

IN-SITU FRICTIONAL TESTS FOR GEOMEMBRANE/SOIL AND GEOMEMBRANE/GEOTEXTILE INTERFACE

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ABSTRACT: In order to estimate the frictional characteristics between six geomembranes including HDPE, EPDM etc. and geotextiles or soils, in-situ frictional tests were conducted. Developed device was very simple one and was consisted of concrete mass having a size of 300 x 400 x 300 mm³ and a weight of 1.56 kN and a pulling unit with a winch. Tests were conducted at natural water content and submerged conditions. The results from in-situ tests were compared with those from laboratory tests. As the results it was found that the ratio of frictional coefficient estimated at submerged condition to that at natural water condition was about 70 - 80 % for loam ground while it was 90 % for drain sand. It was also found that the frictional coefficient between geomembrane and soil estimated at in-situ tests were about 125 to 200 % of those obtained at laboratory shear tests while the frictional coefficients between smooth surfaced geomembrane and stapled nonwoven geotextile were good coincidence between the both tests.

1. INTRODUCTION

Geomembranes and geotextiles, recently, are becoming to be widely used as essential components of liner system in waste landfill. The frictional characteristics on interface between geomembrane/soil and geomembrane/geotextile are very important factor to design liner's structure such as its anchorage or side slope stability (Richardson and Koerner 1986, Koerner 1994, Giroud 1994). In general, the frictional characteristics can be determined using direct shear type test in a laboratory (Ingold 1991). It is, however, well known to geotechnical engineers that the shear resistance of soil depends on not only its kind but also its condition like water content, density and fabric. Therefor the value being estimated by in-situ testing is more reliable value than in laboratory tests.

In this paper, convenient in-situ equipment to measure a frictional resistance between geomembrane/soil and geomembrane/geotextile was developed. The results of in-situ tests using the developed device are presented and some considerations about effect of difference of testing water condition on an amount of a frictional coefficient are also discussed.

2. PROPERTIES OF GEOMEMBRANES AND GEOTEXTILES USED

Geosynthetics used were six types of geomembrane and two types of geotextiles. Six geomembranes were smooth surfaced HDPE, embossed HDPE, slightly textured EPDM, smooth PVC, smooth TPO (Thermo Plastic Oleffine) and CPE-R (Chlorinated PolyEhtylene Reinforced with textiles). They all have a thickness of 1.5 mm. Their tensile strengths are shown in Table 1. HDPE is the strongest geomembrane and have a strength of as higher as 33 MN/m². CPE-R is also a higher strength of 26 MN/m². PVC and TPO have a same medium strength of 15 MN/m². EPDM has the lowest value of 10

MN/m² which is about one third of HDPE.

The geotextiles used were continuous nonwoven of 4.86-mm thick and stapled nonwoven of 10 mm thick. Their tensile strengths are also listed in Table 1. Continuous nonwoven has a strength of 6 MN/m² which is about twenty times higher than stapled nonwoven.

The grounds on which the tests were conducted were two loam-made ground and one sandy ground. One loam ground was in Utsunomiya University and the other in a construction site for residents near Utsunomiya-city. The sandy ground was chosen on sandy soil of 500 mm thick for drainage /protection layer laid on bottom liner of waste landfill that was under construction. Their natural water contents and cone resistance values were shown in Table 2. Two natural water contents of loam ground were near the plastic limit and had cone resistance values of 544 and 310 kN/m². Sandy ground had a natural water content of 5.15 % which was much lower than its optimum water content of 12.3 % and was almost dried condition. The cone resistance value of sand was 220 kN/m² which was a little lower than loam grounds.

