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Loading test of earth flow prevention embankment reinforced with geosynthetics

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ABSTRACT: Traditionally stiff structures like concrete retaining wall have been employed for preventing earth flow due to slope failure, avalanche of earth and rocks, and so on. Flexible structures like embankment reinforced with geosynthetics have the following advantages. 1) Soils excavated on the site are effectively used for the structural material. 2) The structures can be applied at a narrow space and a steep slope ground. 3) The structures are well matched to natural environment. 4) It is easy to repair and maintain the structures. At the present stage, however, the displacements and failure strength of the reinforced embankment structures have not been clarified yet when shock loads or dynamic loads are applied. This paper reports the result of field model test of reinforced embankment against quasi-static lateral loads.

1 INTRODUCTION

The experiment reported herein was such that a semi-static load was made to act on a geosynthetics-reinforced embankment structure to take a field observation and to verify the effectiveness of the reinforced embankment utilized as a protection retaining wall. Two types of model test are performed. One is a small type, the height of which is 2m. The other is a full-scale model test, the height of which is 6m. Some of model tests investigate the effect of pre-stress applied to embankment. The pre-stress is employed for preventing vertical separation of embankment. In the model test, displacement and earth pressure of embankment, stresses on geosynthetics, and so on are monitored. An outline of the experiments and test results involved are reported hereunder.

2 OUTLINE OF EXPERIMENT

2.1 *Experimental methods*

The geosynthetics which had the highest tensile strength of 35kN/m (strain 5%) was used for the experiment. For wall surface material, an L expanded metal (h = 0.25m, 0.5m) was applied as slope unit. (See Figure 1.) The embankment material applied was clayey sand. Table1 shows the material properties. With the natural ground taken for reaction force, a linear semi-static load was applied to an embankment on one side by means of a hydraulic jack.

The horizontal force applied to the embankment was measured with a load cell while the horizontal displacement was determined with a displacement gauge located at the loading point of embankment.

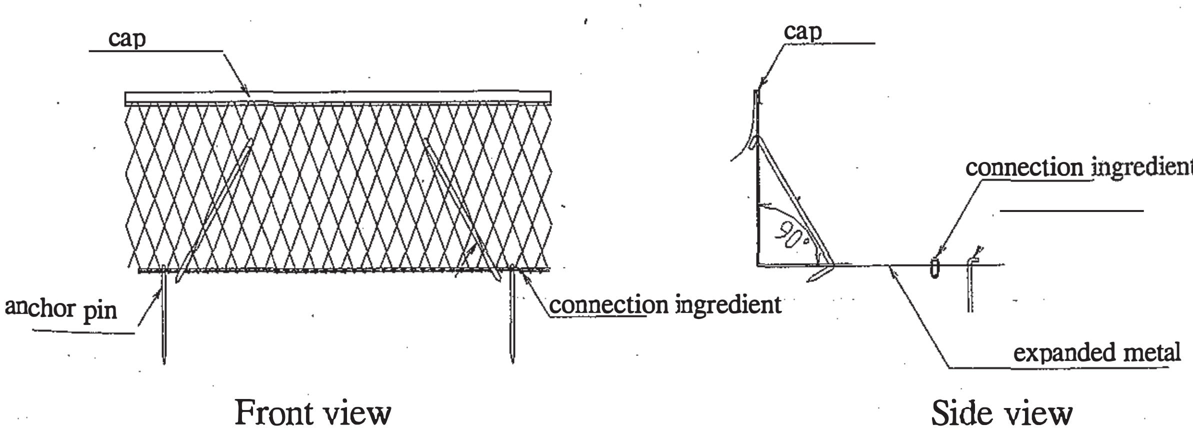

Figure 1. Slope unit.

Table 1. Properties, embankment materials.

