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Model experiments for earthquake-resistant performance of geotextile using aluminum rod layer

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ABSTRACT: When an ordinary retaining wall is subjected to seismic force, seismic earth pressure acts on the retaining wall, and the wall is designed to resist the seismic earth pressure. But in the case of reinforced-retaining wall, such as geotextile, the design method is different from that of ordinary retaining walls because reinforced ground and wall resist seismic force as an integrated body. In this study, earthquake-resistant performance of the geotextile reinforced retaining wall is discussed by model experiments using aluminum rod layer.

In experiments, behavior of the model ground and wall are observed by computer image measurement using digital camera. Another purpose of this study is to develop a measurement system for behavior of the aluminum rod layer. In this paper, the method of the image measurement and collapse behavior of the model reinforced wall and the ground are also discussed.

1 INTRODUCTION

When thinking about the stability problems of reinforced retaining walls in earthquakes, it is important to understand the behavior of ground and wall. In this study, experimentation to observe the two-dimensional behavior of the model ground using aluminum rod layer is executed. To observe the behavior accurately, the image measurement method using a digital camera is applied.

The parameters of these experiments are reinforcement length and its number. The influence which they give to earthquake-resistant performance is examined.

2 METHOD OF IMAGE MEASUREMENT

2.1 *Summary of image measurement*

The characteristic of this measurement method is the ability to understand the behavior of the object at the same time as experimenting, because the analysis of the image of each loading step can be completed in a short time.

In this measurement method, a digital camera and a personal computer of the general spread type are used. Figure 1 shows the flowchart. A lot of round color labels (diameter: 3-10 mm) are stuck on the aluminum rod layer as marking points. It is necessary to put the marking point on the center of the aluminum rod section in order to avoid the error of displacement of marking point by the rotation of aluminum rod (Figure 2). Photographs are taken of the aluminum rod layer in each loading step, and tracks of marking points are analysed by the computer.

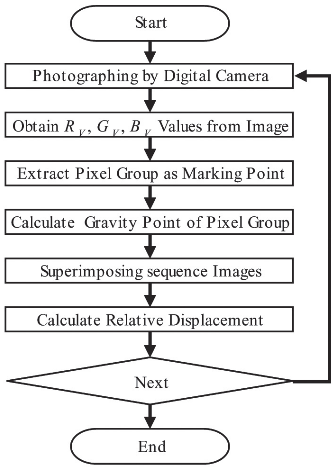


Figure 1. Flowchart.

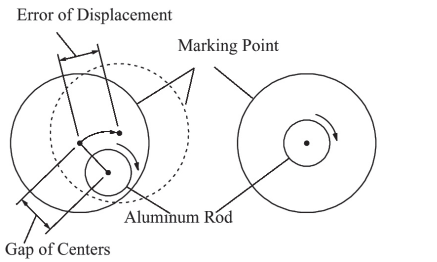


Figure 2. Error of displacement by rotation of aluminum rod.

2.2 *Recognition method of marking point*

The image obtained using digital camera comprises millions of pixels. Each pixel expresses the tone by three primary colors (red, green, and blue). These three primary colors have the radiance value (R_V, G_V, and B_V) that is usually shown in the step of 256, and shown by the integer value from 0 to 255. Table 1 shows the characteristic of each radiance value concerning three typical colors (red, green and blue series). In this method, pixels in the marking point are extracted by using the difference of the radiance values (Figure 3). This method is enabled to use two or more colors for the marking point. The difference of the radiance value is judged by:

Red Series: $R_V - (G_V + B_V)/2 > \alpha_R$

Green Series: $G_V - (B_V + R_V)/2 > \alpha_G$

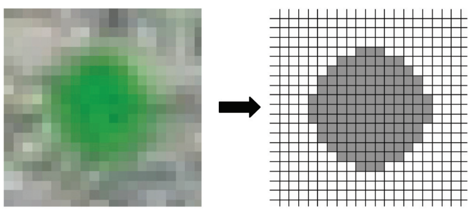
Blue Series: $B_V - (R_V + G_V)/2 > \alpha_B$

α_R, α_G and α_B are the values to extract the pixel within the appropriate range, and these values change depending on the kind of the digital camera and the lighting condition etc.

