Geosynthetics, J. Kuwano & J. Koseki (eds)

Effect of reinforcing expanded-beads mixed light-weight soilwith geogrids

Furumoto, K. & Kohashi, H.
Soil Mechanics Team, Public Works Research Institute, Japan

Geshi, H. & Chiba, T.
Yokohama Port and Airport Technical Investigation Office, MLI T, Japan

Nishimura, J
Mitsui Chemicals Industrial Products Ltd., Japan

Saito, K. & Furuichi, M.
Central consultant Ltd., Japan

Kudo, H.
Kubota Construction, Ltd., Japan

Keywords: expanded-beads, light-weight, geogrid, pullout, relaxation

ABSTRACT: The expanded-beads mixed light-weight soil, reinforced with geogrid are being applied to the bridge approach embankment located on the deep soft ground in order to cut down the area. Both light fill material and geogrid reinforced soil are individually popular with high reliability. However, the effect of the geogrid in the expanded-beads mixed light-weight soil was not well understood. In addition, the effect of cement, which improves the strength of embankment, on the flexibility of the filling material interaction was uncertain. This paper introduces the results of two tests in order to clarify these problems. In pullout test, the pullout resistance, tension distribution in geogrid and the stress relaxation phenomenon of geogrid in expanded-beads mixed light-weight soil were evaluated. And the geogrid was confirmed to be applicable for reinforce material of expanded-beads mixed light-weight soil. In the large-scale deformation following test to examine the flexibility of expanded-beads mixed light-weight soil, the effect of cement on the soil was figured out.

1 INTRODUCTION

The Tokyo Coastal Highway will be located on ground where soft alluvial clay has accumulated and long-term consolidation settlement is caused by the weight of landfill soil. The use of the expanded-beads mixed light-weight soil (Photo 1) as embankment soil at the bridge abutment attachments of the highway on top of this ground to reduce the load on the ground and the use of geogrid as steep embankment to narrow the embankment were both planned.

Photo 1. Expanded-beads mixed light-weight soil.

Design and execution method of reinforced embankment by geogrid and for the expanded-beads mixed light-weight soil have been separately established based on basic research and many implementations, so these can now be described as highly reliable construction methods.

However, they have never been combined, so it is necessary to verify the possibility to construct more effective embankment structures through the mutual synergistic effects of the distinctive characteristics of the two methods.

This report presents the results of two tests, the pullout resistance of the geogrid and the ability of the embankment to follow settlement of the ground in a reinforced embankment made of the expanded-beads mixed light-weight soil reinforced with cement

2 PROPERTIES OF THE THE EXPANDED-BEADS MIXED LIGHT-WEIGHT SOIL AND THE GEOGRID

The expanded-beads mixed light-weight soil is a mixture of soil and foam beads (diameter of about 1 to 10 mm) that may also have hardener added in order to ensure its strength.

Table 1 shows the particle diameter distribution of the soil material used to make the expanded-beads mixed light-weight soil for these tests.

Table 1. Grain size distribution.

Gravel (2~75 mm)	30.6%
Sand (0.075~2 mm)	44.4%
Silt (0.005~0.075 mm)	18.1%
Clay (under 0.005 mm)	6.9%

The unit weight of the expanded-beads mixed light-weight soil was set to 10.5 kN/m^3 (volume mixing ratio: soil: foam beads = 1:1.8) in order to reduce the settlement of the soft ground. The properties of the geogrid are shown in Table 2.

Table 2. Properties of the geogrid.

Raw material	High-density polyethylene
Width	1.0 m
Size of Grid	166 mm × 22 mm
Thickness	2.2 mm
Strength	36.0 kN/m
Creep Strength	21.6 kN/m

3 PULLOUT TEST OF THE GEOGRID

3.1 *Purpose*

In order to act an appropriate tension on the geogrid in the reinforced embankment, adequate friction force must be provided between geogrid and the surrounding soil. However, the friction force between the expanded-beads mixed light-weight soil that was made by mixing foam beads in soil and the geogrid is not unknown.

In pullout test, the geogrid was laid in expanded-beads mixed light-weight soil and it was pulled to clarify its pullout resistance.

And, in order to study the effect of the compressive properties of the foam beads on the pullout resistance, The change of the stress was also measured.

3.2 *Experimental setup and procedure*

The expanded-beads mixed light-weight soil was placed inside the pit shown in Figure 1 (depth 40 cm, width 100 cm, height 40 cm) and compacted (thickness 20 cm), then the geogrid was laid. Then mixed soil was placed on top of this and compacted (thickness 20 cm).

Then, confining pressure was loaded from above the mixed soil with the airbag, the geogrid was pulled and the tensile force was measured (Pullout speed 1.0 mm/min).