Item	Property
Cohesion c'	$0kN/m^2$
Angle of shear resistance ϕ'	37.27°
Unit weight	$15.87kN/m^3$
Water content	20.0%
Density of soil particle	$2.662g/m^3$
Maximum dry density	$1.654g/cm^3$
Optimum water content	19.1%

An earth pressure gauge was installed to grasp a vertical earth pressure and a horizontal earth pressure. Measurements, moreover, were taken, with a strain gauge attached to grasp the tensile force that would act upon geosynthetics and on a prestressed reinforcement.

2.2 *Experiment for three models*

Model 1: Extrusion test without geosynthetics.
Model 2: Extrusion test with geosynthetics (see Figure 2).
Model 3: Bending test with geosynthetics and prestress (see Figure 3).

By using the expanded metal, these model structures were constructed and thoroughly compacted at each layer. In model 3, geosynthetics was prestressed with a compressive force to check the effect of pre-stressing. The monitoring points are shown in Figure 2 and 3.

2.3 *Experiment for actual size structure*

The experiment for actual size structure was performed for proves the effect of retaining structure reinforced with geosynthetics and pre-stress. The basic structure is the same as the structure in model 3 except the size (see Figure 4). The geosynthetics-reinforced embankment was prestressed with a compressive prestress to set up a reinforced embankment.

3 TEST RESULTS

3.1 *Model experiment*

1) Extrusion test (model 1 and 2)
Figure 5 shows the results of an extrusion experiment on extrusion horizontal stress and horizontal displacement. Though slightly, a difference could be observed. As shown in Figure 6, the strain gauge attached to geosynthetics showed a tendency to shrink until the extrusion load had reached the maximum displacement. The larger the displacement, however, the more the material tended to elongate. According to Figure 7, the earth pressure gauge read a rise of vertical earth pressure presumably because geosynthetics restrained a deformation of the embankment. Under the influence of such restraint, the vertical earth pressure could be deemed to rise. Figures 8 and 9 show the situations upon completion of the test. Model 1, which did not have geosynthetics, lay out in the interior, caused a significant crack to appear at the upper part of the embankment, with the slope unit falling down in front.

2) Bending test (model 3)
After the embankment had been constructed, it was prestressed at 30kN. Figure 10 and 11 show the changes in earth pressure and in strain of geosynthetics.

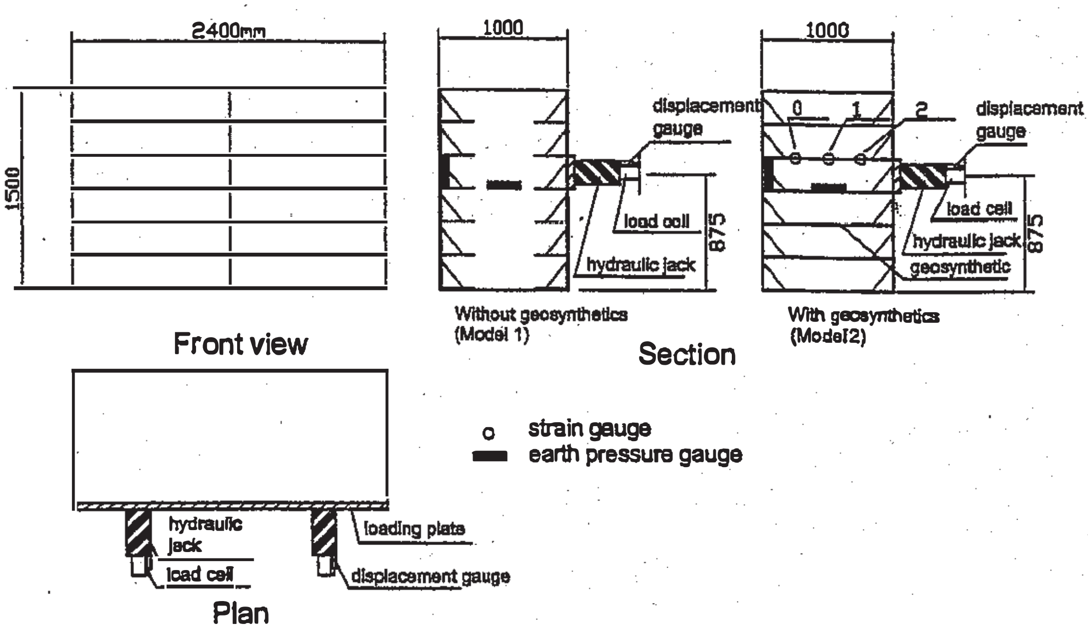

Figure 2. Shape of models 1 and 2.

