Manufacturing and Assessment of Long-Term Drainage Performance of Hybrid Geotextiles

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ABSTRACT
Drainage performance of nonwoven geotextiles is estimated by the transmissivity and therefore, it would be needed to modify the ultimate transmissivities of geotextiles to consider these reduction factors. In this study, two type nonwoven geotextiles-typical and hybrid types- which are widely applied as drainage materials for waste landfill sites in Korea were used to compare the drainage performance. And reduction factors to affect the allowable flow rate of geotextiles were applied to examine the drainage function of geotextiles. Total reduction factors to affect the allowable flow rate of typical type nonwovens were larger with weight and the allowable flow rates were decreased. On the other hand, hybrid type geotextiles showed the reverse trends for both values to compare with typical type geotextiles.

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 (FHWA 1989, Koerner 1998, 1990). 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 (Holtz et al. 1995, Hokanson et al 1989). Therefore, it would be needed the hybrid 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 hybrid 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

The principal transmissivity mechanism of hybrid geotextiles in this study is represented in Figure 1 and analyzed by equation (1)~(4) (Koerner 1998). 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 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:

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

Finally, transmissivity of hybrid geotextile could be written as following:

$$\theta_{SGT} = \sum \theta_i = \sum (\theta_U + \theta_I + \theta_L) = \sum k_{\theta_i} \times t_i \tag{4}$$

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

3. EXPERIMENTAL

3.1 Preparation of hybrid geotextiles

The hybrid geotextiles of 3-layer structure which have the adaptative drainage function under confined loading condition were manufactured by needle punching method. Table 1 showed the specifications of the hybrid geotextiles – SMGT 1, 2, 3 and 3 types of geonet composites – GNC-1, -2, -3 etc. - having the same thickness as hybrid geotextiles were used as comparison materials for drainage function.

Table 1. Specifications of hybrid geotextiles

Geosynthetics for Drainage		Thickness(mm)	Composition	Drainage Layer
Hybrid Geotextiles	SMGT 1	1.2	Nonwoven /Drainage Layer /Nonwoven	* (Waste) PP or PET fibers * 20-1,000 deniers
	SMGT 2	1.4		Accumulation of web
	SMGT 3	1.7		Pre-punched nonwovens
Geonet Composites	GNC 1	6.2	Nonwoven /Drainage Core /Nonwoven	2-layer HDPE core
	GNC 2	7.2		
	GNC 3	8.0		

3.2 Evaluation of transmissivity

Radial in-plane flow test apparatus in accordance with GRI Test Method was used to evaluate the transmissivity, in-plane permeability of hybrid geotextiles and geonet composites through hydraulic gradient interpretation. The size of test specimen is 100cm^2 and confining load ranges to be applied to the specimen are 1~240 kg. Transmissivity of hybrid geotextiles and geonet composites under confined loading conditions were evaluated and before testing, specimens were immersed in the distilled water to eliminate the vapors in the specimens.

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 (5) by using the variation constant of the geotextile,

$$T/T_0 = (\sigma/\sigma_0)^{-a} \quad (5)$$

,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 (5) to compensate the variation constant, a. Therefore, the variation of thickness with compressive stress could be written as following:

$$T = T_0 - a\ln\frac{\sigma}{\sigma_0} = T_0\left(1 - \ln\frac{\sigma}{\sigma_0}\right) \quad (6)$$
$$b = a/T_0$$

Figure 1 shows the relative decrease of thickness with compressive stress of geosynthetics by using equation (6). Geonet composites showed more significant decrease of thickness with confined loading due to the considerable intrusion of upper nonwovens than hybrid geotextiles.

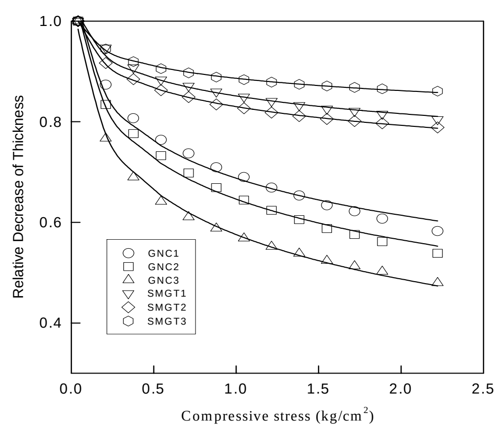

Figure 1. Relative decrease of thickness with compressive stress for hybrid geotextiles and geonet composites

4.2 Thickness and in-plane permeability

The constants of equation (6), T_0, a_T, b_T and correlation coefficient, R^2 for hybrid geotextiles and geonet composites were represented in Table 2. In-plane permeability with thickness of hybrid geotextiles and geonet composites was shown in Figure 2. From this, it is seen that the linearity between thickness and in-plane permeability for hybrid geotextiles and geonet composites should be obtained with compressive stress.

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

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

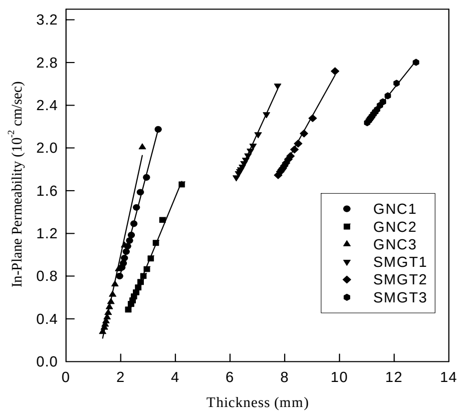

Figure 2. Thickness and in-plane permeability with compressive stress for hybrid geotextiles and geonet composites

4.3 In-plane permeability and compressive stress

Figure 3 shows the relationship between relative decrease of in-plane permeability and compressive stress of hybrid geotextiles and geonet composites. Hybrid 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 hybrid geotextiles and geonet composites.