In addition, in the case of confining pressure of 10 kPa, to clarify the pullout resistance relaxation between the geogrid and the expanded-beads mixed light-weight soil, the geogrid was left for 4 days to confirm change of the pullout resistance after it was confirmed

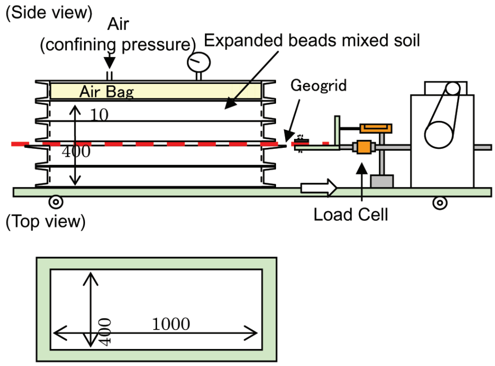

Figure 1. Outline of test facility. (unit: mm)

that the maximum pullout resistance was measured.

The pullout tests were conducted for three different type of the expanded-beads mixed lightweight soils. These soils differ in cement ratio (0%, 2%, and 4%). Table 3 shows the results of triaxial compressive tests of the soils.

Table 3. Results of triaxial compressive test.

		Original Soil	Expanded beads mixed soil (Cement ratio)		
			0%	2%	4%
γ	kN/m^3	16.9	10.5	10.5	10.5
c	kN/m^2	32.7	18.0	22.8	34.8
φ	°	34.2	26.7	28.8	30.9

3.3 *Test results and discussion*

In every case with a different cement ratio, the pullout load increased along with the rise of the pullout displacement. And the yield point was not measured clearly. Therefore, the pullout load at the displacement of 10% of the length of the pit (100 cm) was regarded as the maximum pullout load. The pullout resistance was given by:

$$\tau^* = \frac{P}{2 \cdot W \cdot L} \qquad (1)$$

where
P: Maximum pullout load (kN/m)
W: Width of the pit (m)
L: Length of the pit (m)

Figure 2 shows the relationship between the vertical stress and the maximum pullout stress. When the confining pressure is small, the maximum pullout resistance is proportional to the cement ratio. However, in large confining pressure, pullout resistance was not affected on the cement ratio.

Table 4 shown the apparent cohesion c* and the apparent angle of shear resistance φ* which obtained based on the relationship shown in Figure 2. It was

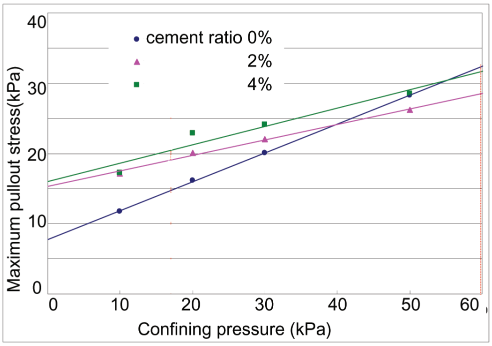

Figure 2. Maximum pullout stress and vertical stress.

Table 4. Apparent cohesion and internal friction angle.

Cement ratio		0%	2%	4%
c*	kN/m^2	7.72	15.27	16.02
φ*	°	22.32	12.48	14.56

shown that apparent cohesion c* tends to rise but φ* tends to fall as the cement ratio become large.

Compared with the soil of cement ratios of 2% and that of 4%, there is no large difference in φ*, and c* tends to rise slightly, and there is little difference between maximum pullout stresses. Consequently, even if the cement ratio is raised from 2% to 4%, there is no particular increase in the pullout resistance.

In Figure 3, on the other hand, the distribution of the tensile force of the geogrid when the maximum pullout load was measured. This figure shows that tensile force is produced almost uniformly.

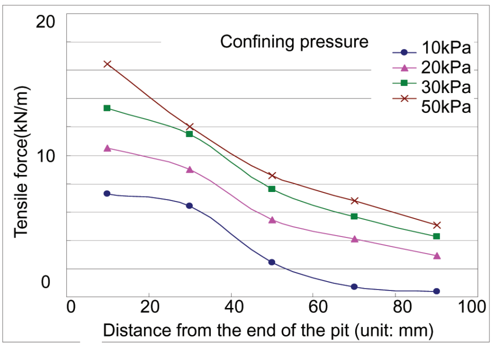

Figure 3. Distribution of the tensile force of the geogrid at the time of the maximum pullout load. (Cement ratio: 0%).

Figure 4 shows the results of the relaxation phenomenon (The process of the decline of the pullout load). The vertical axis shows the pullout load after maximum pullout load was measured. The horizontal axis shows the elapsed time and the vertical axis shows the pullout load. The quantity of decline of the load is the sum of the decline of the pullout

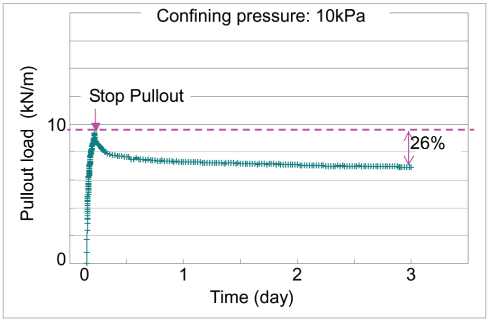

Figure 4. Decline of the pullout load. (Cement ratio: 0%).

resistance between geogrid and the expand-beads mixed soil, and the decline of the stress produced outside the pit.