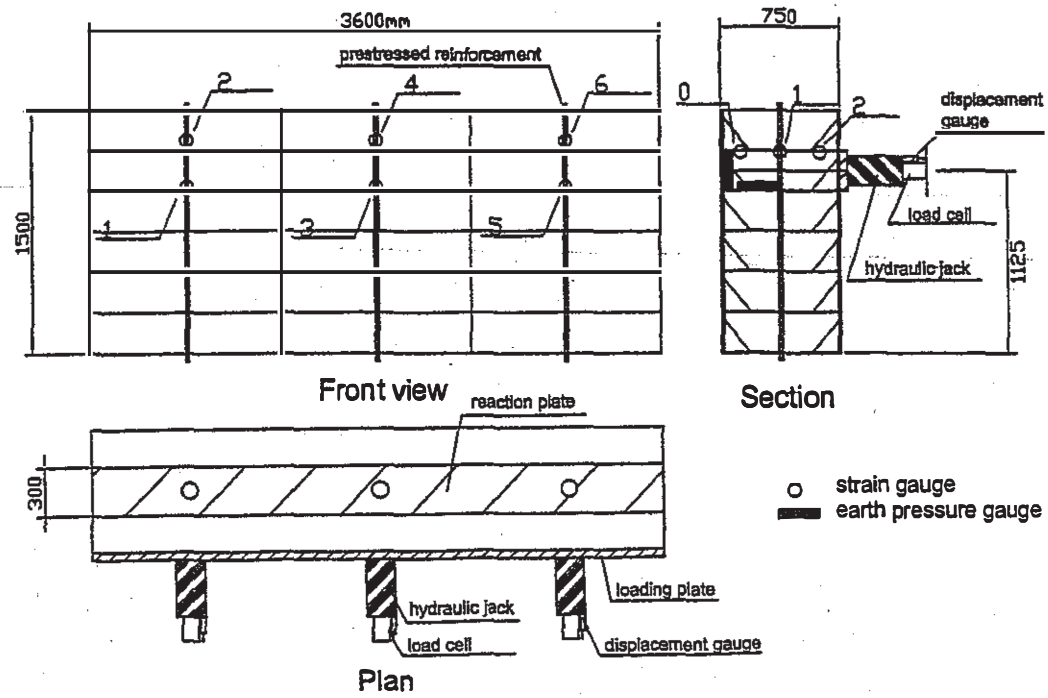

Figure 3. Shape of model 3 bending test with pre-stress and geosynthetics.

