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Simple convenient method to evaluate the tensile force at the shoulder of barrier sheet in landfill

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ABSTRACT: Tensile forces can occur due to waste compaction which is transferred into the geosynthetics by friction. It is very important to estimate the amount of the forces in order to design how much area requires. In this paper, a simple method called "elastic method considering rigidity of barrier sheet" is proposed to evaluate the tensile forces creating at the shoulder of the liner system. The data of the large-scaled field experiments conducted in 1997 are analyzed based on the proposed evaluation method, and the values calculated by using weights method and staged methods were compared with experimental value.

1 INTRODUCTION

A barrier sheet and geotextile are installed on the bottom and the side slope of a waste landfill as a liner system. Tensile forces can occur due to waste compaction which is transferred into the geosynthetics by friction. To design how much area requires, it is very important to estimate the amount of force created in the liner system. However, there are few examples of the large-scale field experiment. Especially, the analysis of the data of the large-scale field experiment has been not reported. However, there are few experiments about how much the tensile force creates in the geomembrane. Koerner (1994) presented a method based on the friction forces transmitted between the materials to evaluate the tensile force of a barrier sheet on the slope of landfill, but the amount of the elongation of barrier sheet is not considered in this method. Kanou(1997) conducted the large-scale field experiment making the slope model of 5000 mm in height, to measure the stress of the barrier sheet by the compression of waste, the thermal stress of the barrier sheet with the change of environmental temperature. But the tensile force at the shoulder with the compression of waste was not analyzed.

In this paper, the convenient method called "elastic method considering rigidity of barrier sheet" is proposed to evaluate the tensile force created at the shoulder of the liner system by compaction work of waste. The data of the large-scale field experiment conducted by Kanou in 1997 is analyzed by using the proposed evaluation method.

2 FIELD EXPERIMENT

2.1 *Outline of large-scale field experiment*

The large-scale field experiments had a side slope of Kanto loam with a angle of 34 degree (H:L = 1:1.5) and a height of 5000 mm height (Figure 1). Stapled non-woven geotextile was then placed on the surface of the Kanto loam over which an HDPE geomembrane with a thickness of 1.5 mm was over laid. A protective layer of stapled non-woven geotextile was spread over the geomembrane.

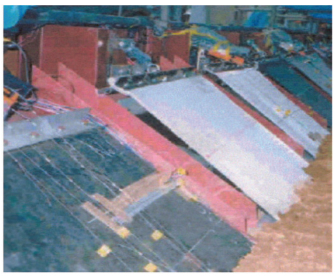

Figure 1. Field experiment.

The thermopair was glued on the surface of the HDPE geomembrane at the center part of the slope. The forces induced within the top layer of geotextile and HDPE geomembrane were measured through load cell which were fixed at the top of slope.

Kanto loam was used as a false waste, and was compacted to be unit weight of 15 kN/m^3. The total

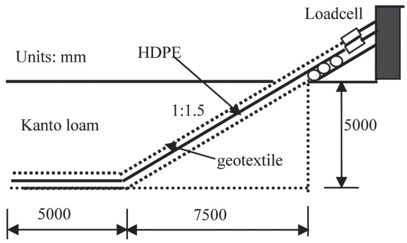

Figure 2. Field experiment cross section.

height of the Kanto loam is 5000 mm. Compaction work was conducted every day with a lift of 500 mm. Moreover, the compaction work of every day was conducted between 10:00 AM and 4:00 PM. At this time, the surface temperature the tensile forces of HDPE geomembrane and geotextile at the shoulder were measured.

In order to change the friction characteristic of a barrier sheet, the cases where geotextile was placed on the surface of HDPE geomembrane and was not were conducted.

2.2 *Materials*

Smooth surfaced HDPE geomembrane with a thickness of 1.5 mm is used as barrier sheet, non-woven stapled geotextile with a thickness of 10 mm was used as protecting material. Its tensile strength, at failure strain and elastic modulus at 20° Celsius are listed in Table 1. The friction characteristic between Kanto loam, barrier sheet, and geotextile was evaluated by direct shear tests are shown in Table 2. The relationship between relative displacement and the friction coefficient on the surface between HDPE geomembrane and geotextile is shown in Figure 3.