Moreover, the pixel group that the extracted pixels consist of the same kind of mark is recognized as a marking point, and the coordinates of the gravity of the marking point are decided.

Table 1. Radiance value of typical colors.

	Red Series			Green Series			Blue Series		
	R_V	G_V	B_V	R_V	G_V	B_V	R_V	G_V	B_V
high	⇕				⇕				⇕
⇕									
low		⇕	⇕	⇕		⇕	⇕	⇕	



(a) Digital Image (Green Marking Point) (b) Pixels with high G_V ($\alpha_G = 30$)

Figure 3. Extract pixels of marking point.

2.3 *Method of tracking marking points*

Several standard points are stuck on an immovable frame of the experimental stage. Images in all steps are overlapped. In this step, it is necessary to agree with each standard point by rotate, expansion and contraction of image. The gap of the marking point is determined. Therefore, the behavior of the inclined model ground can be tracked. Moreover, it is possible to calculate the amount of displacement of each marking point from the distance between standard points.

3 EXPERIMENTAL PROGRAM

3.1 *Examination method*

Table 2 shows the parameters of the experiment (H: height of wall, L: length of reinforcements). The influence of length of reinforcements is examined by Case 1 and 2 and the influence of the number of reinforcements is examined by Case 3, 1 and 4. The entire test stage is inclined in order to simulate the state where earthquake force acts. The sequence images are photographed in each incline angle 0.5°. The behavior of the model ground is analysed, and final collapse angle is recorded.

3.2 *Experimental device*

Figure 4 shows the device used in the examination. The examination stage can be rotated by expanding the screw jack (Photo 1). Table 3 shows characteristics of aluminum rod layer. Length of the aluminum rod is 150 mm, and diameters of the rods are 1.3 mm and 3.0 mm. Weight ratio of these aluminum rods is 3:2. The model wall is made by C-shape aluminum, and woven cloth is used as the reinforcements (Table 4).

4 EXPERIMENTAL RESULTS

4.1 *Collapse angle*

Table 5 shows the gradient collapse angle θ_u of the stage and converted horizontal seismic intensity k.

Table 2. Parameters of examination.

Case	Height of Wall H [mm]	Length of Reinforcements L [mm]	Number of Reinforcements
1	400	400	4
2	400	600	4
3	400	400	2
4	400	400	8

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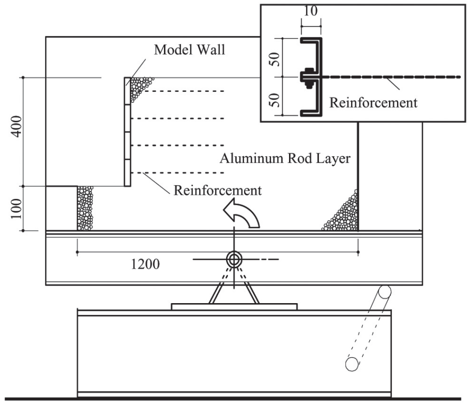


Figure 4. Experimental device.

Photo 1. Experiment situation (Case 4).

Table 3. Characteristics of aluminum rod layer.

Internal friction angle	31.24°
Weight per unit volume	22.0 kN/m^3
Void ratio	0.23

Table 4. Characteristics of reinforcement.

Friction angle between Alminum rod layer and reinforcement	21.23°
Tensile strength	5.8 kN/m

Table 5. Experimental results.

Case	Gradient angle θ_u [deg]	Horizontal seismic Intensity k
1	6.10	0.106
2	7.75	0.135
3	3.75	0.065
4	7.25	0.126

4.1.1 *Influence of length of reinforcements*

From the results of Case 1 and 2, it is understood that cases with long reinforcements have a higher and more performance of earthquake-resistant.