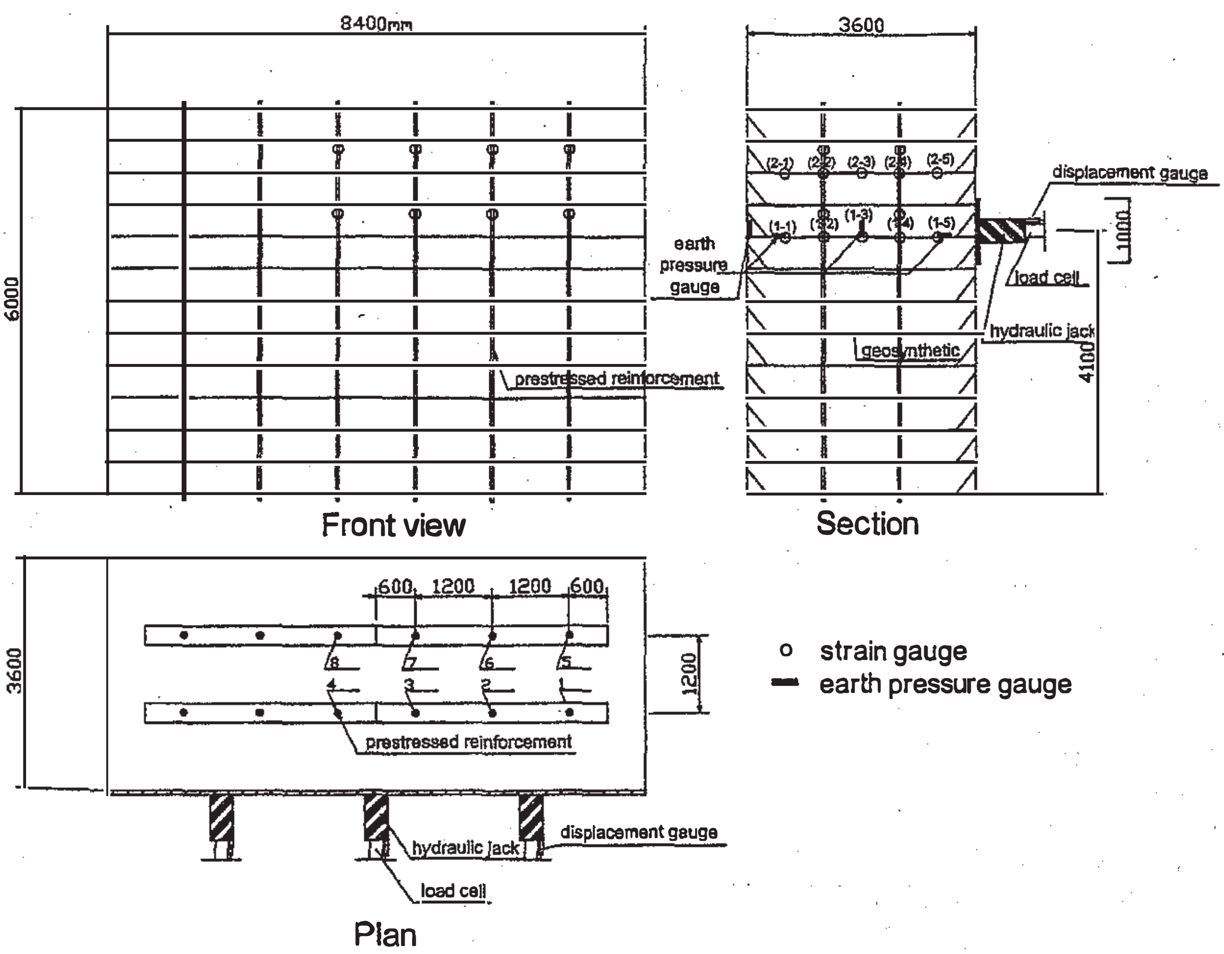

Figure 4. Experiment for actual size bending test with pre-stress and geosynthetics.

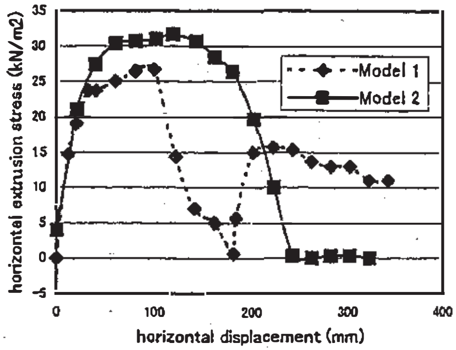

Figure 5. Horizontal displacement and horizontal extrusion stress.