Table 1 Tensile strength of Geosynthetics used

Type	Geomembrane					Geotextile	
	Smooth surfaced HDPE	Slightly textured EPDM	PVC	TPO	CPE-R	Continuous Nonwoven	Stapled Nonwoven
Tensile Strength [MN/m ²]	33.34	9.81	14.71	14.71	26.48	6.18	0.33

Table 2 Properties of the ground

Ground Type	Atterberg limit			Natural Condition		Submerged Condition	
	Liquid Limit %	Plastic Limit %	Plasticity Index %	Water Content %	Cone Resistance kN/m ²	Water Content %	Cone Resistance kN/m ²
Loam in Utsunomiya Univ.	140.6	79.1	72.9	72.9	544	108.9	255
Loam in Construction Site	106.9	62.6	64.2	42.7	310	113.6	164
Sand for Drainage	NP	NP	—	5.15	220	9.1	134

3 DEVICE OF IN-SITU TEST AND PROCEDURES

1) SET-UP OF A DEVICE

A test device is consist of concrete mass and pulling unit as shown in Photo. 1. The concrete mass has a width of 300 mm, a length of 400 mm and a height of 300 mm and a weight of about 1.56 kN. This concrete mass was a assemble of four small rectangular blocks having a weight of 0.39 kN (Photo. 3), because one workman could carry it easily. The pulling unit was made up from a base steel plate having a thickness of 4 mm, a width of 400 mm and a length of 800 mm and a small winch which aimed to wind up a wire of 3 mm in diameter connecting to the concrete mass. In addition, between the winch and the concrete mass there was a spring meter having a maximum capacity of 1.96 kN in order to measure the peak pulling force, that is, frictional resistance force.

2) PROCEDURE

- The base plate of pulling unit was fixed on the ground through four pins at the corners or on a stapled nonwoven geotextile which had been installed for a drainage/protection sand layer in landfill site.
- The surface of ground near there was made flatten using a cutting plate. In case of tests at submerged condition, sufficient of water was poured on the ground such as water surface appeared (Photo. 2).



Photo. 1 In-situ device to measure in-situ frictional coefficient



Photo. 2 Submerged condition of sandy ground

- c. A geosynthetic specimen having a width of 300 mm and a length of 1200 mm was spread over flattened ground. After the concrete mass was put on the center of tested geosynthetic, front and back edges of the geosynthetics were folded to make a area of interface consistent with base area of concrete mass.
- d. After the wire from the load scale was connected to concrete mass (Photo. 4), it was wound up at a constant rate of about 1 mm per second.
- e. The peak pulling force T_p indicated on force scale was read through mans eyes (Photo. 5) and recorded on a note.

4 RESULTS AND DISCUSSION

1) RESULTS FROM IN-SITU TESTS

Interface frictional coefficient μ_p at peak was calculated as follows:

$$\mu_p = T_p / N$$

where T_p is the peak pulling force measured

N is the weight of concrete mass (= 1.56 kN)

