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Drainage performance of composite geotextiles under confined loads

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ABSTRACT: Polypropylene and polyester staple fibers and other synthetic waste fibers(;20～1,000deniers) as filling materials and nonwoven geotextiles of 300～1,200g/㎡ were used to manufacture the smart geotextiles and the special needle punching mechanism was applied to do this. 3-layer composition structure, - [nonwoven/drainage layer/nonwoven] -, was adopted to manufacture these smart geotextiles. The typical 2- or 3-dimensional structured geonet composites having the similar thickness as these smart geotextiles were used as reference materials to be compared the drainage properties. Variation of thickness, in-plane permeability and transmissivity with compressive stress were evaluated and analyzed between smart geotextiles and geonet composites.

1 INTRODUCTION

Some composite types of geosynthetics which have the special functions are used in waste landfills and now geonet composites are adopted the proper materials that protect the geomembrane and have the drainage function. But for the waste landfills, marvel stones to be used as drainage materials of leachates over 50 mm diameter will cause to occur to the intrusion phenomena of geonet composites.
These intrusion phenomena of geonet composites are the causes to decrease the drainage efficiencies in waste landfills. Therefore, it would be needed the smart geotextiles which have not only the excellent drainage function but also the distinguished protection function to the geomembranes for slope and liner system of waste landfills.
In this study, it was designed and manufactured the smart nonwoven geotextiles, which have the differential compositions by the special needle punching method. Changes of thickness, transmissivity, in-plane permeability with compressive stress were analyzed by the constitutive equations of drainage function.

2 THEORETICAL BACKGROUND

Transmissivity is evaluated by the amounts of water to be passed through the geotextile specimen flow under the confined normal stress and the specific hydraulic gradient in accordance with ASTM D 4716. The principal transmissivity mechanism of smart geotextiles in this study is analyzed by equation (1)~(4).
If water flows along the surface of geotextiles horizontally and the amounts of water-in should be equal to those of water-out, flow rate of water, q, for drainage system could be written by equation (1) from Darcy's law,

$$q = K_p \times i \times A = K_p \frac{\Delta h}{L} \times w \times t \tag{1}$$

And transmissivity of geotextiles for drainage in Figure 1 is as following

$$\theta = K_p \times t = q \frac{L}{\Delta h \times w} = \frac{q}{i \times w} \tag{2}$$

where :
θ : transmissivity of the geotextile
i : hydraulic gradient
K_p : in-plane permeability
q : flow rate
L, t : length and thickness of the geotextile, respectively
Δh : total water head lost
w : width of the geotextile

If water flows radially through the geotextile and is collected around the outer perimeter of the device, the theory is adapted as follows:

$$q = K_p \times \frac{dh}{dr}(2\pi \times r \times t) \tag{3}$$

And the amounts of radial drainage are calculated by the following equations:

$$2\pi(K_p \times t)\int_{h_1}^{h_2} dh = q\int_{r_1}^{r_2}\frac{dr}{r}$$
$$\theta = \frac{q\ln(r_2/r_1)}{2\pi\Delta h} \tag{4}$$

where :
r_1 : inner radius of the geotextile test specimen
r_2 : outer radius of the geotextile test specimen

In this study, smart geotextile has the 3-layer structure composition and transmissivity of smart geotextile could be written as following:

$$\theta_{SGT} = \sum\theta_i = \sum(\theta_U + \theta_I + \theta_L) = \sum k_{\theta_i} \times t_i \tag{5}$$

where :
θ_{SGT} : transmissivity of the smart geotextile
θ_i : transmissivity of *i* component of the smart geotextile
k_{θ_i} : in-plane permeability of *i* component of the smart geotextile
t_i : thickness of *i* component of the smart geotextile

3 EXPERIMENTAL

3.1 *Preparation of smart geotextiles*

The smart geotextiles of 3-layer structure which have the adaptative drainage function under confined loading condition were manufactured by needle punching method.
Three different punching patterns were applied to manufacture these geotextiles as ↑, ↑ and ↓ punching mechanism.

Table 1 showed the specifications of the smart geotextiles – SMGT 1, 2, 3 and 3 types of geonet composites – GNC-1, -2, -3 etc. - having the same thickness as smart geotextiles were used as comparison materials for drainage function and

Figure 1 showed the cross sectional morphology of smart geotextiles and geonet composites.

3.2 *Tests of drainage properties*

3.2.1 *Apparatus*

Radial in-plane flow test apparatus in accordance with GRI Test Method used to evaluate the transmissivity, in-plane pearmeability of smart geotextiles and geonet composites. The size of test specimen is 100cm^2 and confining load ranges to be applied to the specimen are 1~240 kg

3.2.2 *Evaluation of transmissivity*

Transmissivity of smart geotextiles and geonet composites under confied loading conditions were evaluated by equation (4). Before testing, specimens were immersed in the distilled water to eliminate the vapors in the specimens.

