Estimation of dynamic interface properties between geomembrane and geotextile
지오멤브레인과 지오텍스타일 사이의 동적 접촉 마찰 특성평가

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SYNOPSIS : 본 연구에서는 진동대 실험을 실시하여 매립지에서 널리 사용되고 있는 지오멤브레인과 지오텍스타일 사이의 동적 접촉 마찰 특성을 살펴보았다. 연직응력, 진동 주파수, 건조/수침 상태의 영향에 대해서 평가하였으며, 또한 지오멤브레인과 지오텍스타일 사이의 상대적인 미끄러짐의 정도를 측정하였다.

실험 결과, 지오멤브레인과 지오텍스타일 사이를 통해 전달되는 한계 가속도(limited acceleration)가 있음을 확인할 수 있었으며, 이를 통해 지오멤브레인과 지오텍스타일 사이의 동적 접촉 마찰각을 산정할 수 있었다. 이러한 가속도는 수침상태의 경우 건조상태보다 더 작게 산정되었으며, 변위의 경우 수침상태에서 더 크게 발생함을 관찰하였다. 또한 실험조건에 따라 지오멤브레인과 지오텍스타일 사이에 발생하는 상대적인 미끄러짐의 정도가 다르게 측정되었다. 본 연구에서는 지오멤브레인과 지오텍스타일 사이의 slip equation을 제안하였으며, 이 식을 통해 주어진 가속도와 주파수에서 지오멤브레인과 지오텍스타일 사이를 따라 발생되는 최대 미끄러짐의 정도를 예측 가능하게 하였다.

Key words : 매립지, 진동대, 토목섬유, 동적 접촉 마찰 특성

1. Introduction

Municipal and hazardous waste landfills are required to include liner and cover systems containing low-permeable layers, protection layers, leachate collection layers, and so on. These systems usually are composed of compacted clay, granular soils, and geosynthetic materials.

However, on using geosynthetics in landfill, the stability analysis of bottom and slope of landfill should be made in advance. Generally, the interface frictional properties of geosynthetic/geosynthetic and soil/geosynthetics are known to be key parameters. The interface frictional properties of geosynthetic/soil systems are largely divided into two parts. One is related to the static interface properties, and the other deals with the dynamic interface properties(Castelli et al., 2001). Up to now, the study of interface properties of geosynthetics under static loads has been focused, and the research on dynamic interface properties was not dealt with sufficiently. In most landfills, the stability under the static loads is considered at design or construction. However, the necessity of conducting of dynamic analysis in landfill has been risen recently(Yegian et al., 1995, Zimme et al., 1994). Therefore, in the study, the shaking table tests were conducted to estimate of the dynamic interface frictional properties between geosynthetics.

2. Test Method

2.1 Materials

2mm thick of smooth geomembrane and nonwoven geotextile are used. These are manufactured in Korea. The properties of used geosynthetics are summarized at Table 1.

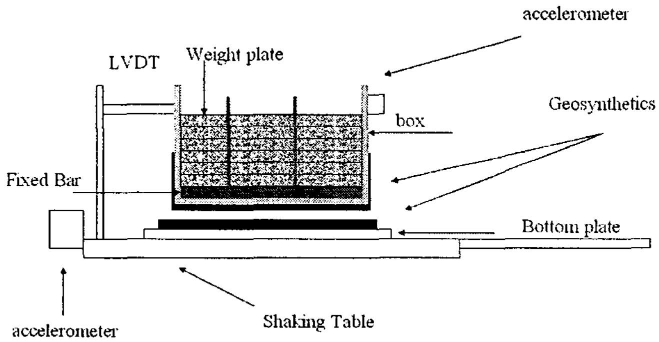
Table 1 Properties of used geosynthetics

type	description	thickness(or weight per unit area)
S-GM	smooth geomembrane	2.0mm
GT	nonwoven geotextile	9.0mm(1,000g/mm^2)

