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Prediction of the deformation of a reinforced soil wall

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ABSTRACT: We examined if the mechanical model which we propose could also apply to the prediction of the deformation of a reinforced soil wall, and in this case model experiments were also carried out. As a result, calculated values approximately agreed with the actual deformation of the reinforced soil wall. We also could estimate the strain distribution on geotextiles put on a wall panel of each stage by using the mechanical model. It was proven that the overburden pressure greatly influenced the strain of the geotextile installed wall panel. These results can be utilized for the design method of reinforced soil walls taking into account deformation.

1 INTRODUCTION

The deformation of a reinforced soil wall is greater than for a concrete gravity retaining wall because the rigidity of a reinforced soil wall is less. The research on the deformation of this reinforced soil wall has not been sufficiently carried out.Therefore, we tried the prediction of the deformation of a reinforced soil wall. First we carried out the pull out test. The deformation distributions of the geotextiles are not constant when the pull out force affects a geotextile put under ground. Research about deformation by pull out tests has been reported by many researchers. This summary is a written introduction of a paper reported by Gurung and Iwao (1999). However, a unified view about the deformations has yet to be reached.We have also examined deformation when a pull out force acts on a geotextile under ground. As a result, the trend of deformation distributions by analysis agreed approximately with experimental results. As the next step, we estimated if our study can apply to the prediction of the deformation of reinforced soil walls. As a result, the value calculated by the mechanical model agreed approximately with the deformation of the reinforced soil wall. We also estimated the strain distribution on geotextiles put on a wall panel of each stage by using the mechanical model. It was proven that the overburden pressure greatly influenced the strain of the geotextile installed wall panel. These results can be utilized for the design method of reinforced soil walls taking into account of deformation.

2 EXPERIMENTAL PROCEDURE

We used spun-bounded 100% non-woven fabric and polyethylene Netron sheet in this experiment. The Young moduli of nonwoven fabric and Netron sheet were 5,500 and 17,200 kN/m^2, respectively.

In this experiment, we used 2 kinds of sand; coarse sand and fine sand. Each grading curve is shown in Figure 1. The relationship between the internal friction angle and initial void ratios of the sand obtained by the single shear test is shown in Figure 2. First, we conducted the pull out tests shown in Fig. 3. Dimensions of the specimen used for this experiment were 50 cm in length and 10 cm in width. The pull out rate was 1 mm/min.

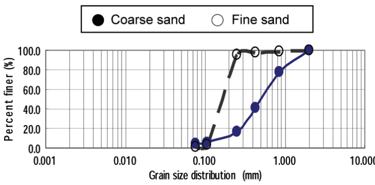

Figure 1. Grain size distribution curve of sand.

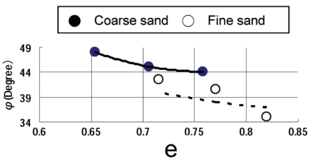

Figure 2. Relationship between e and ϕ.

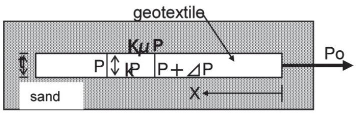

Figure 3. Pull out test and mechanical model.

The experimental equipment which modelled the reinforced soil wall was made by using an earth tank as shown in Figure 4. There were 2 kinds of each earth tank. The dimensions of the earth tank are shown in Table 1. The size of earth tank type T-2 is about 2 times as large as type T-1. The reinforced soil wall was made by putting wall panels one on top of the other. The wall panel is made from wood and the width, length and thickness are shown in Table 2. Type T-1 was combined with type of panel P-1, and type T-2 was combined with P-2. Also, the geotextiles were attached at the center of the panel wall with wood screws(refer to Fig. 5), and we used 3 kinds of sizes and 2 kinds of geotextiles for the geotextiles. The dimensions are shown in Table 3. We attached the geotextiles of the same size to a panel wall. The number of sheets attached were of 2 types.

