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Use of geogrid for surface protection of a reinforced steep slope

Watanabe, K., Kumada, T. & Ogata, T.
Reinforced Earth Div., Hirose & Co., Ltd., Japan

Alfaro, M.C.
Department of Civil Engineering, University of Manitoba, Canada

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ABSTRACT: This paper presents results of an investigation on the use of geogrid sheet as a surface protection of a reinforced steep slope. Loading test was performed on reinforced slope that has an inclination of 1V:0.3H and about 2 m in height. The slope was built in a silt-sandy soil deposit. The geogrid sheet was made from high strength polyester and was fixed by bearing plate on the head of the reinforcing pile. Strain gauges were installed in the geogrid to measure the strains. Surcharge load of about 30 kPa was imposed near the crest of the slope using soil packs. The strains in the geogrid were found to be maximum at the center of the geogrid sheet. This value increases as the load was increased incrementally. When the the load was maintained constant, the strains remained steady or decreased. This observation was considered as to result to a stabilizing trend wherein the stresses in the early stage of loading are being distributed within the geogrid sheets. It was found that the slope surface protection using geogrids forms a more flexible material that is compatible with the deformation of the slope surface at the same time provided stability to the slope surface.

1 INTRODUCTION

One of the slope stabilization methods is the use of root pile system driven into the ground. The root pile system consists of steel reinforcing bars installed in cut slopes at prescribed intervals. The slope surface is usually covered with shotcrete to prevent localized failure of the slope surface or erosion.

The use shotcrete for slope surface protection usually needs large construction equipments and therefore results to higher costs depending on the construction scale. The costs can be prohibitively high when dealing with small scale-construction. In small-scale construction sites, expanded metal panels were sometimes used. Because of their rigidity, however, gaps might occur between the deforming ground surface and expanded metal panels. Geogrid sheets which have inherent flexibility to follow the deformation of the slope surface are being investigated as an alternative slope surface protection material. Details of this technology can be found in Watanabe et al. (2002).

Load test was carried out on the slope to assess the performance of geogrid sheets in protecting the slope surface against localized failures. The results of this investigation are presented here.

2 EXPERIMENTAL TESTING METHOD

The load testing was planned to confirm whether the surface protection using geogrid sheets follows the deformation of the slope at the same time prevents a localized collapse of the slope surface.

The load testing was done on the edge of reinforced steep slope that has an inclination of 1 Vertical: 0.3 Horizontal and about 2 m in height. The slope consists of silt-sandy soil. The cross-section of the experimental set-up is shown in Fig.1 indicating the locations of the root piles. The drilled diameter of the piles is 60 mm, and the length is 6m. The reinforcing bar is made up of steel pipe that has a diameter of 25.7 mm

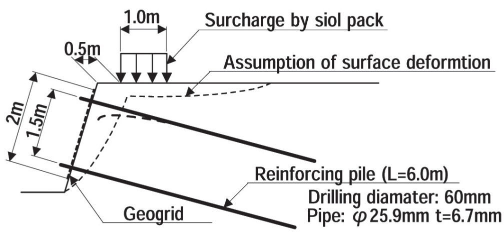


Figure 1. Cross section of experimental embankment.

and thickness of 6.7 mm. The strength of the concrete grouting is f'ck = 24 N/mm^2.

The layout of piles is 1.5 m in horizontal direction and 1.5 m in the slope direction. A surface protection used geogrid sheets made from the high strength polyester have the size of 2.0 m × 2.0 m. These were fixed by bearing plate on the head of the reinforcing piles and were placed with 1.5 m × 1.5 m which means that there is an overlap of 0.5 m on both directions. Table 1 summarizes the properties of the geogrid used in this investigation. A surcharge loading of 30 kPa was was applied using soil packs in the crest of the slope as depicted in Figs. 1 and 2 and shown in Photograph 1. This loading was applied in three increments. A total of 32 strain gauges were installed in the geogrid strands in orthogonal directions as shown in Fig. 3.

Table 1. Property of Geo-grid.

Ultimate tensile strength	52 kN/m
Characteristic strength	44 kN/m
Creep reduction factor	0.65
Design strength	29 kN/m
Mesh size	20 mm × 20 mm
Weight	500 g/m^2

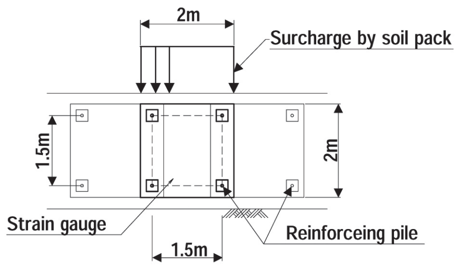


Figure 2. Front view of experimental slope.