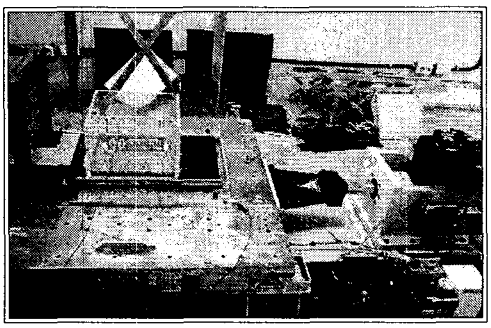
2.2 Test Equipments

Fig. 1 shows the shaking table facility used to evaluate the dynamic interface frictional properties between geomembrane and geotextile.

The shaking table comprises of a vibration exciter connected to a rigid aluminum table mounted on frictionless linear bearing pillow blocks moving on two stainless steel guide rails. One geosynthetic is fixed to the shaking table, and the other geosynthetic is fixed to upper hollow box. Static weight was added in the hollow box. Two accelerometers were attached to a shaking table and a hollow box, respectively. The relative displacements between the bottom geosynthetic and upper geosynthetic was measured by linear variable differential transducer(LVDT) attached on the table. The amplitude and the frequency of the table motion were controlled by a signal generator. All data acquisition and analysis were made by using a personal computer and a commercially available software.



(a) Schematic diagram of shaking table test



(b) Photo of shaking table test

Fig. 1 Side view of shaking table

The size of the shaking table is 1000mm×1000mm, and the dimension of box is 300mm×300mm which is the size proposed in ASTM D 5321-92. Normal stress was changed with increasing weight plates which is fixed by the fixed bar. Also, tests were conducted under two different conditions, dry and wet conditions.

2.3 Evaluation of dynamic interface friction angle

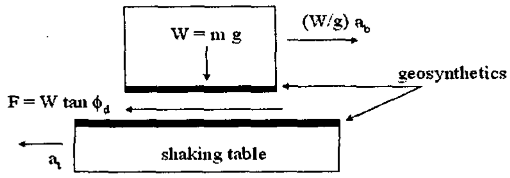


Fig. 2 Freebody diagram

Fig. 2 shows schematically the dynamic forces acting on the table and the box. Frictional force, F, is transmitted to the box through the interface. This frictional force cannot exceed the interface shearing strength for the geosynthetics. Assuming the Mohr-Coulomb type of failure mechanism, the value of F can be written as :

$$F = W \tan \phi_d \qquad \cdots (1)$$

, where W is the weight of a box and superimposed plates, and φ_d is the dynamic interface friction angle of geosynthetics.

Under the limiting condition when sliding of a box is not initiated, the frictional force will be equal to the product of the mass and acceleration of the box, a_b

$$F = m\, a_b = (\, W / g\,)\, a_b \qquad \cdots (2)$$

Thus combining (1) and (2) gives

$$\tan \phi_d = a_b / g \qquad \cdots (3)$$

This implies that the box and the table move together as long as the table acceleration is smaller than the limiting box acceleration. When the acceleration exceeds the limiting value, relative movement will be induced between the box and the table.

2.4 Evaluation of slip displacements

For the seismic stability of structure, it is important to estimate the earthquake-induced deformation of structure. In landfills, the seismic response of geosynthetic interface needs to be considered. Seismically-induced slippage of geosynthetic interface can cause localized damage to components of the gas collection, irrigation, drainage system, and eventually give rise to landfill failures(Martin et al., 1984).

