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Study on the performance of a reinforced earth wall during earthquake based on Tottori-ken Seibu earthquake event

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ABSTRACT: The Tottori-ken Seibu earthquake of Mjj = 7.3 occurred on October 6, 2000. A lot of reinforced earth walls were built in a range of a radius of 10 km from epicenter. We investigated it after an earthquake disaster. The damage was not confirmed to most reinforced earth walls. However, the damage occurred at two reinforced earth walls that are near the epicenter comparatively. We carried out execution of repair and reinforcement for them. From a main shock 1 year and 6 month later, the aftershock of Mjj = 4.5 occurred on March 6, 2002. It is a point in time that passed for 1 year since we reinforce it. Therefore, we carried out investigation again. This paper is described about the investigation result that we performed after a main shock, the establishment of the technique to judge the damage of a retaining wall that is based on the investigation result, the implementation of a repair and reinforcement by the judgment technique.

1 INTRODUCTION

The Tottori-ken Seibu earthquake of Mjj = 7.3 around west of Tottori prefecture occurred on October 6, 2000. A lot of reinforced earth walls were built in a range of a radius of 10 km from epicenter. We investigated it after an earthquake disaster. By the those days, the technique to judge the damage of a retaining wall to be it was not established. Therefore, we inspected in the visual inspection and the hanging check. For all reinforced earth walls that we checked, we ranked a soundness evaluation by degree of the damage. The damage was not confirmed to most reinforced earth walls. However, the damage occurred at two reinforced earth walls, which are near the epicenter comparatively. (Site 1 in Figure 1) We examined repair and reinforcement for them. The two reinforced earth walls exceeded a serviceability limit. We carried out execution of repair and reinforcement for them.

From a main shock 1 year and 6 month later, in March 6, 2002, at the point near the main shock, the aftershock of Mjj = 4.5 occurred. It is a point in time that passed for 1 year since we reinforce it. Therefore, for the reinforced earth wall that we repaired and reinforced, we carried out investigation again.

This paper is described about the investigation result that we performed after a main shock, the establishment of the technique to judge the damage of a retaining wall that is based on the investigation result,

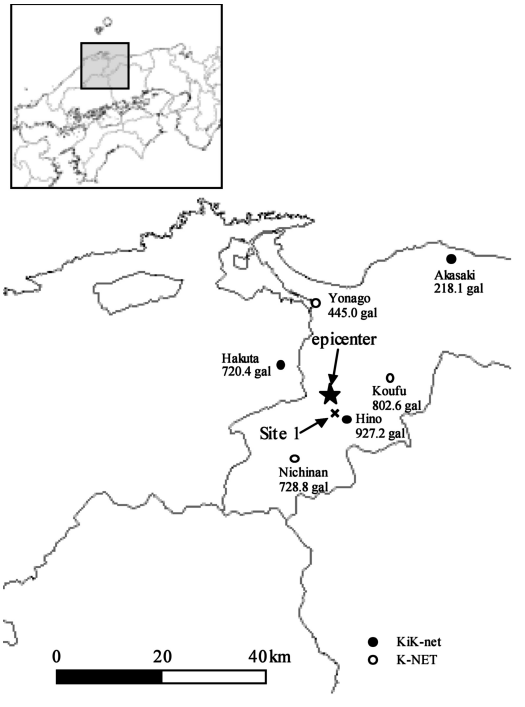

Figure 1. Location of the investigated site.

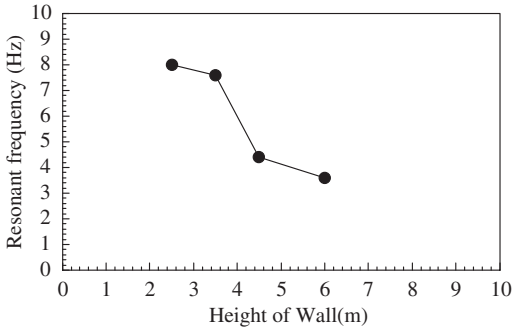

Figure 2. Resonant frequency for the wall height.

