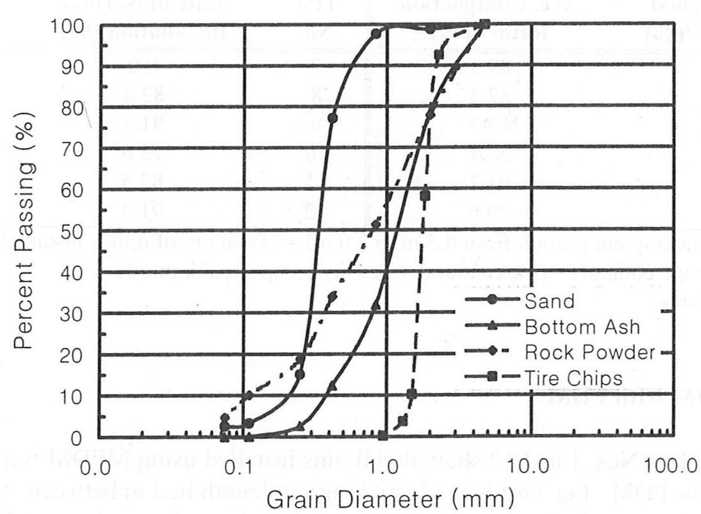

FIG. 3. Size Distribution of Drain Materials

Construction of Drain Columns

In a field test carried out in Pusan, Korea, vertical drains were installed for 12 combinations of bag, drain material, and installation method as shown in Table 2. In installation methods, MPDM is referred to as the modified PDM using a casing of 132 mm in inner diameter with a anti-twisting rod of 9 mm in diameter and a specially designed guiding plate as shown in Fig. 1. When placed inside the casing, the guiding plate situated at the bottom of the bag is not allowed to rotate by the anti-twisting rod. This is expected to prohibit the bag from being twisted. In this test, PDM for Test No. 12 is identical to MPMD except for that no guiding plate is used. When casing was withdrawn from the ground, air pressures of different magnitude was applied inside the casing. The air pressures applied varied depending on the drain materials usd, ranging from 687 kN ~ 1177 kN.

TABLE 2. Test Conditions

Test No.	Installation Method	Drain Material	Type of Bag	No. of Drains	Test No.	Installation Method	Drain Material	Type of Bag	No of Drains
1	MPDM	Sand	W1	20	7	MPDM	Tire	NW1	7
2	MPDM	Sand	W2	16	8	MPDM	BA	W1	12
3	MPDM	Sand	NW1	4	9	MPDM	BA	W2	12
4	MPDM	Sand	NW2	4	10	MPDM	RP	W1	12
5	MPDM	Tire	W1	8	11	MPDM	RP	W2	8
6	MPDM	Tire	W2	4	12	PDM	Sand	W1	36

note: RP is rock powder and BA is bottom ash.

RESULTS AND DISCUSSION

Since vertical drains were installed in the ground to 25 m in depth, the upper portion of each drain sticking out of the ground was supposed to be approximately 1 m long under normal conditions. Taking uncertainty in installation process into account, it is not unreasonable to define normal installation as the cases where protruding length falls in between 0.5 m and 2.0 m. For the constructed drains, compactness of drain materials in the bag was investigated. The results of the test are summarized in Table 3 and Fig. 4.

TABLE 3. Some Results of the Test

Test No.	Rate of Normal Installation*1(%)	Ave. Compaction Ratio *2(%)	Test No.	Rate of Normal Installation (%)	Ave. Compaction Ratio (%)
1	100.0	89.1	7	0.0	N/A
2	75.0	82.3	8	83.3	75.2
3	0.0	N/A*3	9	91.7	75.5
4	0.0	N/A	10	75.0	72.5
5	75.0	91.2	11	87.5	75.5
6	50.0	79.6	12	91.3	90.3

*1. (No. of drains with sticking out portion from 0.5 m to 2.0 m) ÷ (Total no. of drains installed)
*2. (Dry density of drainage column) ÷ (Maximum dry density compacted in mold)
*3. N/A means not available

Comparison of MPDM with PDM

The results of Test Nos. 1 and 12 show that drains installed using MPDM were 100 % normally installed while 92 % for PDM. For Test No. 12, sticking-out length lied in between 1.0 m and 1.5 m for the normally installed drains and were less than 0.5 m for the others. It may be said that MPDM has no

