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


# The friction characteristic between lightweight soil materials with mixing foamed scrap glass and application on the reinforced soils

Kubo, T. & Yokota, Y.
*Maeda kosen. Co., Ltd*

Makiuchi, K. & Minegishi, K.
*College of Science and Technology, Nihon University*

Keywords: reinforced soil, geogrid, friction, lightweight soil, foamed scrap glass

ABSTRACT: In this research, it is one of the research themes currently performed in the new technical committee of Japan Chapter of International Geosynthetics Society.

Recently, it is promoted that it is created a recycling society such as Construction Material Recycling Act is promoted. Therefore, the embankments materials cannot keep friction such as cohesive soil and loam is increasing for effective surplus soil use. In addition, constructing embankments on unstable soft ground is increasing for effective land use. Then, the writers thought it could be expected to get bearing capacity, and increase the friction with mixing foamed scrap glass, which is a lightweight granular object, into foundation soil material.

In this research, it has inspected the influence of the frictional resistance between geogrids and soil constant by changing the rate of mixture of the scrap glass. In addition, it has inspected the influence of the reinforced soil's design.

## 1 INTRODUCTION

The soil reinforcement method using geogrids (referred to as soil reinforcement method below) is applicable to embankment materials with a wide variety of geological properties. Soils to be reinforced by the method are soft and, unlike soils reinforced with concrete, do not need high load bearing capacity. The method is therefore adopted where soils are reinforced on unstable supporting ground. Using the method also has been enabling locally available materials in which friction is unlikely to develop such as cohesive soils and loam to be used as embankment materials. The soil reinforcement method relies on the friction of embankment materials. The geological properties of embankment materials therefore considerably influence the layout or tensile strength of geogrids. The authors mixed soil materials that were unlikely to have friction with foamed scrap glass composed of light-weight particles, in order to reduce the weight and increase the angle of shearing resistance of reinforced soils. The mechanical properties of soils mixed with foamed scrap glass have been confirmed based on existing works such as Miracle-sol Association (2000) and Makiuchi et al. (2003).

## 2 OBJECTIVES OF TESTS

This study aims to verify the characteristics of friction and the pullout resistance between geogrid and lightweight soil materials mixed with foamed scrap glass. To apply reinforced soil using lightweight soil to practical soil structure, effects of geogrid are investigated base on laboratory test.

## 3 OUTLINE OF TESTS

### 3.1 *Materials*

#### 3.1.1 *Soil materials*

In the test, locally available materials in which friction was unlikely to develop were used. Volcanic cohesive soils (Kantoh loam VH2) collected in a Nihon University field in Futawa, Funabashi, Chiba Prefecture were used. The physical properties of Kantoh loam are listed in Table 1.

#### 3.1.2 *Foamed scrap glass*

Foamed scrap glass is generated by burning ground scrap glass to which a foaming agent has been added. Foamed scrap glass is composed of separate porous particles. Its specific gravity can vary from 0.3 to 1.5

Table 1. The physical properties of Kantoh loam.

| Item | Unit | Kantoh loam |
|---|---|---|
| Density of soil particles | ($g/cm^3$) | 2.7 |
| Natural water content | (%) | 115.0 |
| Lquid limit | (%) | 143.4 |
| Plastic limit | (%) | 100.9 |
| Plasticity index | – | 54.5 |

according to the quantity of foaming agents added. The foamed scrap glass is non-absorptive because it consists of separate porous particles.

In the test, foamed scrap glass with a specific gravity of 0.4 was used. The properties of foamed scrap glass are listed in Table 2.

Table 2. The properties of foamed scrap glass.

| Item | Unit | Foamed scrap glass |
|---|---|---|
| Specific gravity | – | 0.4 |
| Range of grain size | (mm) | 2-75 |
| Unconfined compressive strength | ($N/mm^2$) | 3.0-4.0 |
| Toxic substance | – | Nothing |
| Permeability | (cm/s) | $1.2 \times 10^0$ |

### 3.1.3 *Geogrids*

The geogrids used in the test were made by coating aramid fiber with high density polyethylene. Table 3 gives the specifications for geogrids.