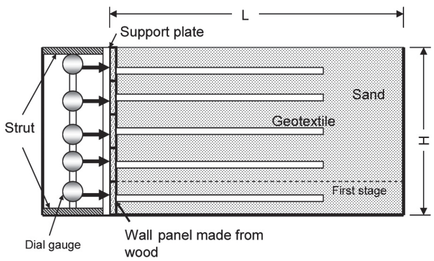

Figure 4. Experimental equipment of reinforce soil wall.

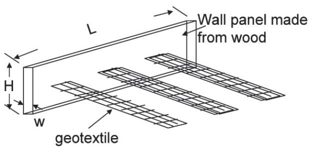

Figure 5. Wall panel.

One type used 3 sheets and other type used 2 sheets (refer to Fig. 5).

We piled up sand on the wall panel. Combinations of wall panels were not done. Next, we installed a dial gauge to measure the deformation of the reinforced soil walls as shown in Figure 4. After the reinforced soil wall was completed, we removed the struts on both sides at once. The support of the support-plate was cancelled by this. The wall panels of the reinforced soil wall were deformed outside.

The deformation volumes of each wall panel of a reinforced soil wall were measured by the dial gauges.

Table 1. Type of earth tanks.

Type No	Width (W) cm	Length (L) cm	Height (H) cm
T-1	50	100	50
T-2	30	200	90

Table 2. Size of wall panels.

Type No	Width (W) cm	Height (H) cm	Thickness (t) cm
P-1	50	10	50
P-2	30	10	90

Table 3. Type of geotextiles.

Type No	Matter	Width (W) cm	Length (L) cm	Thickness (t) cm
Mnon-1	Non	10	55	0.1
Mnon-2	Non	5	55	0.1
Mnon-3	Non	5	70	0.1
Mnet-1	Net	5	55	1.0
Mnet-2	Net	5	70	1.0

Non: Non-woven Net: Netron sheet

3 MECHANICAL MODEL TO EVALUATE DEFORNMATION OF GEOTEXTILE PUT UNDER GROUND

To predict the deformation of a geotextile put under ground, we proposed mechanical model as shown in Figure 3. From the equilibrium condition of this model, the differential equation is expressed as follows:

$$-dPt = 2k\,\mu\,Pdx \qquad (1)$$

t, thichness of geotextile
Solving with the boundary conditions of

$X = 0$, $P = Po$, $X = L$, $P = 0$

We obtained the following:

$$P = P_0 e^{-2k\mu/t} \qquad (2)$$

In addition, we obtained the strain from Hooke's law.

$$\varepsilon = P_0 e^{-2k\mu/t}/AE \qquad (3)$$

E: Yang modulus
A: cross section area of geotextile

The pull-out test shown in the Figure 3 was carried out in order to examine whether this mechanical model can estimate the deformation. As a result, we obtained a result of showing in the Figure 6. Strain distribution of the prediction and strain distribution of the observation of the pull-out test were almost equal. Then, we considered that this mechanical model which we proposed is utilized for the prediction of deformation volume of reinforced soil walls.

We proposed the strain distribution of a geotextile under ground which is attached to a wall panel as

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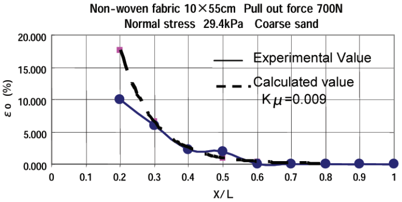

Figure 6. Deformation of non-woven fabric put under soil.

shown in Figure 7. As shown in this figure, the strain distributions on the right side and left side from the slip plane are different, and the strain reaches a maximum at the position where the slip plane passes the geotextile. In this research, equation (3) was applied for the strain distribution on the right side. And, trapezoid strain distribution which many researchers have proposed was applied for the strain distribution of the left side. The maximum strain of the trapezoid becomes Po/AE at the point where the slip plane passes the geotextile and the minimum strain becomes 0.75Po/AE at the wall panel. The strain distribution between the maximum strain and minimum strain becomes a straight line. The trapezoidal area becomes the deformation volume of the geotextile on the left side from the slide plane. Thus we obtained the following equation.