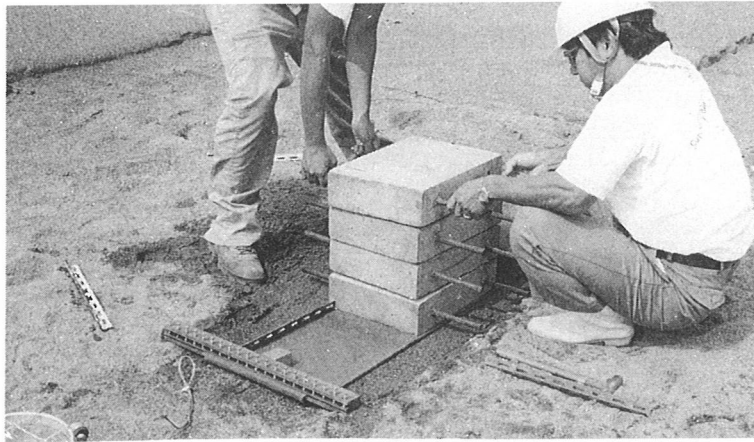


Photo. 3 Assemble of four concrete blocks for normal load



Photo. 4 Work of connecting the concrete blocks to pulling unit

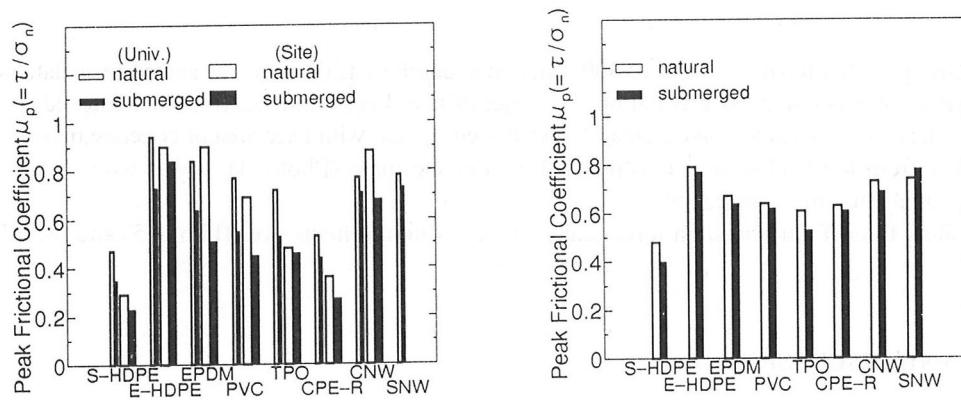


Fig. 1 Peak frictional coefficients estimated at in-situ tests for various types of geosynthetics

Table 3 shows average resultant interface frictional coefficient μ_p . Figs. 1(a) and 1(b) show frictional coefficients between geosynthetic and loam or sand, respectively. In the figures, the results at natural water condition and at submerged condition were separately presented. From these figures, it can be seen that amounts of frictional coefficients of embossed HDPE and slightly textured EPDM are larger than

others and have as high as about 0.84 to 0.94 at loam grounds of natural water content. At sandy ground, their amounts show a little lower as 0.67 to 0.79. Continuous nonwoven and stapled nonwoven presented somewhat higher values as 0.73 to 0.88. On the contrary, smooth HDPE and TPO show lower values such as 0.29 to 0.53 at loam and 0.48 and 0.61 at sandy ground. In case of smooth HDPE and TPO, the values on sandy ground were a little higher than on loam grounds.

Figs. 2(a) and (b) show the coefficient at natural water condition versus that at submerged condition, where the relations were presented separately according to the types of ground; (a) loam at Utsunomiya university and at residential construction site and (b) drainage/protection sand layer at landfill under construction. On the average, it can be said that the frictional coefficient between geomembranes and loam ground at submerged condition decreases by 30 % of that at natural water condition, though the frictional coefficient between geomembrane and sand at submerged condition decreases by as small as 10 % of that at dry condition. However continuous nonwoven and stapled nonwoven does not decrease so much its coefficient owing to submergence of the ground.

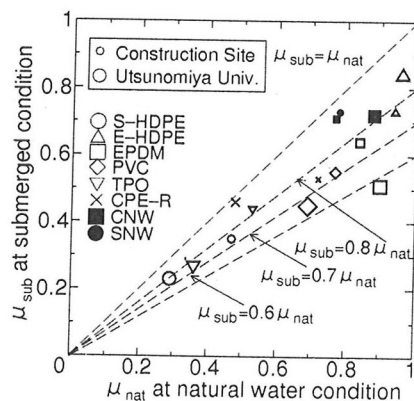
One major reason of the reduction of coefficient at submerged condition is thought that there was a water lamination between geomembrane and ground surface and it lubricates the interface. In case of geotextile and/or sandy ground, there would be little water lamination due to high permeability of them and it results in less reduction of the coefficient.

Table 3 Peak frictional coefficient μ_p estimated by in-situ tests

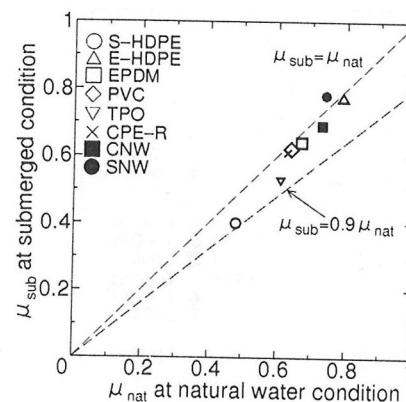
Ground	Condition (Temp. °C)	Type of Geosynthetics							
		Geomembrane						Geotextile	
		Smooth surfaced HDPE	Embossed HDPE	Slightly textured EPDM	PVC	TPO	CPE-R	Continuous Nonwoven	Stapled Nonwoven
Loam in Utsunomiya Univ.	Natural (19.4)	0.47	0.94	0.84	0.77	0.53	0.72	0.77	0.78
	Submerged (13.8)	0.35	0.73	0.64	0.55	0.44	0.53	0.71	0.73
Loam in Construction Site	Natural (38.5)	0.29	0.90	0.90	0.69	0.36	0.48	0.88	※1
	Submerged (39.6)	0.23	0.84	0.51	0.45	0.27	0.46	0.68	※1
Sand for Drainage	Natural (28.4)	0.48	0.79	0.67	0.64	0.61	0.63	0.73	0.74
	Submerged (30.3)	0.40	0.77	0.64	0.62	0.53	0.61	0.69	0.78
Stapled Nonwoven over Sand	Natural (37.5)	0.38	※2	※2	0.73	0.54	0.71	0.67	※2