Results from shaking table experiments performed on various geosynthetic interfaces were used to estimate the slip deformation. Yegian and Harb(1995) utilized shaking table tests to estimate the slip deformation at different types of geosynthetic interfaces. They suggested normalized equation which can predict slip displacement under harmonic dynamic excitations. The normalized slip displacement, S_n, can be expressed as follows :

$$S_n = \frac{S_d}{K_a \cdot T^2} \qquad \cdots (4)$$

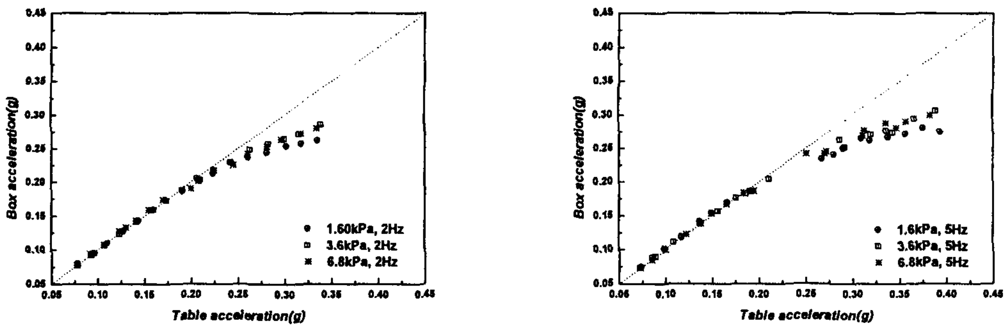
where S_d is measured maximum(peak-to-peak) slip, K_a is the base acceleration and T is the period of the base motion.

Also, the normalized slip displacement is related to K_y/K_a ratios for the different types of geosynthetic interfaces, where K_y is the yield acceleration. That is commonly defined as the maximum acceleration that can be transmitted through the geosynthetic interfaces.

3. Results

3.1 Effect of normal stress

Shaking table tests were conducted at the normal stress of 1.6kPa, 3.6kPa, and 6.8kPa. The acceleration of table and box between smooth geomembrane/geotextile interface is shown in Fig. 3.



(a) 2Hz frequency (b) 5Hz frequency

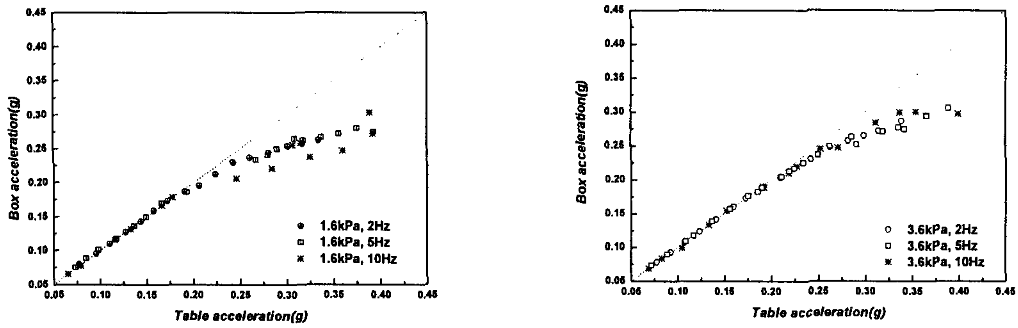
Fig. 3 Accelerations of table and box

As shown in Fig. 3, the dynamic interface friction angle was estimated to be constant inrespective of normal stresses. Hence, it was found that the normal stress does not influenced the dynamic interface friction angle between smooth geomembrane/geotextile interface.

3.2 Effect of frequency of excitation

Similar tests were performed with different frequencies of excitation using vibration exciter connected to shaking table facility. Applied frequencies of excitation were 2Hz, 5Hz, and 10Hz. Fig. 4 shows the table acceleration versus box acceleration between smooth geomembrane/geotextile interface.

As identified in Fig. 4, dynamic interface friction angle are nearly 0.18g for all cases. It means that the frequency of excitation has little effect on the dynamic interface friction angle.



(a) 1.6kPa normal stress (b) 3.6kPa normal stress

Fig. 4 Accelerations of table and box

3.3 Effect of interface submergence

Shaking table tests were conducted in wet condition, where the interface is made to be submerged. Tests results were compared to those in dry condition.