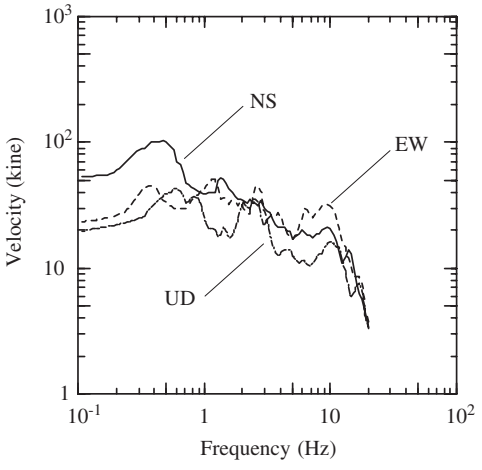

Figure 3. The spectrum of the main shock.

the implementation of a repair and reinforcement by the judgment technique.

It tried whether or not it was possible to use the full-scale experiments on the shaking table results for the sorting-out of an investigation object this time.

Relation between the wall height and the resonant frequency in the full-scale experiments on the shaking table results, which was implemented in the retaining wall with the same structure is shown in Figure 2. Futaki et al. said the amplification ratio is approximately 7.

Using the corrugated dater in which is provided from National Research Institute for Earth Science and Disaster Prevention (KiK-Net), a replying spectrum near the investigation place is shown in the Figure 3. The damped-ratio in this place used 5%. It doesn't lead by comparing with the shaking table results but this place shows that 0.6 Hz excel. This dater is one in the basis. It is possible to estimate that the wave that is similar approximately, because the object part is on the rock and doesn't leave with the KiK-net point occurred.

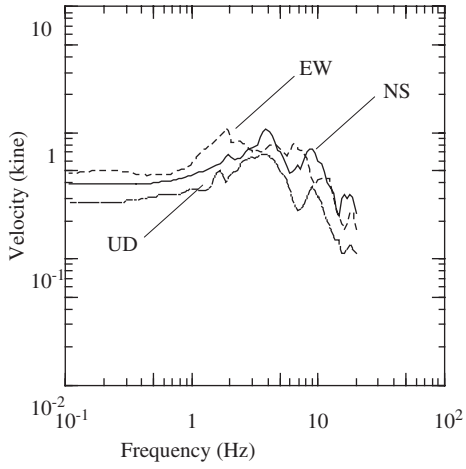

Figure 4. The spectrum of the aftershock.

It thought that it was the one where the wall is high in the earthquake this time from these results and that the damage occurred.

Also, a spectrum at the time of the aftershock is shown in the figure 4.

2 INVESTIGATION

We investigated it after an earthquake disaster. By the those days, the technique to judge the damage of a retaining wall to be it was not established. Therefore, we inspected in the visual inspection and the hanging check. For all reinforced earth walls that we checked, we ranked a soundness evaluation by degree of the damage. The damage was not confirmed to most reinforced earth walls. However, the damage occurred at two reinforced earth walls, which are near the epicenter comparatively.

As for one reinforced earth wall, because to have been built by the steep slope part, looseness on the slope in the front was seen. Also, opening in the vertical joint part was seen at the part, which is close to the other wall. As for another reinforced earth wall, damage to the wall was hardly seen but a partial hanging was seen. Therefore, the two reinforced earth walls were judged to have to be investigated in detail.

In this report, investigated Result of which the hanging in the seen one and it is on is described. In the amount of displacement at the wall, hanging a plumb bob from the wall upper end, it measured a distance from the plumb bob to the wall with the detailed investigation. It implemented measurement in the position of the upper and lower end of the panel near the vertical joint at the wall.