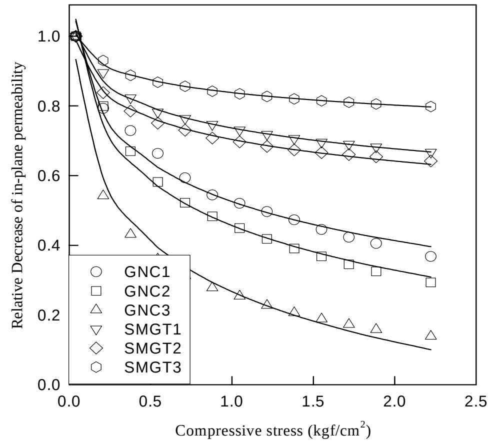

Figure 3. Relative decrease of in-plane permeability and compressive stress for hybrid geotextiles and geonet composites

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 (6) is as following:

$$K_p = K_0 - a_K \ln\frac{\sigma}{\sigma_0} = K_0\left(1 - b_K \ln\frac{\sigma}{\sigma_0}\right) \tag{7}$$
$$b_K = a_K / K_0$$

, 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 (7), transmissivity of geotextile could be written as following:

$$\begin{aligned}\theta &= T \times K_p \\ &= T_0\left(1 - b\ln\frac{\sigma}{\sigma_0}\right) \times K_0\left(1 - b_K \ln\frac{\sigma}{\sigma_0}\right) \\ &= (T_0 \times K_0)\cdot\left(1 - (b + b_K)\ln\frac{\sigma}{\sigma_0} + b\cdot b_K \ln^2\frac{\sigma}{\sigma_0}\right) \\ &= \theta_0\left(1 - (b + b_K)\ln\frac{\sigma}{\sigma_0} + b\cdot b_K \ln^2\frac{\sigma}{\sigma_0}\right)\end{aligned} \tag{8}$$

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

For equation (8), 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 simplify 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:

$$\theta = \theta_0 \left(1 - b_\theta \ln \frac{\sigma}{\sigma_0} \right) \tag{9}$$

, where b_θ : variation constant of the geotextile

Figure 4 shows the relationship between transmissivity and compressive stress and solid line indicates the theoretical values of the equation (9) 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. 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. Table 3 shows the parameters to be related to in-plane permeability and transmissivity of hybrid geotextiles and geonet composites.

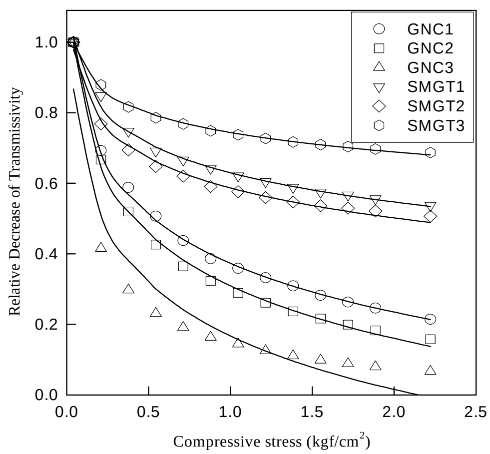

Figure 4. Relative decrease of transmissivity and compressive stress for hybrid geotextiles and geonet composites

Table 3. Parameters to be related to in-plane permeability and transmissivity of hybrid geotextiles and geonet composites

Samples	In-plane permeability				Transmissivity			
	K_0	a_K	b_K	R^2	θ_0	a_θ	b_θ	R^2
GNC1	0.023	0.003	0.155	0.982	0.741	0.146	0.198	0.998
GNC2	0.017	0.003	0.177	0.986	0.699	0.151	0.216	0.997
GNC3	0.019	0.004	0.223	0.979	0.485	0.123	0.253	0.930
SMGT1	0.026	0.002	0.085	0.993	2.023	0.239	0.118	0.994
SMGT2	0.027	0.002	0.090	0.996	2.618	0.328	0.125	0.992
SMGT3	0.028	0.001	0.052	0.996	3.581	0.286	0.080	0.997

5. CONCLUSION

The variations of thickness with compressive stress of hybrid geotextiles were smaller than those of geonet composites. This is due to the the difference of intrusion by compressive stress between hybrid geotextiles and geonet composites. The decrease of in-plane permeability and transmissivity with compressive stress of hybrid geotextiles showed the same tendency as the case of variations of thickness. The variation of thickness, in-plane permeability and transmissivity of hybrid geotextiles could be analyzed the equation (7).

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REFERENCES

FHWA, (1989). *Geotextile Design & Construction Guidelines*, U.S. Dept. of Transportation Federal Highway Administration, Publication No. FHWA HI-90-001, 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, 27-105.

Koerner, R.M. (1998). *Designing with Geosynthetics*, 4th Ed., Prentice-Hall, Eaglewood Cliffs, New Jersey, U.S., 69-314, 387-414.

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

Hokanson, S.A., Daniel, D.E. and Richardson, G.N. (1989). *Requirements for Hazardous Waste Landfill Design, Construction, and Closure*, U.S. EPA Seminar Publication, 53-74.