Figure 5 shows the process of the decline of the pullout load in a case of Toyoura sand. Compared with these two cases, it was indicated that the relaxation phenomena is not affected with the kind of the soil. For this result, it was confirmed that the safety factor used for normal design is able to be used for the reinforcing expanded-beads mixed light-weight soil with geogrids.

Figure 6 compares the distribution of the tensile force in geogrid at maximum pullout with after the relaxation. It shows that there is no difference between

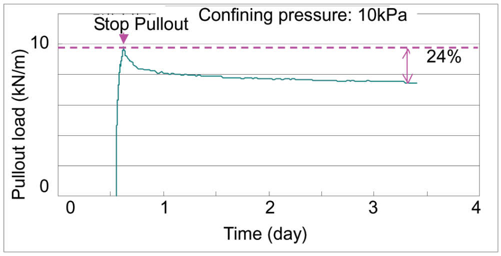

Figure 5. Decline of the pullout load of geogrid in Toyoura sand.

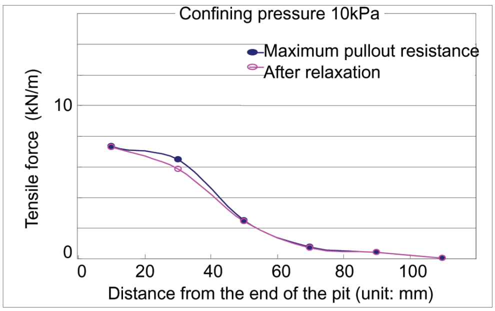

Figure 6. Distribution of the tensile force of the geogrid after relaxation.

them. From this result, it is assumed that the relaxation was produced out of the expanded beads mixed soil and the stress relaxation of the geogrid in the expanded bead mixed soil was small.

4 MODEL TEST SIMULATING THE DIFFERENTIAL SETTLEMENT

4.1 *Purpose*

As mentioned before, the ground where this method will be applied may settle down unequally and there is fear that when cement is added, the deformation following performance of the embankment will decline, and reduce the integration of the expanded-beads mixed soil and the geogrid. So this test surveyed the deformation behavior of expanded- beads mixed soil with cement.

4.2 *Experimental setup and procedure*

The expanded-beads mixed light-weight soil was placed in the pit shown in Figure 7 (width 300 cm, height 100 cm, depth 50 cm). The bottom panel of this pit was possible to be raised and lowered.

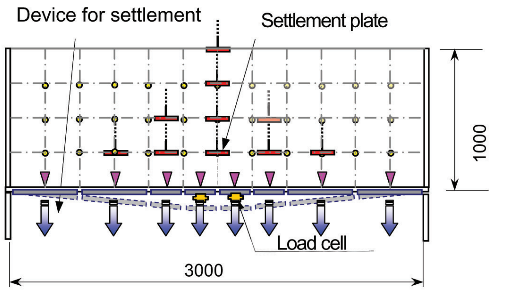

Figure 7. Outline of Test Facility (unit: mm).

The bottom plate was gradually lowered to measure the state of displacement of the embankment.

4.3 *Test results and discussion*

The state of settlement is shown in Figure 8. The horizontal axis represent the horizontal distance of the pit and the vertical axis represent the settlement of the bottom of the soil and the shape of thee bottom plate after lowering.

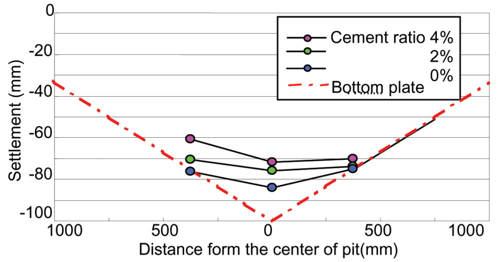

Figure 8. Distribution of settlement.

According to this figure, at a cement ratio of 0%, the soil can follows the ground deformation, but if cement is added, many cracks are initiated and developed and it is not appropriate for large unequal settlement.

5 CONCLUSIONS

The following conclusions are drawn from present study:

- The pullout resistance under small confining pressure is increased by the cement. However, at large confining pressure, it is not affect with the cement ratio.
- The tendency of the relaxation of geogrid in expanded beads mixed soil is same as in common soil.
- The flexibility of the expanded beads mixed soil with no cement is appropriate for differential settlement, and the cement has an impact on the pullout resistance caused by cracking.

ACKNOWLEDGEMENTS

The authors wish to extend special thanks to: SASAKI, H., OCDI, Japan, SHODA, A., CDIT, Japan, and TATSUI, T., Techno Sol Ltd., Japan.

REFERENCES

Public Works Research Institute, (1997). "Manual for expanded-beads mixed light-weight soil", Japan

Technical Committee of Geotextile Reinforced Soil Structure (Public Works Research Center), (2000). "Manual for geotextile reinforced soil structure", Japan