It defines the gradient of the wall as the percentage that removed the relative difference of the coping concrete upper side and the amount of displacement

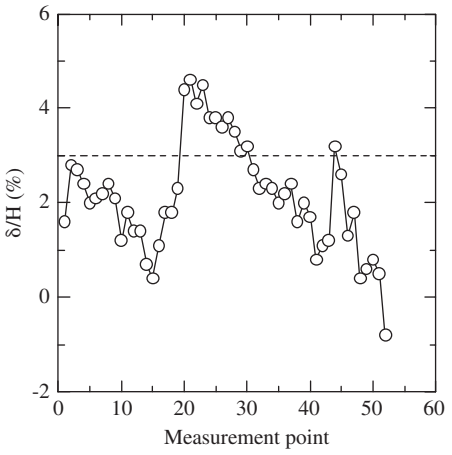

Figure 5. The measuring result after the main shock.

of the horizontal direction in the back filling surface position in wall height of the ground level. As for the measuring result, it is shown in the Figure 5. The meaning of Measurement point shows the part that was measured in the vertical joint from the edge in the wall to the direction of the extension. In the interval, it is 1.5 m. The vertical axis shows a gradient. The gradient is the one to have divided a horizontal direction amount of displacement by the height. Here, it does the central part finding of the thing that the hanging is big nearby.

3 REINFORCEMENT MEASURE

The part that exceeds 3% of the construction management standard value had the gradient of the wall facing and the wall decided to plan reinforcement. In case of selection of the reinforcement, it considered the following two. It decided to select from the inside of the reinforced earth method, which adopts the same mechanism and it adopted soil nailing of construction which is one of the reinforced earth methods. Because it becomes the structure which can resist the earth pressure of reinforced soil mass, being made from the reinforced concrete with 14 cm thickness, not to have a bad influence on the wall material by the reinforcement vs. Also, because it didn't range over the whole reinforced earth wall, the implementation section of the reinforcement decided to secure the system of the outward appearance. As for the design of the reinforcing rod insertion, the design earth pressure to use for the effect of the reinforcement without considering a stiffening effect by the strip in the reinforced earth wall uses the design earth pressure of the reinforced earth wall method of construction.

It calculates the resistance, which occurs to the reinforcing rod using the sought earth pressure. It bores the reinforcing rod insertion at the 15° angle in the

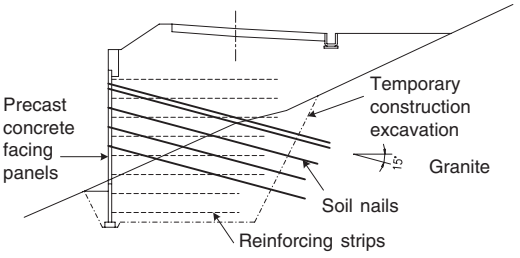

Figure 6. A cross section of the reinforcement range.

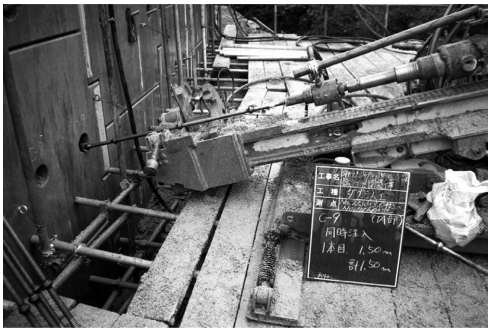

Figure 7. Boring status.

direction of the level more and the bottom. Here, it calculates resistance by the following equation.

$$R = T / \cos\alpha \tag{1}$$

where, R is the resistance which occurs to the reinforcing rod, T is the tension which was calculated from the earth pressure, α is the boring angle.

A necessary anchorage length is found by the following equation.

$$L = \frac{R \cdot f}{l \cdot \tau} \tag{2}$$

where, L is the necessary anchorage length, f is the safety factor, l is reinforcing rod circumference, τ is the allowable bond stress.

The crossing section of the reinforcement range is shown in the Figure 6.

Boring status is shown in the Figure 7. Reinforcement completion is shown in the Figure 8.