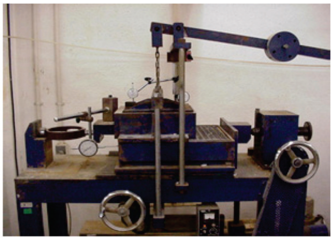
Table 3. The specifications for geogrid.

| Item | Unit | Characteristics |
|---|---|---|
| Fiber | – | Aramid |
| Coating material | – | Polyethylene |
| Mesh size | (mm) | 26 * 28 |
| Tensile strength | (kN/m) | 46.0<br>77.0 |
| Elongation ratio | (%) | 4.0-6.0 |

## 3.2 *Test apparatus*

A test apparatus consisting of a lower shear box 504 × 510 × 120 mm and an upper shear box 340 × 316 × 120 mm was used for a large-scale shear box test (Photograph 1). The test was conducted like generally practiced shear box tests. Dummy materials (woodchips) were placed in the lower shear box and a geogrid was fixed at the top of the lower box. The geogrid was fixed in an area 412 × 480 mm.

Geogrid pullout testing was conducted using an apparatus shown in Figure 1. The pullout resistance of geogrid was measured with a load cell. The displacement of geogrid that was pulled out was measured using a displacement gauge to which a wire was fixed for measuring displacements at three points of the geogrid. An earth pressure gauge was installed to confirm the normal stress at the location where the geogrid was laid. The earth pressure gauge was therefore installed where no pullout of the geogrid



Photograph 1. The large-scale shear box test apparatus.

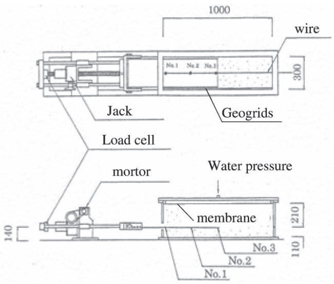



Figure 1. The geogrid pullout test apparatus.

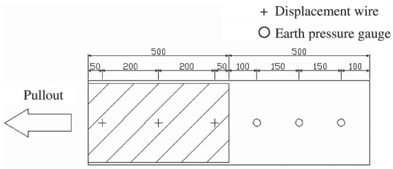



Figure 2. The geogrid pullout test apparatus.

was likely. A geogrid 280 × 500 mm was placed at the center of the earth tank.

## 3.3 *Test conditions*

Tests were conducted while controlling strain to 1 mm per minute. Normal stresses are listed in Table 4. Material mix proportions of specimens were adjusted according to the relative weight. Tests were carried out for specimens with ratios of foamed scrap glass to Kantoh loam of 1/9, 1/6, 1/3, 0/1 (Kantoh loam only) and 1/0 (foamed scrap glass only). Table 5 lists respective mix proportions. The degree of compaction was held to 90% of maximum dry density based on the results of impact compaction in existing studies. Rammers were used for compaction.

# 4 TEST RESULTS AND DISCUSSIONS

## 4.1 *Large-scale shear box test*

Figure 3 shows the relationship between shear stress and horizontal displacement by mix proportion at a normal stress of 70 $kN/m^2$. With the increase of percentage of foamed scrap glass, shear stress also increased although slightly. Similar tendencies were


© 2006 Millpress, Rotterdam, ISBN 90 5966 044 7

Table 4. The specifications for geogrid.

| Item | normal stress ($kN/m^2$) | | | |
|---|---|---|---|---|
| Large-scale box shear test | 20 | 50 | 70 | 100 |
| Geogrid pullout test | 20 | 40 | 60 | – |

Table 5. Material mix proportions of specimens.

| Item | Material mix proportions (Formed scrap glass/Kantoh loam) | | | | |
|---|---|---|---|---|---|
| Large-scale box shear test | 1/3 | 1/6 | 1/9 | 1/0 | 0/1 |
| Geogrid pullout test | 1/3 | 1/6 | 1/9 | 1/0 | 0/1 |

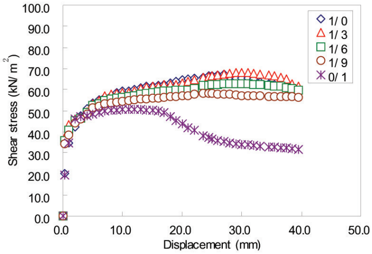



Figure 3. The relationship between shear stress and horizontal displacement. (normal stress of 70 $kN/m^2$).

observed at different normal stress levels although not shown in the Figure.

Table 6 lists the angle of shear resistance and apparent cohesion.