※1 Not performed

※2 Impossible



(a) Loam ground



(b) Sandy ground

Fig. 2 Relation between μ_{nat} at natural water condition and μ_{sub} at submerged condition

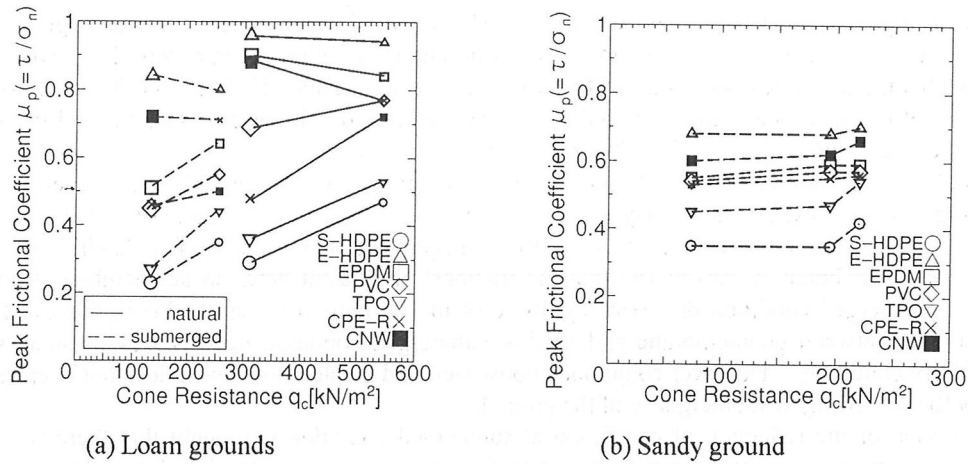


Fig. 3 Cone resistance q_c of tested grounds versus peak frictional coefficient

Figs. 3(a) and 3(b) show frictional coefficient versus cone resistance value of the ground. In case of loam grounds, the amount of coefficient seems to increase with increasing of resistance, though the coefficient higher than 0.7 presents unchangeable independently of the strength of the ground. In case of sandy ground the coefficients seem to be not effected from the strength of the ground.

2) COMPARISON WITH RESULTS FROM LABORATORY TESTS

The authors conducted direct shear tests in laboratory using the same soil as in-situ tests, geomembranes of HDPE and EPDM and geotextile of stapled nonwoven. The shear box used was a width of 100 mm, a length of 200 mm and a depth of 80 mm. The geosynthetics tested were glued on wooden plate. Then the soil taken from in-situ testing site was put into shear box and tamped so as to become a density consistent with in-situ and was placed on the geosynthetics. Normal pressures were selected as 24.5 kN/m², 49 kN/m², 73.5 kN/m² and 98.0 kN/m², which were applied by dead weight. The upper shear box was moved by electric screw jack at rate of 1 mm/min. The displacement and shear resistance force was measured electric dial gauge and load transducer respectively. In case of estimating the coefficient between geomembrane and geotextile, the geomembrane glued on wooden plate was inserted into an upper box. When submerged condition was simulated, the lower wooden plate and the upper shear box were placed into a shallow bucket made of acryl having a length of 370 mm, a width of 170 mm and depth of 34 mm. After soil and geosynthetics were submerged for 3 hours, the test was started.