4 REINVESTIGATION

4.1 *Reinvestigation result*

After the aftershock occurs, it implemented reinvestigation. The time is time of the elapse in 1 year after reinforcement. The investigation method measured the gradient which used a visual examination and a plumb

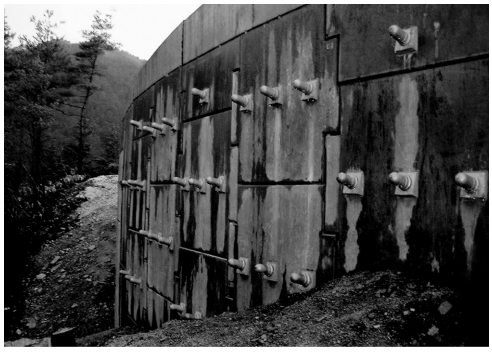

Figure 8. Reinforcement completion.

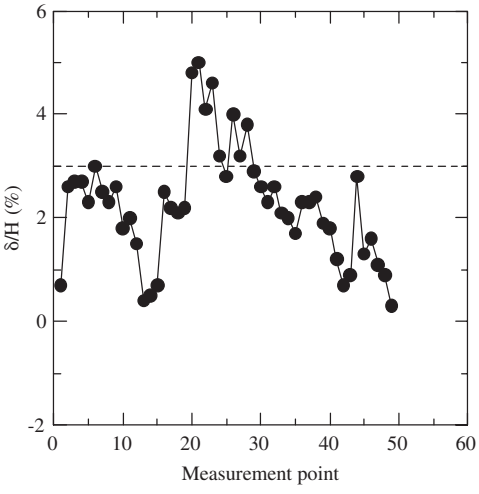

Figure 9. The measuring result after the aftershock.

bob like the after the main shock it. At the visual examination, specifically, a change was observed with after the main shock when there was not it. Here, this time, a measuring result is shown in the figure.

4.2 *Reinforced effect*

It gives the variation of the gradient in after the main shock and after the aftershock to be being reinforced by the following equation.

$$V = \frac{\Delta 2 - \Delta 1}{\Delta 1} \tag{3}$$

where, V is variation, Δ1 is The vertical degree after the main shock, Δ2 is The vertical degree after the aftershock.

The change of the vertical degree in the direction of the wall extension is shown in the figure. When the change quantity is positive, it shows that a wall is inclined on the side of the front. Oppositely, when the change quantity is a negative, it shows that a wall is inclined on the side of the mound.

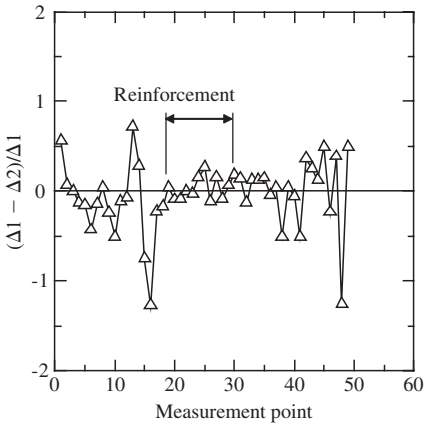

Figure 10. Variation of the gradient.

As for the section that was reinforced by the soil nailing range, there is not a change in the gradient before and after the aftershock. However, that the change has occurred to the vertical degree in the section that isn't reinforcing is confirmed.

5 CONCLUSIONS

That the reinforced earth method is earthquake-resistant could be confirmed from Research Result. With the investigation after the aftershock, the thing where the reinforcement, which uses the soil nailing is effective for the earthquake could be confirmed. As for the reinforcement, which uses the soil nailing, the system of the outward appearance can be secured. It thinks that the research method and the judgment method, which was used this case can be applied about the similar case, too. It thinks that the way of reinforcing this time in addition to the one which is occurs with the earthquake can be applied. To investigate the outward appearance of the whole wall immediately beforehand after building, too, is important.

ACKNOWLEDGEMENT

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REFERENCE

Futaki, M., Ogawa, N., Sato, M., Kumada, T., and Natsume, S. (1996). "Experiments about Seismic performance of Reinforced Earth Retaining Wall." *Proceedings of Eleventh World Conference on Earthquake Engineering,* Elsevier Science, Ltd.