Table 6. The angle of shearing resistance and cohesion.

| Item | Unit | Material mix proportions 1/0 | 1/3 | 1/6 | 1/9 | 0/1 |
|---|---|---|---|---|---|---|
| Cohesion | ($kN/m^2$) | 17.6 | 16.2 | 20.1 | 22.7 | 12.9 |
| Angle of shearing resistance. | (degree) | 29.9 | 30.6 | 27.5 | 24.6 | 27.4 |

Test results show that mixing soils with foamed scrap glass increased the angle of shearing resistance and apparent cohesion. It has examined that the friction characteristic is occurred by mixing Kantoh loam with the formed scrap glass. The formed scrap glass enters into mesh of geogrid, so that the interlocking effect increases.

### 4.2 *Geogrid pullout test*

Figure 4 shows the relationship between shear stress and displacement by mix proportion at a normal stress of 20 $kN/m^2$. Pullout resistance was measured at intervals of 100 N. The displacements in the Figure were obtained from a constant strain. As in the large-scale box shear test, shear stress increased as the content of foamed scrap glass increased. The tendency was similar at other normal stresses although the results are not shown in the Figure.

Table 7 lists the angle of shear resistance and apparent cohesion. As shown in the large-scale box shear test, mixing soils with foamed scrap glass increased the angle of shear resistance and apparent cohesion. The reasons are the same as identified in the large-scale box shear test. When the soil specimen was dug out after the pullout test, fragments of foamed scrap glass were visually confirmed on the plane of friction between soil and geogrid. The phenomenon was outstanding at a high normal stress where only foamed scrap glass was used. The fracture may have occurred because the movement of foamed scrap glass and soil particles was restrained.

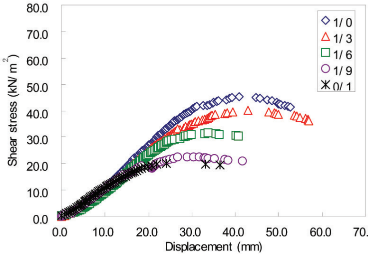



Figure 4. The relationship between shear stress and horizontal displacement. (normal stress of 20 $kN/m^2$).

Table 7. The angle of shearing resistance and chesion.

| Item | Unit | Material mix proportions 1/0 | 1/3 | 1/6 | 1/9 | 0/1 |
|---|---|---|---|---|---|---|
| Cohesion | ($kN/m^2$) | 35.1 | 26.7 | 25.2 | 28.7 | 13.2 |
| Angle of shearing resistance. | (degree) | 30.5 | 34.1 | 19.2 | 5.11 | 17.4 |

## 5 APPLICATION OF THE METHOD TO REINFORCED SOILS

### 5.1 *Effects of the method on the embedded length of geogrid*

Embankment materials with reduced weight were likely to have an adverse effect on the effectiveness for reinforcement because reinforcing soils with geotextiles depended on the friction of embankment materials. Then, parameters of reinforced soils were estimated using the soil constant obtained based on the pullout test results. Increases in apparent cohesion with the increase of the content of foamed scrap glass were ignored. Only the angle of shear resistance and cohesion of Kantoh loam itself were considered for specimens with varying contents of foamed scrap glass. The specimen with a mix proportion of 1/3 had a larger angle of shear resistance than the specimen containing foamed scrap glass only, so the angle of shear resistance obtained for the specimen only with foamed scrap glass but cohesion was ignored. For the design cross section, the slope gradient was set at 1/0.3 and the height of the retaining wall at 8.0 m (case 1) or 12.0 m (case 2). The geogrids were laid at horizontal spacings of 1.2 m. The design horizontal seismic coefficient kh was set at 0.15.

Figure 5 shows the relationship between the embedded length of geogrid and mix proportion. Tables 8 and 9 show the estimates obtained. The safety factor was calculated for the safety against rotational slip of the entire soil mass. As a result of estimation, it was found that mixing soils with foamed scrap glass helped reduce the embedded length of geogrid. With the increase of the content of foamed scrap glass, the tensile strength required for the geogrid decreased. This is because the weight reduction of soil mass led to the reduction of the sliding moment, the denominator of equation (1) and because the angle of shear resistance increased and the resistance of the cohesion component increased while the resisting moment, the numerator of the equation, was also affected by the weight of soil mass.

$$F_S = \frac{R\Sigma\{cl + (W\cos\alpha + T\sin\theta)\tan\phi + T\cos\theta\}}{R\Sigma W\sin\alpha} \qquad (1)$$

### 5.2 *Load bearing capacity of reinforced soils*

To evaluate the load bearing capacity of reinforced soils, stability was checked while regarding the area where geotextiles were laid as a virtual retaining wall. Soil reaction was calculated in the case where geogrids were embedded for the depth calculated during the study of the length of geogrids. Figure 6 shows the relationship between the reaction of reinforced soils and mix proportion. As a result of calculation, it was found that reducing the content of foamed scrap glass caused the reaction of reinforced soils to decrease.