Table 1. Properties of materials.

Material	Tensile strength (MPa)	Failure strain (%)	Elastic modulus (MPa)
HDPE geomembrane	34.2	820	494
Geotextile	1.4	154	6.13

Table 2. Interface friction properties.

Material	Friction cofficient
HDPE geomembrane-Kanto loam	0.32
Geotextile-HDPE geomembrane	0.22
Geotextile-Kanto loam	0.66

2.3 *The results of experiment*

The thermal tensile force is calculated according to the change of surface temperature, the experimental value deducts temperature tensile force as the tensile force caused by compression of Kanto loam. The relationship between estimated tensile forces by the

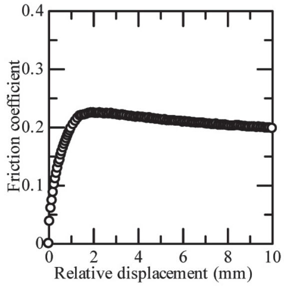

Figure 3. The relationship between relative displacement and friction coefficient.

compaction work and the elapsed time (stage of compaction) are shown in Figure 4. The tensile forces increase with stage of compaction. When geotextile is used between HDPE geomembrane and Kanto loam the tensile force of HDPE geomembrane was 2.0 KN/m, the tensile force of geotextile was 0.5 KN/m at 5000 mm in height. When geotextile is not used between HDPE geomembrane and Kanto loam the tensile force of HDPE geomembrane is 1.3 KN/m.

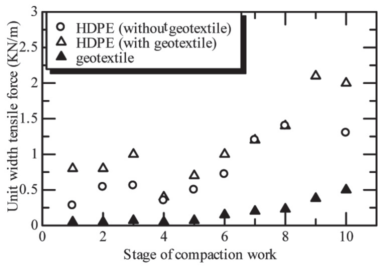

Figure 4. The relationship between stage of compaction work and tensile force.

3 ELASTIC METHOD CONSIDERING RIGIDITY OF BARRIER SHEET

When the wastes are compressed by working, they slide towards the bottom end of the liner system on side slope. They must be resisted by earth pressure at the toe of the slope, this resistance must be taken into consideration. A calculation model is shown in Figure 5. In this model, barrier (HDPE geomembrane) is covered by protective material of geotextile. The normal force (N) and friction coefficient ($\tan\delta_1$) between the waste and the top geotextile are expressed as equation (1) and (2).

$$N = P_0 \sin\beta + W \text{co}\,\beta \tag{1}$$

$$\tan\delta_1 = \frac{W \sin\beta - P_0 \cos\beta}{P_0 \sin\beta + W \cos\beta} \tag{2}$$

Where, P_0 is earth pressure acting at vertical section from the toe of the slope and expressed as $P_0 = \frac{1}{2}$

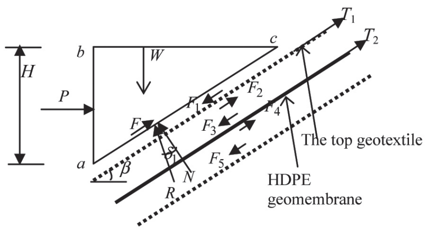

Figure 5. The calculation model.

$\gamma_t H^2 K_0 = \frac{1}{2}\gamma_t H^2(1 - \sin\phi)$; β is the angle of slope.