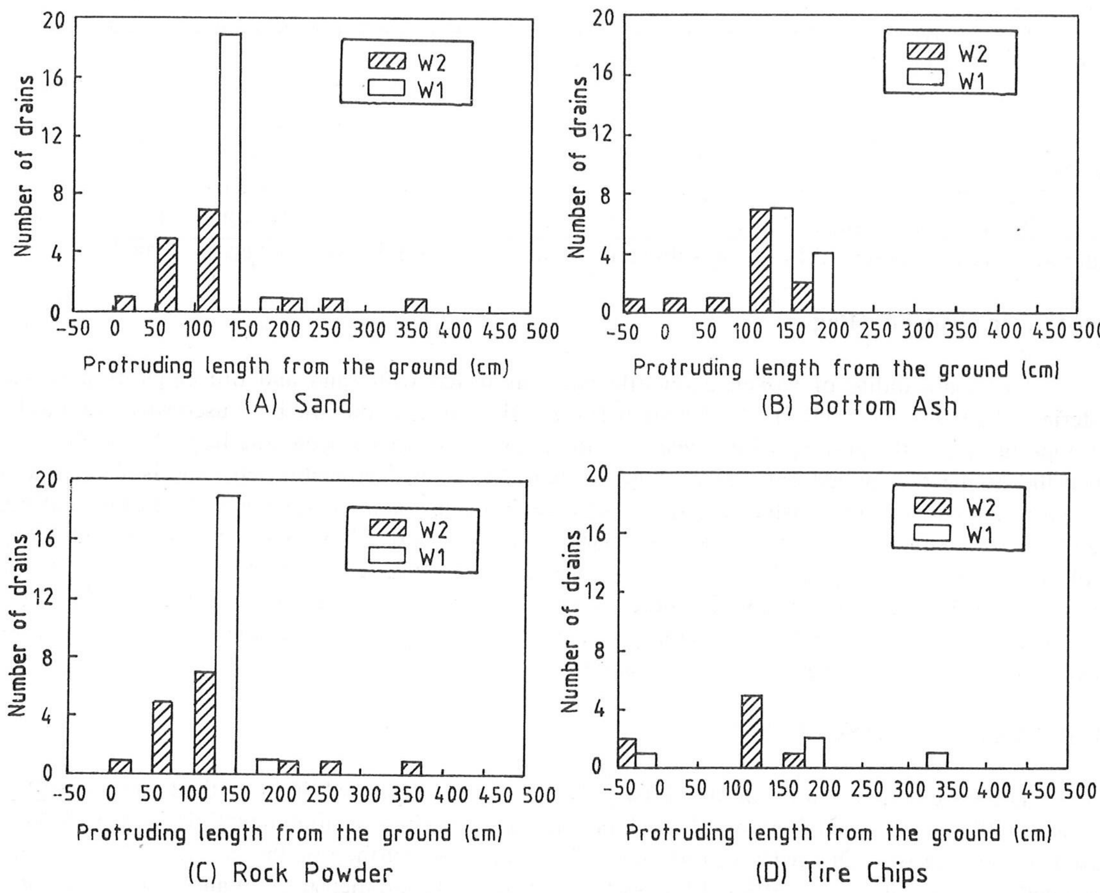

FIG. 4. Length of Drain Sticking out of the Ground as a Function of Different Drain Materials: W1 is Net Bag and W2 is Woven Geotextile Bag of multifilament

adverse effect in practical aspects compared to the conventional packed drain method (PDM) and may outperform it. For this reason, MPDM was chosen in this test to investigate the efficiency of different types of bags with different drain materials.

Woven Geotextile Bag

In order to evaluate compactness of drain materials placed in the drain, it is necessary to define a term called relative compaction ratio (RCR) as dry density of drain material in drainage column to maximum dry density compacted in mold. It can be observed from Table 3 that the RCR of sand and tire chips ranged from 80 % to 90 % while approximately 75 % for bottom ash and rock powder. This may be due to inexperience of workers at field for new materials, which can be overcome.

In cases where net bags (W1) were used (Test Nos. 1, 5, 8, 10, and 12), the percentage of normal installation was 91 % ~ 100 % for sand; 75 % for tire chips; 83 % for bottom ash; and 75 % for rock powder. Lower values for the drain materials other than sand may be attributed to inexperience in operation as well as unit weight of material, similarly for the cases of relative compaction ratio. Due to the nature of equipment for the packed drain method, it is important for driver to apply air pressure and vibration of adequate magnitude for a proper time period when filling the bag and pulling out the casing. Since drain material fills a bag free-falling from a hopper, it is more important for drain material to be heavy enough to: expand the cross-section of the bag to a maximum extent; and compact by itself during free-falling.

Test Nos. 2, 6, 9, and 11 are the cases where geotextile bags of multifilament (W2) were used. As can be seen in Table 3, the percentages of normal installation for sand, rock powder, and bottom ash are in acceptable ranges while only half of the tire drains are considered normally installed. In view of the results for bottom ash and rock powder with W1 and W2, it can be concluded that these two materials have high potential for being substituting materials for sand in the packed drain method.

Non-Woven Geotextile Bag

The applicability of woven geotextile bag was tested with sand and tire chips as drainage materials (Test Nos. 3, 4, and 7). As shown in Table 3, the woven geotextile bags used was found to be not appropriate for the purpose of this test. All the drains with woven geotextile bag fell into the hole when the casing was pulled out. This is due primarily to highly elongating characteristic of woven geotextile and partly to the existence of space between drainage column and inner surface of the casing: the tensile elongation rates of NW1 and NW 2 are 80 %. After driving a casing into the ground, a bag is placed inside the casing with the top of the bag securely tightened the bottom of hopper. It was observed that the bag contracted in the direction perpendicular to the drain as drain material filled the bag. This is because (1) the bag was subject to tensile stress; and (2) the bag expanded into the space between the bag and the inner surface of the casing.

SUMMARY AND CONCLUSIONS

Drainage columns were installed using the conventional packed drain method and a modified method (MPDM) with sand, bottom ash, rock powder, and tire chips as drain materials. The MPDM is based on the use of a anti-twisting rod attached on the inner surface of the casing and a specially designed guiding plate. Four different types of bags were made and their performance was evaluated in terms of percentage of normal installation and compaction ratio. The conclusions of this study are as follows:

1) The results of the test with sand indicated that the performance of the modified method (MPDM) was equivalent to or better than that of the conventional packed drain method
2) The percentage of normal installation of drains with woven geotextile bag was slightly less than that of et bag due to inexperience with new material.
3) The non-woven geotextile bags had an elongation rate of 80 % so that they underwent a large radial contraction and longitudianal expansion caused by the self-weight of fillers. As a result, the drains constructed sunk in the ground. Non-woven fabric is favored to woven fabric where criteria for filtering take high priorities. Therefore, more studies are yet to be needed to develop thinner woven geotextile bag with less elongation.
4) Bottom ash and rock powder were found to have high potential for being substituting materials for sand for the construction of vertical drain. However, tire chips were not appropriate for fillers in the packed drain method due to their light weight.

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