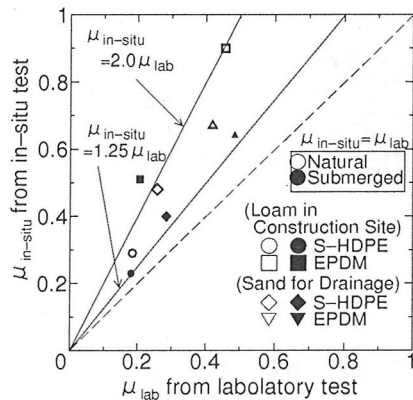


Fig. 4 Relation of frictional coefficients of geomembrane /soil between laboratory tests and in-situ tests

Fig. 4 shows a relation of frictional coefficients of geomembrane/soil between laboratory tests versus in-situ tests. In all cases, the amounts from in-situ tests are higher than those from laboratory tests. In case of HDPE, the values of in-situ tests was 125 to 182 % of those of laboratory tests. In case of EPDM, the in-situ tests showed 132 to 200 % of direct shear tests. Its trend is remarkable in case of loam. This difference seems to owing to the difference of the fabrics of the soil and normal stress σ_n applied on interface. In case of in-situ test, the grounds have stable soil fabric before it was not disturbed. The normal stress at in-situ test was much lower than at laboratory tests and this might cause higher frictional coefficient.

Fig. 5 shows normal stress versus shear resistance for interface between geomembrane and stapled nonwoven geotextile. Relating to the data from laboratory tests, shear stresses were plotted against four different normal stresses. The relations of them seem to be linear in all kinds of materials. The data obtained from in-situ tests are also presented on this figure and are well coincidence with relation of laboratory tests, though the normal stresses are different. Therefore, the frictional coefficient between smooth surfaced HDPE geomembrane and stapled nonwoven geotextile was almost similar value at both test.

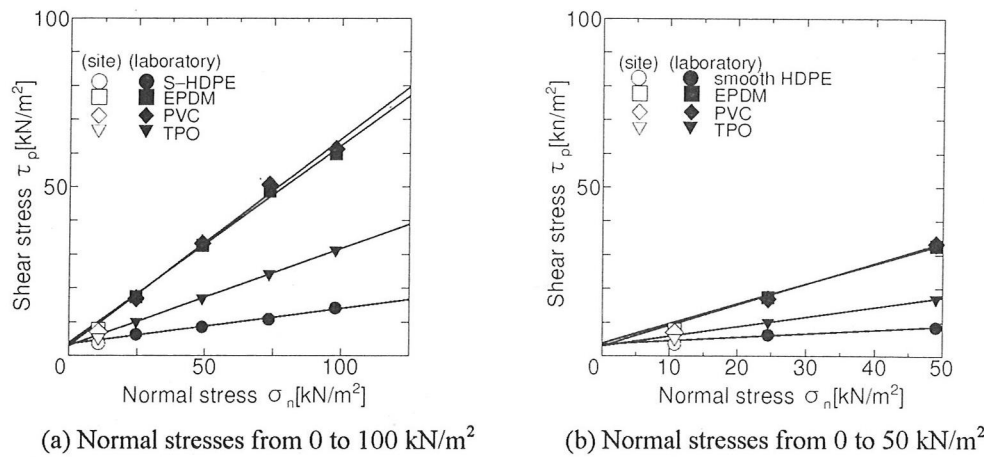


Fig. 5 Relation between normal stress σ_n versus shear stress τ

5 CONCLUSIONS

A convenient in-situ equipment to estimate a frictional resistance between geomembrane/soil and geomembrane/geotextile was developed. Using this device, field tests for six different geomembrane including HDPE, EPDM, PVC and etc. were conducted, where water conditions of tested ground were also changed. The results from field test were compared with those from laboratory tests.

The followings were main conclusions.

- (1) The ratio of frictional coefficient estimated at submerged condition to that at natural condition is about 70 - 80 % for loam ground while it is 90 % for drain sand.
- (2) The frictional coefficients between geomembrane and soil estimated at in-situ tests were about 125 to 200 % of those obtained at laboratory tests. The reasons for this difference were considered to be due to a difference of the fabric condition of tested soil and the normal stress.
- (3) The frictional coefficients between smooth surfaced geomembrane and stapled nonwoven geotextile estimated at in-situ tests is good agreement with the relationship between normal stress and shear stress obtained by direct shear tests in laboratory

Frictional properties are very important for designing the structure of liner in landfill. Investigating an effect of soil kind, water condition, density and fabric of the ground on frictional coefficient should be done using developed device.

6 ACKNOWLEDGMENT

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