The friction force ($F = \tan\delta_1 \times N$) is adopted when the friction force (F) is smaller than maximum friction force ($F_{max} = \mu_1 \times N$), otherwise the resistance soil pressure (P) is newly assumed to be an unknown value, the vertical force (N) is calculated by formula (3) by using the maximum friction coefficient ($\tan\delta_{1m} = \mu_1$).

$$N = \frac{W}{\tan\delta_{1m}\sin\beta + \cos\beta} \tag{3}$$

Tensile force (T_1) of the top geotextile and tensile force (T_2) of HDPE geomembrane are evaluated by expression (4)-(9) by using above-determined of friction angle (δ_1) and vertical force (N).

$$F_1 = N\tan\delta_1 \tag{4}$$

$$F_2 = N\mu_2 \tag{5}$$

$$F_3 = F_2 \tag{6}$$

$$F_4 = N\mu_3 \tag{7}$$

$$T_1 = F_1 - F_2 \tag{8}$$

$$T_2 = F_3 - F_4 = N(\mu_2 - \tan\delta_3) \tag{9}$$

Where, μ_2 is frictional coefficient between the top geotextile and HDPE geomembrane; μ_3 is frictional coefficient between HDPE geomembrane and lower geotextile.

Assuming that the amount elongation of HDPE geomembrane at the shoulder is equal to relative displacement between HDPE geomembrane and lower geotextile, mobilized frictional coefficient is got based on experimental relationship between the frictional coefficient and the relative displacement relation as shown Figure 3. Tensile force (T_2) of HDPE geomembrane is evaluated according to the following procedures.

(a) Friction coefficient ($\tan\delta_3$) between HDPE geomembrane and lower geotextile is assumed (0 or μ_3), and (T_2) is calculated by expression (9).

(b) Because the top part of barrier sheet is fixed, the elongation amount D of HDPE geomembrane is calculated by the next expression.

$$D = \frac{1}{Et_g}\left[\frac{(T_2)^2}{2(\mu_2 + \tan\delta_3)}\right] \tag{10}$$

Where, E is the elastic modulus of HDPE geomembrane (MPa); t_g is the thickness of HDPE geomembrane (m).

(c) It is assumed that the calculated elongation amount D is equal to the amount of relative displacement between lower geotextile and HDPE geomembrane, friction coefficient ($\tan\delta_3$) corresponding to amount D of relative displacement is evaluated by using the relationship between relative displacement and friction coefficient.

(d) If the evaluated $\tan\delta_3$ is equal to the assumed value, tensile force (T_2) of HDPE geomembrane is calculated by using the $\tan\delta_3$. Otherwise, the value is newly assumed to calculate the friction coefficient $\tan\delta_3$ again according to the step of (b)-(c).

4 ANALYSIS OF EXPERIMENTAL RESULT

The tensile force measured at the first lift and the tenth lift of the large-scale field experiment shown in Figure 4 is analyzed. A slope inclination $\beta = 33.69°$ and the internal friction angle $\phi_d = 31°$ of the Kanto loam are used to calculate the tensile force. The unit weight of the Kanto loam is 15 kN/m^3. First of all, the calculation condition in the first stage and the tenth lift is described.

4.1 *Calculation condition*

Compaction work was divided into ten lifts, of 500 mm every day. Meanwhile, because the stress relaxation was generated, the tensile forces of barrier sheet did not increase in an straight line with an increase of lift. And, the calculation model is divided into the all weight method and the stage method.

4.1.1 *All weight method*

The calculation model of the tensile force of the barrier sheet after compaction work of the tenth is shown in Figure 6.

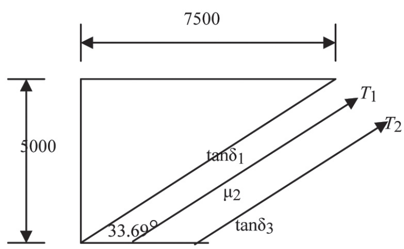

Figure 6. The calculation model.

The weight (W) of Kanto loam, earth pressure (P_0), normal force (N) and the friction coefficient of ($\tan\delta_3$) are calculated by using $\beta = 33.69°$ and $\phi_d = 31°$. The calculation condition is shown in Table 3.

Table 3. Calculation condition.

Parameter	HDPE geomembrane with top geotextile	HDPE geomembrane without top geotextile
W (KN/m)	281	281
P_0 (KN/m)	94	94
N (KN/m)	286	286
tan δ_1	0.27	
μ_2	0.22	0.27
tan δ_3	0.21	0.22

4.1.2 *Stage method*

In this method, the height of Kanto loam compacted on the slope part is constant thickness of the layer. The weight of the Kanto loam acted on the slope of barrier sheet to show in Figure 7 when considering the weight of the Kanto loam of the slope part of every one layer. The calculation condition is shown in Table 4.