$$\Delta Ls = \frac{(0.75Po + Po)Ls}{2EA} \quad (4)$$

ΔLs: deformation volume of the geotextile on the left side from the slide plane
A: cross section area of geotextile
Ls: length of the geotextile from the wall panel surface to slip plane (refer to Figure 7).
Po: maximum pull out force

$$\Delta Le = \frac{Pot}{2\,EAK\,\mu}\left(1 - e^{-2k\mu Le/t}\right) \quad (5)$$

ΔLe. deformation volume of geotextile on the right side from the slip plane
Le: L-Ls

By adding equation 4 and equation 5, the whole deformation volume of the geotextile can be shown as the following.

$$\Delta L = \Delta Ls + \Delta Le \quad (6)$$

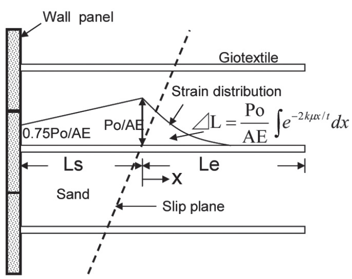

Figure 7. Strain distribution of geotextile put under soil.

4 DEFORNMATION OF A REINFORCED SOIL WALL

We carried out an experiment in which we changed the sand type, size of the earth tank, type of the geotextile and number of sheets of the geotextile attached to the panel in order to confirm whether equation (6) can adapt to various conditions. Afterwards, we compared the deformation volumes calculated from equation (6) with deformation volumes obtained from the experiments.

To use equation (6), it is necessary to know the maximum pull-out force Po. Then, we confirmed the shape of the slip plane by an experiment. The slip plane became almost a straight line. From this result, we considered that the Rankin earth pressure theory could be used. From this, the maximum pull-out force Po that acts on a sheet of geotextile was obtained by using the Rankin earth pressure theory. ΔLs of the geotextile on the left side from the slide plane was calculated by equation (4). ΔLe on the right side from the slide plane can be calculated by equation (5). However, the values of coefficients k and μ are necessary in order to use this equation (5). These coefficients k and μ have not yet been clarified. But, we can simply estimate that coefficient k relates to an earth pressure coefficient and that the coefficient μ is the friction between soil and the geotextile. Then, we calculated ΔLe by using the coefficient of an active earth pressure $\tan^2(45 + \phi/2)$ for k, and $\mu = \sigma \tan\phi$ (σ: overburden pressure, ϕ: internal friction angle). Consequently, these coefficients could not be used, since ΔLe becomes a very large value. Then, we obtained a value of $k \cdot \mu$ using a pull out test. This value of $k \cdot \mu$ was about 1/10 that of the aforementioned $k \cdot \mu$. Therefore, we made $k \cdot \mu = \tan^2(45 + \phi/2) \times \sigma \tan\phi/10$. ΔLe was calculated by using this $k \cdot \mu$. However, the decision procedure of $k \cdot \mu$ can not be yet clarified. The whole deformation value (ΔL) of the geotextile at each stage was finally obtained by equation (6).

The representative examples are shown in Figures 8 (a) (b) (c) and Figure 9 (a) (b). Dotted lines in these figures are calculated values, and solid lines are experimental values. Figure 8 shows experimental results using earth tank T-1. Figure 9 shows results using earth tank T-2.

First, we examine the deformation volume obtained by the experiment. As shown in Figure 8 (a) (b) (c), The fundamental deformation becomes a maximum near the center. Figure 8 (a) and (c) are the same type of geotextile and number of sheets. However, the type of sand is different. The internal friction angle of coarse sand is larger than that of fine sand. It is shown that the deformation volume is in inverse proportion to the size of the internal friction angle. Next, we examine he dotted lines of Figures 8 (a) (b) (c) which show the calculated value. As shown in