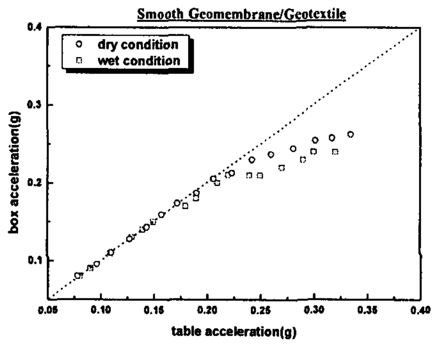


Fig. 5 Accelerations of table and box (1.6kPa normal stress, 2Hz frequency)

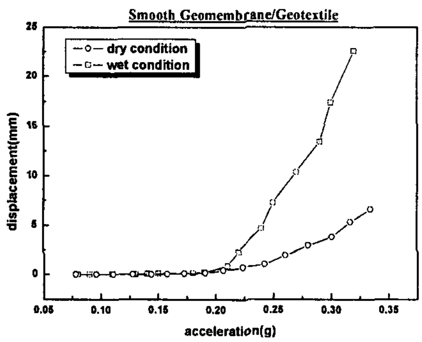


Fig. 6 Accelerations vs. displacement (1.6kPa normal stress, 2Hz frequency)

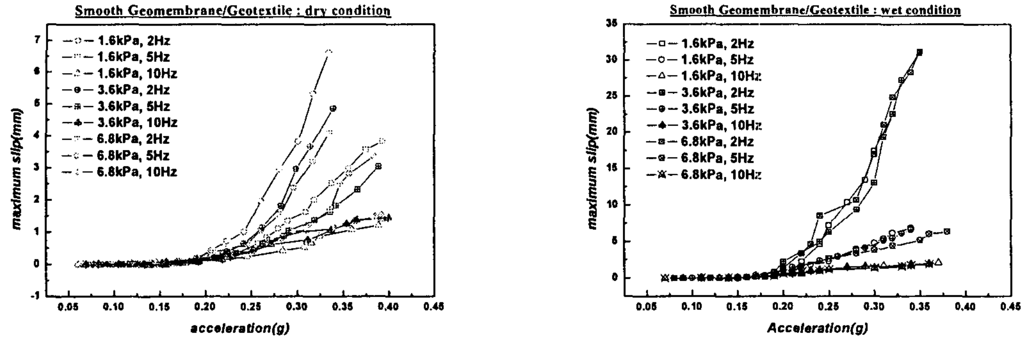
As shown in Fig. 5 and 6, for the wet condition, yield acceleration(K_y), i.e. the acceleration beyond which measurable slip deformations are observed, is lower than that for the dry condition. It was found that wetting of the geosynthetics during the shaking table tests has some effects on the dynamic interface friction angle.

Also, for the wet condition, the measured maximum(peak-to-peak) slip is more than that for the dry condition. As the dynamic interface frictional force is decreased with interface submerged, relative displacements occurred much more.

This means that the dynamic interface friction angle and the relative displacement are significantly influenced by the presence of water at the interface.

3.4 Relationship between the acceleration and the maximum(peak-to-peak) slip

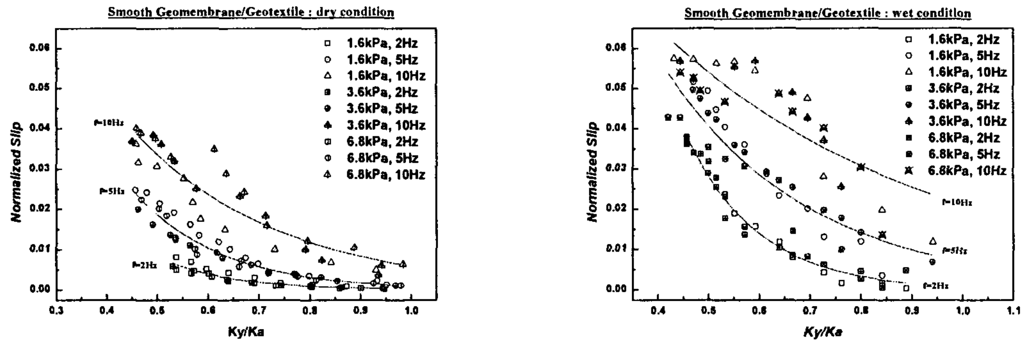
Fig. 7 shows the relationship between acceleration and relative displacements measured using LVDT. As shown in Fig. 7, when the acceleration of table was small, the relative displacement are not measured. However, once slip was initiated, maximum(peak-to-peak) slip was exponentially increased as the table acceleration increased. Also the level of maximum(peak-to-peak) slip was almost same for different normal stresses. However, it is seen that maximum(peak-to-peak) slip is dependent on the frequency of excitation. The measured maximum(peak-to-peak) slip under the low frequency of excitation was larger than that under the high frequency.