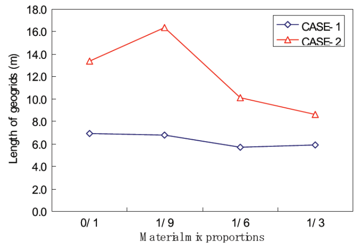



Figure 5. The relationship between the embedded length of geogrid and mix proportion.

Table 8. Calulation result. (Case-1).

| Item | | Layer | Material mix proportions 0/1 | 1/9 | 1/6 | 1/3 |
|---|---|---|---|---|---|---|
| Tensile strength | | 7 | 20.0 | 20.0 | 20.0 | 20.0 |
| | (kN/m) | 6 | 20.0 | 20.0 | 20.0 | 20.0 |
| | | 5 | 20.0 | 20.0 | 20.0 | 20.0 |
| | | 4 | 35.0 | 20.0 | 20.0 | 20.0 |
| | | 3 | 35.0 | 28.0 | 20.0 | 28.0 |
| | | 2 | 35.0 | 28.0 | 20.0 | 28.0 |
| | | 1 | 35.0 | 28.0 | 20.0 | 28.0 |
| Length of geogrid | (m) | L | 6.9 | 6.8 | 5.7 | 5.9 |
| Safty factor | | Fs | 1.21 | 1.21 | 1.27 | 1.21 |

Table 9. Calulation result. (Case-2).

| Item | | Layer | Material mix proportions 0/1 | 1/9 | 1/6 | 1/3 |
|---|---|---|---|---|---|---|
| Tensile strength | (kN/m) | 10 | 48.0 | 48.0 | 28.0 | 28.0 |
| | | 9 | 48.0 | 48.0 | 28.0 | 28.0 |
| | | 8 | 48.0 | 48.0 | 28.0 | 28.0 |
| | | 7 | 48.0 | 48.0 | 28.0 | 28.0 |
| | | 6 | 48.0 | 48.0 | 28.0 | 28.0 |
| | | 5 | 48.0 | 48.0 | 28.0 | 35.0 |
| | | 4 | 70.0 | 48.0 | 48.0 | 35.0 |
| | | 3 | 70.0 | 70.0 | 48.0 | 35.0 |
| | | 2 | 70.0 | 70.0 | 48.0 | 35.0 |
| | | 1 | 70.0 | 70.0 | 48.0 | 35.0 |
| Length of geogrid | (m) | L | 13.4 | 16.4 | 10.1 | 8.6 |
| Safty factor | general | Fs | 1.34 | 1.38 | 1.31 | 1.22 |
| | earth | Fs | 1.02 | 1.10 | 1.09 | 1.00 |

## 6 CLOSING REMARK

This study used volcanic cohesive soil in which development of friction is unlikely as a soil material. Mixing the soil with foamed scrap glass enabled the angle of shear resistance to be increased. It was also confirmed that sufficient pullout resistance developed against friction between the soil and geogrid. Also, parameters were estimated for reinforced soil using constants obtained in tests. As a result, it was found that reducing the weight of soil material had little effect owing to the increase in friction and the effect of cohesion component. Mixing the soil with light-weight granular foamed scrap glass reduced the reaction of reinforced soil. Thus, reinforcing soils by mixing foamed scrap glass is effective for loam in which friction cannot be ensured or for bearing soils that are unlikely to have load bearing capacity.

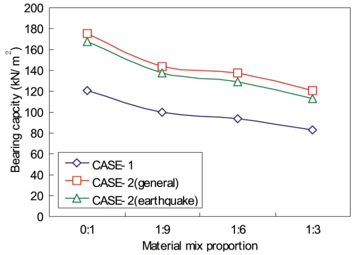



Figure 6. Reaction of reinforced soils and mix proportion.

## REFERENCES


Katsuhiko, M., Kunio, M., Ryo, N. and Tetsuya, K. (2003). "Mechanical Characteristics of Embankment Geomaterial Mixed with Lightweight Disposal Glass Aggregates", 38 th Geo-technical Engineering Research Meeting.

Miracle-sol Association. (2000) "Lightweight. soil method using Miracle-sol design and execution guide".

Public Works Research Center. (2000) "The Reinforced soil using geotextile design and execution guide.

The Japanese Geotechnical Society. (2000). "Method for soil testing and comment."