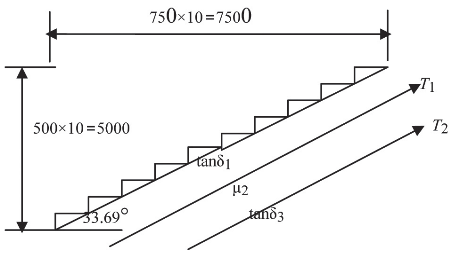

Figure 7. The calculation model (stage method).

Table 4. Calculation condition.

Parameter	HDPE geomembrane with top geotextile	HDPE geomembrane without top geotextile
W (KN/m)	28.1	28.1
P_0 (KN/m)	9.4	9.4
N (KN/m)	28.6	28.6
tan δ_1	0.27	
μ_2	0.22	0.27
tan δ_3	0.16	0.17

4.2 *Calculation results*

The ratio of the tensile force of barrier sheet calculated by using expression (4)-(9) to the measured tensile force is shown in Table 5. The calculated value of the tensile force of geotextile at the first lift is four times larger the experiment value according to figure. The calculated value after the end of compaction work at the tenth lift is 28 times larger the experiment value by using all weight method, but the calculated value becomes to be 2.9 times of the experiment value when considering the weight of the Kanto loam of the slope part of every one layer.

The values of 0.6 and 2.2 are obtained with and without the geotextile respectively regardless of the analysis type. When the top geotextile is used together, the calculated value is 0.9-1.4 of the experiment value after the end of compaction work at the tenth lift regardless of all weight method or the stage method. When the top geotextile is not used, the value evaluated by all weight method is 11 times the experiment value, the value evaluated by the stage method is 2.9 times the experiment value.

Table 5. Relationship between calculated value and experimental value.

		All weight method		Stage method	
		First lift	Tenth lift	First lift	Tenth lift
Geotextile		3.5	28	3.5	2.9
	With GT	0.6	0.4	0.6	0.9
HDPE	Without GT	2.2	10.9	2.2	2.9

Because Kanto loam is well compacted in each lift, so the compression of Kanto loam is not caused at the tenth lift, that is, relative displacement is not so caused between Kanto loam and barrier sheet, the weight (W) of Kanto loam used by all weight method is excessive, the tensile force of HDPE geomembrane and geotextile evaluated by all weight method is larger than experiment value after the tenth lift.

5 CONCLUSION

The tensile force of barrier sheet is analyzed by using the results of the large-scale field experiment conducted by Kanou to evaluate the behavior of the barrier sheet in 1997. The main results are described as follows.

The calculated values by "elastic method considering rigidity of barrier sheet" were as similar as experimental values and the method is valuable to evaluate the tensile force of the geosynthetics.

The tensile forces of geotextile evaluated by all weight method and stage method after the first lift are 28 times and 2.9 of the experimental value.The calculated value of HDPE geomembrane after the tenth lift is 0.9-1.4 of the experimental value regardless of all weight method or the stage method when the top geotextile is used together. The tensile force of HDPE geomembrane evaluated by all weight method is 11 times, by the stage method is 2.9 times of the experiment value when the top geotextile is not used.

REFERENCES

Koerner, R.M. (1994). Designing with Geomembrane, Prentice hall Englewood cliffs, New Jersey 07632, pp. 545-549.

Kanou, H., Doi, Y., Imaizumi, S. and Tsuboi, M. (1997). Evaluation of geomembrane stress on side slope caused by settement of wastes, *Proceedings of Sixth International Landfill Symposium,* Vol. 3, pp. 525-534.

Xu, S. and Imaizumi, S. (2004). Evaluation of tensile force at the anchored end of the barrier sheet spread on the side slope of the landfill caused by compression of the waste, *journal of civil engineering(japan)* 778, 73-84.