Table 1. Specifications of smart geotextiles

Geosynthetics For Drainage		Thickness (mm)	Composition	Drainage Layer
Smart Geotextiles	SMGT1	1.2	Nonwoven /Drainage Layer /Nonwoven	* (Waste) PP or PET Fibers * 20-1,000 Deniers
	SMGT2	1.4		Accumulation of web
	SMGT3	1.7		Pre-punched Nonwovens
Geonet Composites	GNC1	6.2	Nonwoven /Drainage Core /Nonwoven	2-Layer HDPE Core
	GNC2	7.2		
	GNC3	8.0		

Figure 1. Photographs cross section areas of smart geotextiles,

4 RESULTS AND DISCUSSION

4.1 *Thickness and compressive stress*

In general, the thickness of the geotextile is decreased by the compressive stress for installation within the soil structure. For this case, transmissivity of the geotextile would be the function of thickness and it is very important to evaluate the variation of thickness with the compressive stress. The relationship between thickness and compressive stress would be written as equation (6) by using the variation constant of the geotextile,

$$T/T_0 = (\sigma/\sigma_0)^{-a} \tag{6}$$

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where :

T_0, T : thickness of the geotextile with/without compressive stress, respectively

a : variation constant of the geotextile

σ_0, σ: initial and compressive stress of the geotextile, respectively (σ_0=0.04 kg/cm^2)

From this equation, the variation constant, a, will be larger with the thickness of the geotextile and therefore, another variation constant, b, should be introduced to equation (6) to compensate the variation constant, a. Therefore, the variation of thickness with compressive stress could be written as following:

$$T = T_0 - a\ln\frac{\sigma}{\sigma_0} = T_0\left(1 - \ln\frac{\sigma}{\sigma_0}\right) \quad (7)$$

$$b = a / T_0$$

Figure 2 shows the relative decrease of thickness with compressive stress of geosynthetics by using equation (7). Geonet composites showed more significant decrease of thickness with confined loading due to the considerable intrusion of upper nonwovens than smart geotextiles.

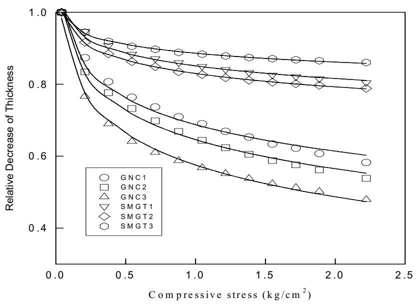

Figure 2. Relative decrease of thickness with compressive stress for smart geotextiles and geonet composites

4.2 *Thickness and in-plane permeability*

The constants of equation (7), T_0, a_T, b_T and correlation coefficient, R^2 for smart geotextiles and geonet composites were represented in Table 2.

In-plane permeability with thickness of smart geotextiles and geonet composites was shown in Figure 3. From this, it is seen that the linearity between thickness and in-plane permeability for smart geotextiles and geonet composites should be obtained with compressive stress.

4.3 *In-plane permeability and compressive stress*

Figure 4 shows the relationship between relative decrease of in-plane permeability and compressive stress of smart geotextiles and geonet composites. Smart geotextiles showed the lower decrease of in plane permeability than geonet composites as described in the case of relationship between thickness and compressive stress. From this, it is seen that this is due to the intrusion by the difference of structural compositions between smart geotextiles and geonet composites.

Table 2. Parameters to be related to thickness of smart geotextiles and geonet

Geosynthetics For Drainage	Coefficients to be Related to Thickness			
	T_0	a_T	b_T	R^2
GNC1	3.4634	0.3585	0.1035	0.9853
GNC2	4.3138	0.4946	0.1147	0.9923
GNC3	2.7448	0.3564	0.1298	0.9964
SMGT1	7.8463	0.3939	0.0502	0.9852
SMGT2	9.8557	0.5285	0.0536	0.9992
SMGT3	12.7900	0.4526	0.0354	0.9982

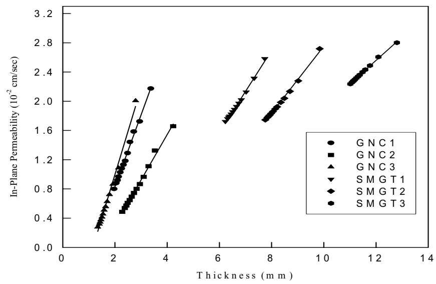

Figure 3. Thickness vs. in-plane permeability with compressive stress for smart geotextiles and geonet composites

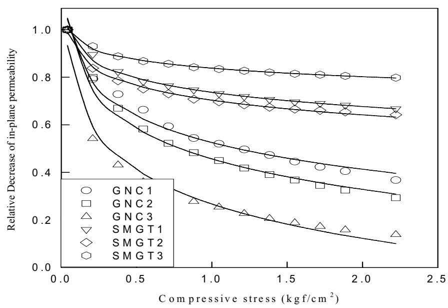

Figure 4. Relative decrease of in-plane permeability vs. compressive stress for smart geotextiles and geonet composites

4.4 *Transmissivity and compressive stress*

Transmissivity is a kind of parameter to determine the drainage properties of geotextiles and this is the function of the multiplication thickness by in-plane permeability of geotextile.