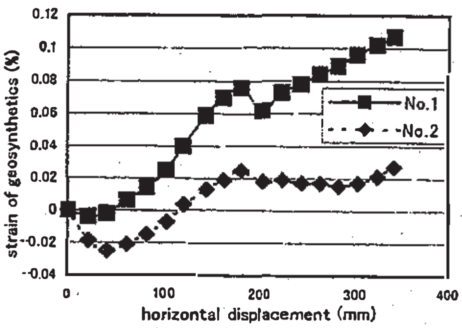

Figure 6. Horizontal displacement and strain of geosynthetics.

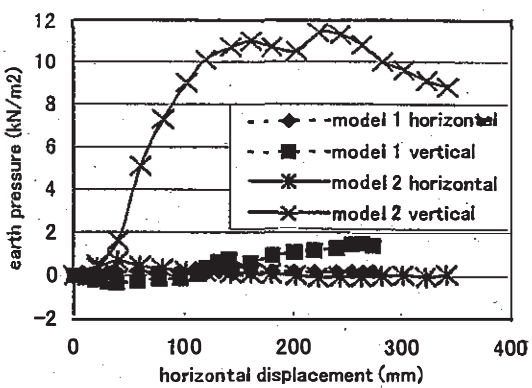

Figure 7. Horizontal displacement and behavior of earth pressure.

Figure 8. After completion of extrusion (model 1).

Figure 9. After completion of extrusion (model 2).

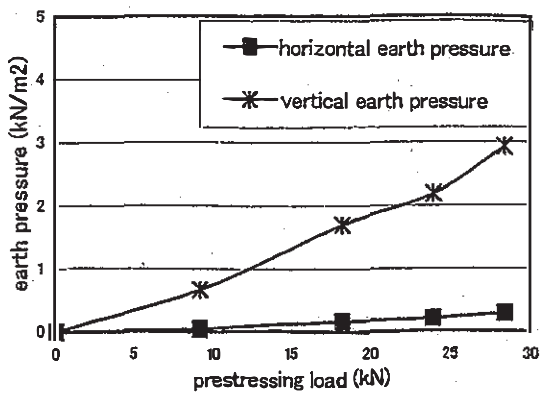

Figure 10. Prestressing load and behavior of earth pressure.

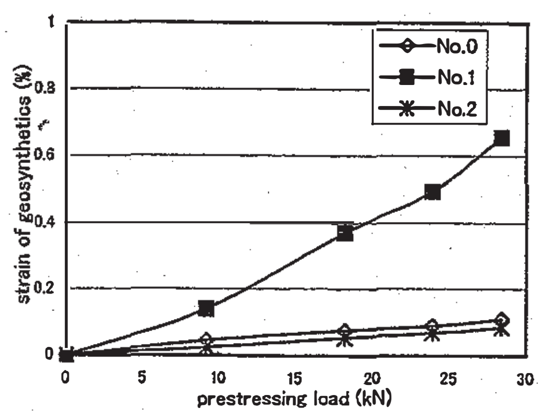

Figure 11. Prestressing load and strain of geosynthetics.

From Figure 12, it may be gathered that the extrusion stress began to slowly drop from a peak of 15kN/m^2. When the displacement reached 430 millimeters, the embankment as a whole toppled over in the form of one solid. (Refer to Figure 13.)

As shown in Figure 14, the prestressed reinforcement strained by 0.87% in front and by 0.67% in rear, thereby generating a bending stress. The geosynthetics in the interior of the embankment had a shrinkage take place as shown in Figure 15, especially shrinking more conspicuously at the center than elsewhere.

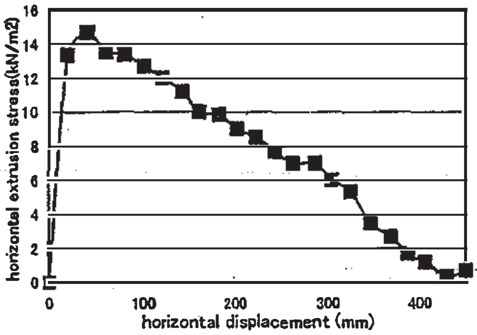

Figure 12. Horizontal displacement and horizontal extrusion stress.