4.1.2 *Influence of number of reinforcements*

Figure 5 shows the relation between θ_u and the number of reinforcements. The gradient collapse angle θ_u tends to become higher in proportion to the number of reinforcements in this examination. The more the number of reinforcements increases, the more earthquake-resistant performance improves.

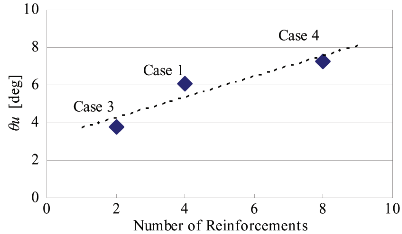


Figure 5. Relationship between the number of reinforcements and the gradient collapse angle.

4.2 *Behavior of model wall and ground*

4.2.1 *Horizontal displacement of walls*

Figure 6 shows the relation between the gradient angle θ and the ratio Y/H; Y is horizontal displacement of wall. The number in this figure is the number of the wall block, and it is sequentially named No. 1, 2 … from the lower side.

From these results, it can be seen that the displacement of central and top part of the wall tends to become larger as the inclination of the stage increases. It is understood that the wall have moved as shown in Figure 7. The horizontal displacement of the wall in critical state is large as the number of reinforcements increases. Tenacity becomes higher as the number of the reinforcements, also.

4.2.2 *Shape of the collapsing ground*

Figures 8 and 9 shows the results of the image measurement in Case 1 and 4. Figure (a) is a displacement vector, (b) shows the magnitude of displacement and (c) shows the principal strain.

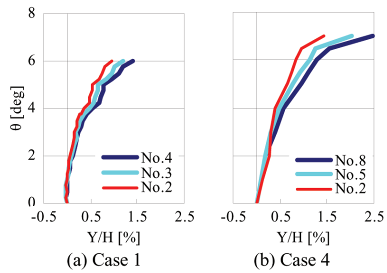


Figure 6. Horizontal displacement of walls.

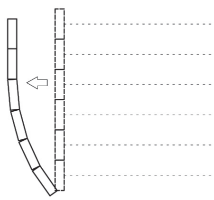
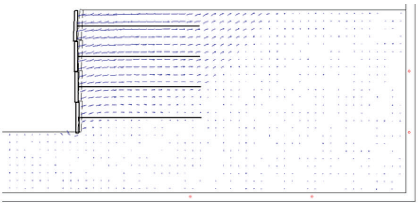
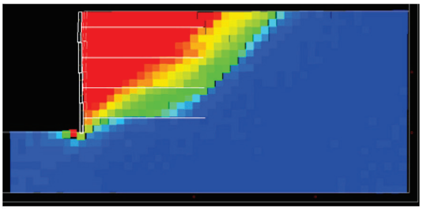


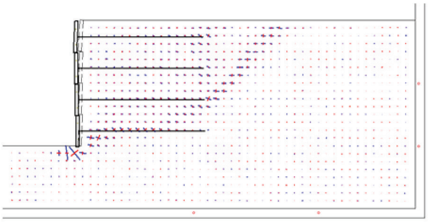
Figure 7. Pattern of wall displacement.



(a) Displacement Vector

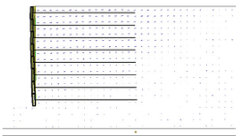


(b) Magnitude of Displacement

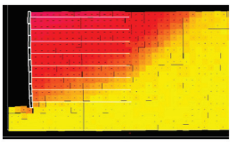


(c) Principal Strain

Figure 8. Results of image measurement (Case 1).



(a) Displacement Vector



(b) Magnitude of Displacement

Figure 9. Results of image measurement (Case 4).

The slip lines are clearly recognized at border of failure area and the end line of the reinforcements. Strains concentrate along the slip lines. In addition, large principal strain dose not appears inside the failure area.

5 CONCLUSIONS

In this paper, the model experiment of reinforced retaining wall was carried out using aluminum rod layer. The behavior of the wall and collapse ground could be captured clearly by the image measurement method. It is understood that the length and the number of the reinforcements influence to performance of earthquake-resistant. Moreover, it is conformed that the image measurement method works effectively.

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