In-plane permeability of geotextile to be derived from the equation (7) is as following:

$$K_p = K_0 - a_K \ln\frac{\sigma}{\sigma_0} = K_0\left(1 - b_K \ln\frac{\sigma}{\sigma_0}\right) \qquad (8)$$

$$b_K = a_K / K_0$$

where :
K_0 : initial in-plane permeability
K_p : in-plane permeability under confined loading
a_K, b_K : variation constants of the geotextile

From the equation (2) and (8), transmissivity of geotextile could be written as following:

$$\begin{aligned}\theta &= T \times K_p \\ &= T_0\left(1 - b\ln\frac{\sigma}{\sigma_0}\right) \times K_0\left(1 - b_K \ln\frac{\sigma}{\sigma_0}\right) \\ &= (T_0 \times K_0)\cdot\left(1 - (b + b_K)\ln\frac{\sigma}{\sigma_0} + b\cdot b_K \ln^2\frac{\sigma}{\sigma_0}\right) \qquad (9) \\ &= \theta_0\left(1 - (b + b_K)\ln\frac{\sigma}{\sigma_0} + b\cdot b_K \ln^2\frac{\sigma}{\sigma_0}\right)\end{aligned}$$

where :
θ_0 , θ : transmissivity with/without confined loading of the geotextile, respectively

For equation (9), the value of (b×bA) is (0.02～0.03) and this value is smaller than (b+bA), (0.3～0.4). Therefore, the 3rd term of equation (9) could be negligible to be simplifying this equation if the value of (σ/σ_0) is not larger than (0.02～0.03).

Finally, transmissivity of geotextile would be written as follows:

$$\theta = \theta_0\left(1 - b_\theta \ln\frac{\sigma}{\sigma_0}\right) \qquad (10)$$

where :
b_θ : variation constant of the geotextile

Figure 5 shows the relationship between transmissivity and compressive stress and solid line indicates the theoretical values of the equation (10) in the condition of the initial compressive stress, σ_0=0.04 kg/cm^2. In here, the errors between experimental and theoretical values of transmissivities for GNC1 were larger than those of the other materials. It means that is the 3rd term of equation (9) should not be negligible because of the larger (σ/σ_0) values. But the errors between experimental and theoretical values of transmissivities for GNC1 will be smaller if the initial compressive stress is larger than 0.04 kg/cm^2. This means that the 3rd term of equation (9) should be negligible and the initial compressive stress should be larger to be applied the equation (10) to the analysis of transmissivity of the geotextile.

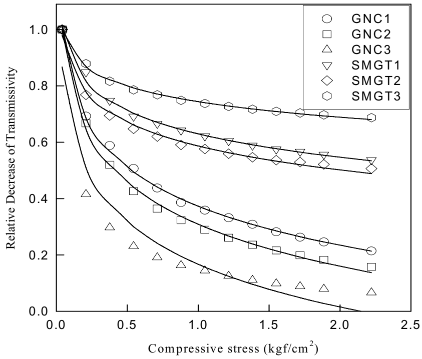

Figure 5. Relative decrease of transmissivity and compressive stress for smart geotextiles and geonet composites

5 CONCLUSION

The variations of thickness with compressive stress of smart geotextiles were smaller than those of geonet composites. This is due to the difference of intrusion by compressive stress between smart geotextiles and geonet composites. The decrease of in-plane permeability and transmissivity with compressive stress of smart geotextiles showed the same tendency as the case of variations of thickness.

REFERENCES

ASTM Committee D-35. (1995). "ASTM Standard on Geosynthetics", Philadelphia, PA., U.S., pp. 53-56.

FHWA. (1989). "Geotextile Design & Construction Guidelines", U.S. Dept. of Transportation Federal Highway Administration, Publication No. FHWA HI-90-001, pp. 24～46.

Holtzs, R. D., Christopher, B. R., and Berg, R. R., (1995). "Geosynthetic Design and Construction Guidelines", U.S. Dept. of Transportation Federal highway Administration, Publication No. FHWA HI-95-038, pp. 27～105.

Koerner, R. M., (2005). "Designing with Geosynthetics", 4th Ed., Prentice-Hall, Eaglewood Cliffs, New Jersey, U.S., pp. 263-273.

Koerner, R. M., (1990). "Geosynthetic Testing for Waste Containment Application", ASTM STP 1081, Philadelphia, U.S., pp. 257～272.

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