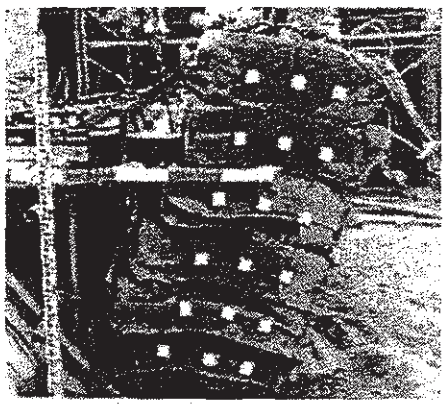

Figure 13. Situations of deformation.

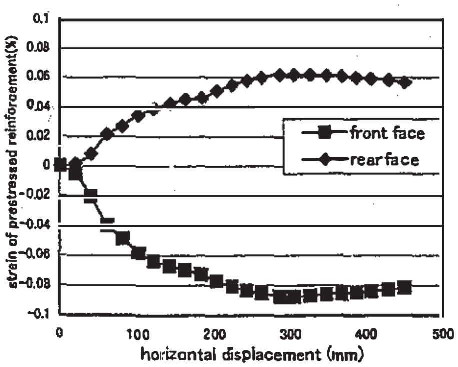

Figure 14. Horizontal displacement and strain of pre-stressed reinforcement.

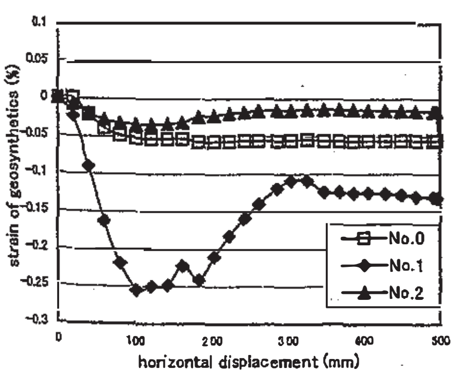

Figure 15. Horizontal displacement and strain of geosynthetics.

3.2 *Actual size experiment*

An actual size embankment was constructed and prestressed over a range of 35kN to 50kN as divided in four cycles. (Refer to Figures 16.) As shown in Figure 18, the pressurizing time decreased stage by stage while the load increased stage by stage. Figure 19 shows the strains that appeared on geosynthetics in the first cycle of prestressing Reinforcement No.7. From the Figure, it may be gathered that prestressing caused geosynthetics to generate a strain. Nevertheless, strains were found concentrated on geosynthetics in the upper stages (2-4 and 2-5). This tells us that prestressing does effectively act on the embankment at the upper part only.

The results of extrusion test are as follows.

As gathered from Figure 20, the horizontal extrusion stress was maximized when the horizontal displacement reached approximately 500 millimeters. When the horizontal displacement reached 1,600 millimeters, the embankment toppled over, with approximately a quarter of the embankment height acting as fulcrum. (Refer to Figure 17).

Figure 21 shows a curve of extrusion displacement vs. strain of No.3 Rod. The prestressed reinforcement had a strain take place at the upper part and shrinkage at the lower part. The earth pressure gauge did not read any rise of either horizontal or vertical earth pressure. For rupture, the reinforcement did not break but was found to have bent at a height of 1.5 meters.

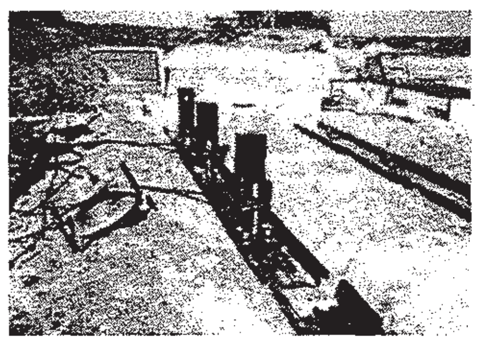

Figure 16. Loading by pre-stressing.