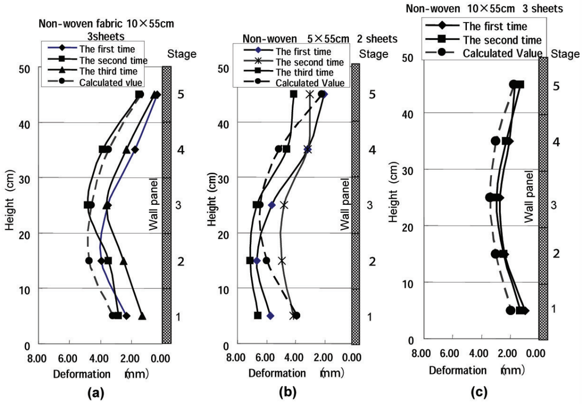

Figure 8. Calculated and experimental value (Earth tank T-1).

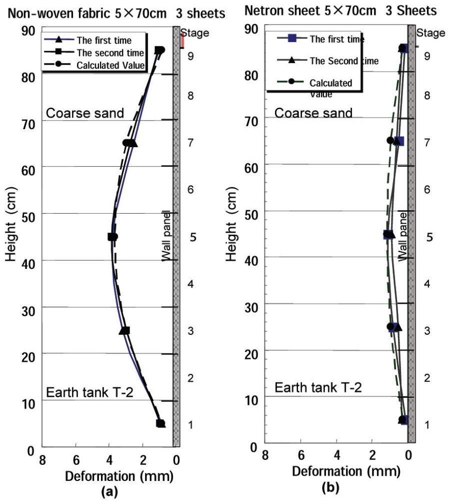

Figure 9. Calculated and experimental value (Earth tank T-2).

these Figures, the calculated value agrees approximately with the actual value. Next, we examine Figure 9 (a) (b) that shows experimental results. The sand used in this experiment is coarse sand. However, the type of the geotextile is different. It is shown that the deformation volume of a reinforced soil wall is in inverse proportion to the size of the Young modulus.

As shown in these figures, the calculated values also agree approximately with the actual value even in this experiment. From these results, it is considered that equation (6) can be utilized for the design method of a reinforced soil wall taking into consideration deformation. Furthermore, it is possible that we can predict the strain distribution of the geotextile put on the wall panel of a reinforced soil wall by using equation 6. The result of the strain distribution in the experimental case in Figure 9 is shown in Figures 10 (a)~(e).

These Figures show from the uppermost stage panel

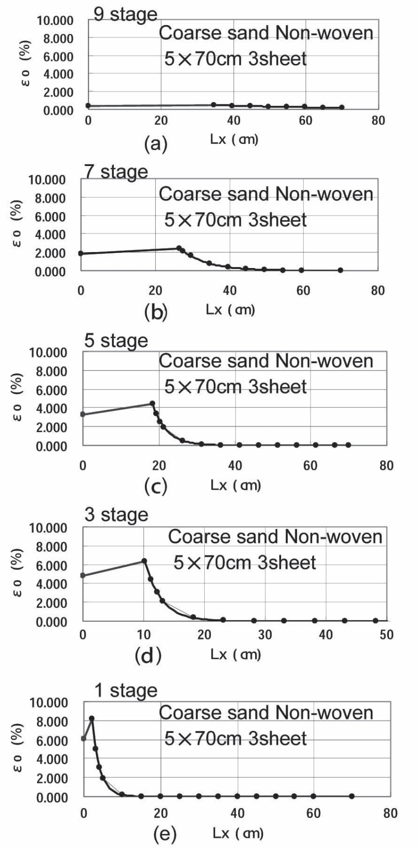

Figure 10. Strain distribution of geotextile.

in Figure 10 (a) to the bottom stage panel in figure 10(e). Though, the strain distribution of the geotextile installed on the uppermost stage panel is small, the strain of the geotextile is widely distributed. The strain distribution of the bottom stage has a sharp peak. However, the strain distribution is narrow. From these results, it was proven that the surcharge load greatly influenced the strain distribution of the geotextile installed on a reinforced soil wall.

5 CONCLUSION

The deformation value of the geotextail calculated by the mechanical model which we propose agreed approximately with the deformation of the reinforced soil wall.

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