Photograph 1. Surcharge by soil pack.

3 TESTING RESULTS

3.1 *Deformation of the pile top*

The inclination of the head of pile from horizontal plane, and amount of change of the distance between piling heads, before and at after the loading, are shown in Fig. 4. Pile head's inclination (No. 5-No. 8) placed

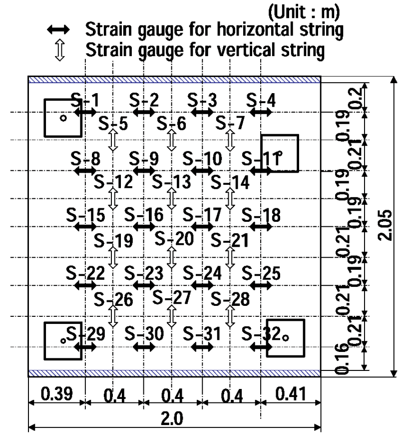


Figure 3. Layout of strain gauges.

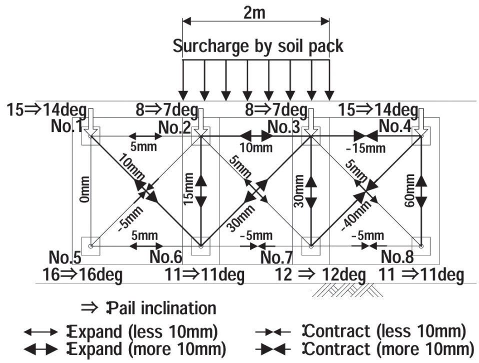


Figure 4. Inclination of pile and fluctuation of pile top distance.

in the bottom of the slope has hardly changed. However, those that were placed on the top of the slope have deviated at approximately 1°.

Furthermore, the amount of the change of distance between Piles No. 5 and No. 6, No. 6 and No. 7, No. 7 and No. 8 is 10 mm or less and almost did not change at piling intervals placed in the bottom of the slope. That means there was no displacement between Piles No. 6 and No. 8. The distances between other piling heads are mostly increasing with the exception between Piles No. 3 and No. 4 which shorten by 15 mm, and between piles No. 4 and No. 7 which shorten by 40 mm. These observations imply that the face of slope falls toward the fill side wherein pile No. 3 was displaced in the direction of Pile No. 4. In addition, Pile No. 4 moved in the direction of Pile No. 7.

3.2 *Strains in the geogrid sheets*

The relationships between the strain at the central part of the geogrid sheet and the step of the loading are shown in Fig. 5 (strain gauge attached in horizontal direction S-15-S-18) and Fig. 6 (strain gauge attached in perpendicular direction S-6, S-13, S-20, and S-27).

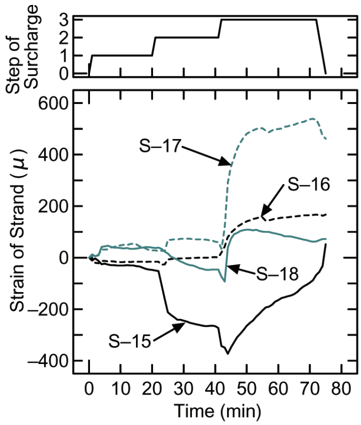


Figure 5. Strains in the horizontal strands.

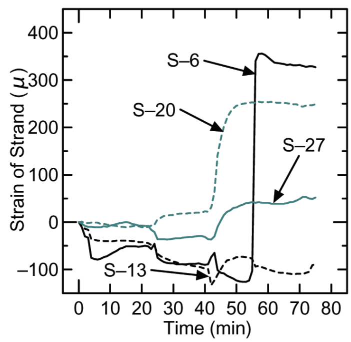


Figure 6. Strains in the vertical strands.

The behavior geogrid sheets during loading tests shows that the induced strain is biggest in the center of the sheet. This value increases of each load steps, and remained steady or tends to decrease while the load is maintained constant. This is thought to result in a stabilizing trend as the stresses in the geogrid during the first stage of loading are being distributed within the geogrid sheets. Tensile strains in the vicinity of the upper part along the slope have been found to be larger than those in the vicinity of the lower part. Across the slope, the strains in the geogrid tend to be compressive at the perimeter of the geogrid sheets. These compressive strains, however, shifted to tensile strains in the long term under constant loading.