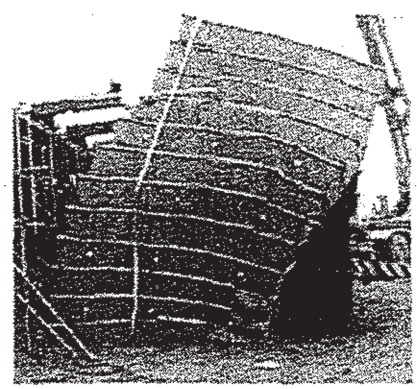

Figure 17. Topple-over situations.

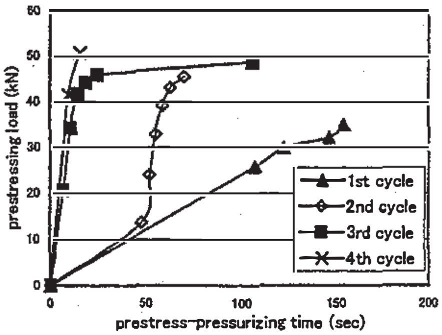

Figure 18. Pre-stress pressurizing time relationship.

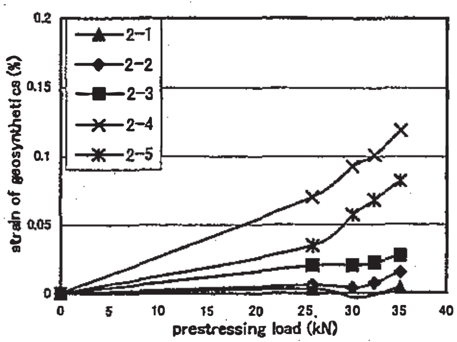

Figure 19. Strains of geosynthetics at the upper part.

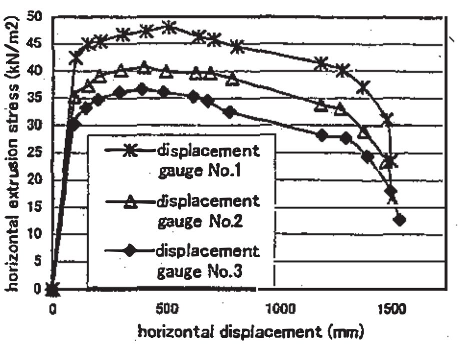

Figure 20. Horizontal displacement vs. horizontal extrusion stress.

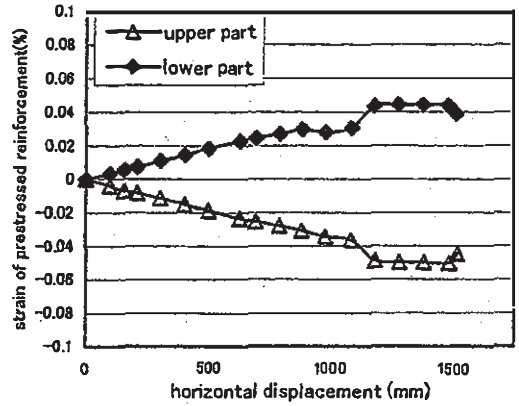

Figure 21. Horizontal displacement vs. strain of pre-stressed reinforcement.

4 CONCLUSION

A series of the model experiments reported hereinabove have resulted in the findings that the embankment reinforced with geosynthetics raises the shear resistance as compared with an unreinforced embankment. It could be verified, moreover, that an addition of prestressing would improve the effective integration.

In the actual size experiment, it was impossible to spread the effectiveness of prestressing all over the embankment because of an insufficient load and/or of a small reaction plate area. As a solution to the problem, therefore, prestressing was carried out step by step while constructing the embankment so that the prestressed stress could be made to remain.

From the results referred to above, it may be gathered that there is a possibility of utilizing the geosynthetics-applied protection retaining wall satisfactorily in the future.