(a) Dry condition (b) Wet condition

Fig. 7 Table acceleration vs. maximum slip

The maximum(peak-to-peak) slip shown in Fig. 7 was normalized using Equation (4) and then plotted in Fig. 8 as a function of the ration of K_y/K_a . It was found that S_n was decreased with increasing K_y/K_a ratio.



(a) Dry condition (b) Wet condition

Fig. 8 K_y/K_a vs. Normalized slip

All of the shaking table tests results between smooth geomembrane and geotextile are summarized at Table 2.

Table 2. K_y and coefficient of normalized slip for the geosynthetic interface tested

Interface	condition	Dynamic friction angle	Normalized Slip		
Smooth Geomembrane/Geotextile	dry	0.18g(10.2°)	y = a exp (b x)		
			f	a	b
			2	0.298	-7.153
			5	0.347	-5.840
			10	0.191	-3.473
	wet	0.16g(9.1°)	y = a exp (b x)		
			f	a	b
			2	0.940	-7.011
			5	0.236	-3.515
			10	0.138	-1.878

For the dry condition, the dynamic interface friction angle between smooth geomembrane and geotextile was 0.18g. However, for the wet condition, it was 0.16g. It was found that wetness of the geosynthetics has some effect on the dynamic interface friction angle. At the Table 2, the coefficient, a, is the intercept of y axis, and the coefficient, b is the curvature at the normalized slip curve. The coefficient, a has little changed as frequency of excitation increased. However, the coefficient, b was linearly increased as the frequency of excitation increased. Using this equation slip displacement between smooth geomembrane and geotextile can be calculated for the case of given acceleration and frequency

4. Conclusions

Shaking table tests were performed to investigate the dynamic interface frictional properties between smooth geomembrane and geotextile. The influence of normal stress, frequency of excitation, and dry/wet condition were examined. The following conclusions are drawn from test results.

1) When the magnitude of table acceleration is small, the table and box move together. But when acceleration reaches at some point, the peak acceleration of the table gets to be smaller than that of the box. At this point, the slip of box is initiated, and transmitted force were decreased through the geosynthetic interfaces as table acceleration increased. It means that under the dynamic excitation, the shear stress transmitted through the smooth geomembrane and geotextile interface is limited. Using this point, the dynamic interface friction angle can be calculated.

2) The normal stress and the frequency of excitation did not influence the dynamic interface friction angle between smooth geomembrane and geotextile.

3) The measured maximum(peak-to-peak) slip under the low frequency of excitation was larger than that under the high frequency. And, when the acceleration of table was small, the relative displacement was not measured. However, once slip was initiated, maximum(peak-to-peak) slip was exponentially increased as the table acceleration increased.

4) The dynamic interface friction angle in the wet condition was about 1° lower than that in the dry condition. Also the amplitude of relative displacement in the wet condition was 2~5 times more than that for the dry condition. It means that the landfill under the wet condition can be easily located in critical state than that under the dry condition.

6) Using the relationship between normalized slip and ratio of K_y/K_a, the maximum slip displacement between geomembrane and geotextile can be calculated for given acceleration and frequency of excitation.

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