The generation of either tensile or compressive strains in the geogrid is dependent on the deformations of the slope and the displacements of the pile head after loading.

3.3 *Distribution of geogrid strains*

The geogrid strain distribution in the horizontal direction (immediately after the loading) is shown in Fig. 7. The corresponding strain distribution in the vertical direction is shown in Fig. 8 at each loading increments. The amount of the strain increases, though the tendency of the strain distribution does not change during each step of loading.

Tensile strains are dominant in the central part in the geogrid sheets. On the other hand, compressive strains are dominant in areas near the piling heads. The distances between piling heads in the upper and lower parts of the slope increase with the increase in loading. The most likely cause of the compressive strains in the geogrid sheets is due to necking.

Photograph 2 shows a slope surface with portions that has localized failure in the forms of shallow slides (peeling off) in the slope surface just after pile driving. This localized failure could have been prevented by the use of geogrid sheets.

Upon loading, compressive strains in the geogrid were generated near the pile head locations. These

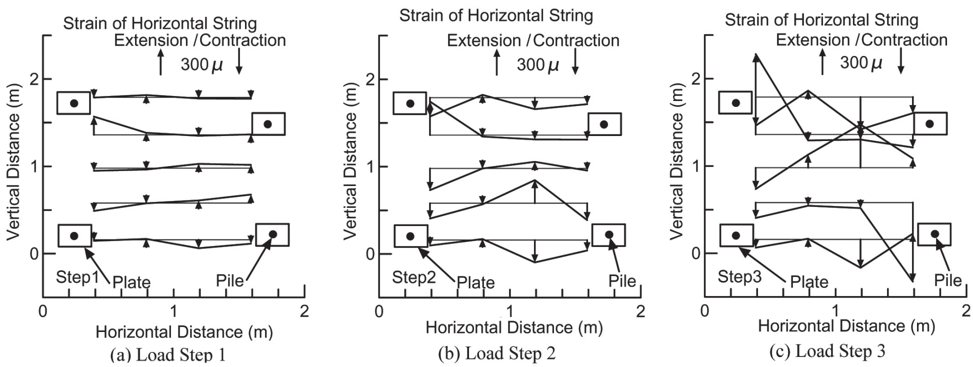
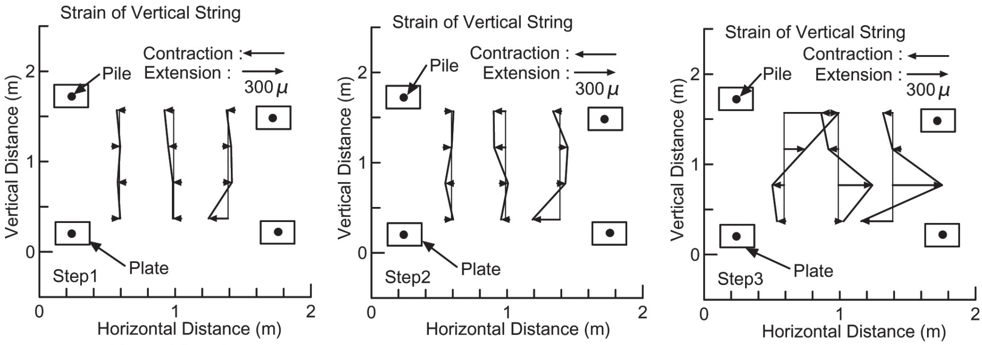


Figure 7. Distribution of strain in the horizontal strands.



(a) Load Step 1 (b) Load Step 2 (c) Load Step 3

Figure 8. Distribution of strain in the vertical strands.

Photograph 2. Fall of slope surface.

Photograph 3. Photo of actual application of geogrid slope surface protection.

strains were however shifted to tensile strains as the load was maintained constant at its final magnitude. The central part of the geogrid generated the maximum tensile strains which was thought to have contributed to the restraining of slope surface deformation and thus localized slope face failures.

4 CONCLUSIONS

The investigation through load testing suggests that geogrid sheets can be used as slope surface protection against shallow and localized slope failures. The geogrid sheets are flexible enough to conform with the deformation of the slope surface while maintaining their integrity even with the deformation of pile heads to which they were connected. Based on the results of this investigation, actual construction work using this technology had proceeded as shown in Photograph 3.

REFERENCE

Watanabe, K., Sakamoto, R. and Yoshimura, K. 2002. "The application of Geo-grid to the slope protection for reinforced steep slope", Proc. of the 57th Annual Conf. of JSCE, III-425, pp. 849-450 (in Japanese).