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Fundamental mechanical properties of geocell reinforced sands

K. Yazawa, T. Ajiki, H. Ohmori, K. Kaneko & K. Kumagai
Hachinohe Institute of Technology, Japan

ABSTRACT: In the geocell reinforced soil structures, we can use the various materials as the material into the geocells. Mechanical properties of geocell reinforced soils change by the kind of filling materials. Therefore, if we want to predict the deformation and strength of them, it is necessary to grasp the relation between the characteristics of the filling materials and the mechanical properties of the geocell reinforced soil structures. In this study, at first, we perform the tri-axial compression tests to examine the mechanical properties of the sandy filling materials. In addition, fundamental experiments on the compressibility and the frictional property for the cell structures are performed. Finally, we analyze the relationship between results of these experiments.

1 INTRODUCTION

The geocells (Sitharam et al 2005) are one of the three-dimensional geosynthetics materials to reinforce earth structures (Fig. 1). They are made by high density polyethylene, and they are excellent at the chemical stability, the rigidity, impact strength, and the low temperature property. Yang's modulus is about about 2.2×10^5 KN/m^2, Tensile strength of seam is about 14.2 KN/m. The geocell reinforced earth structure is reinforced 3-dimensionally by geocells and filling materials, which are put in the cells. Various materials can be used as a filling (Yazawa et al 2006.) Moreover, there are a lot of usages in the geocell reinforcement such as slope stability and protection, foundation and river bulkhead (omori et al 2006). The application to disaster recovery can also be expected, because the geocell is very small and light and easy construction.

Figure 1. Geocell (GeoWeb® made by ALCOA).

In geocell reinforce method, if we can use the local generation soils as the filling materials effectively, we can get large advantages for environments and costs. However, since geocell reinforced earth structures are combined structure made by polyethylene and arbitrary soils, their mechanical properties are very complex and difficult. In the present circumstances, macadam, which is considered a comparatively good quality material as a filling, is bought and used in consideration of the safety aspect.

In this study, aiming at the establishment of the construction method that effectively uses the local generation soil as a filling in geocells, we examine the correlation of the mechanical properties of the filling and the mechanical properties of geocell structure. First of all, we performed the triaxial compression tests for some sandy materials to know their fundamental mechanical properties. Next, we also performed fundamental experiments concerning the compressibility and the shear resistance characteristics of the geocell structure when those materials are used as a filling. Finally, we discuss the relationship between the mechanical properties of filling materials and geocell-structures.

2 TRI-AXIAL COMPRESSION TESTS FOR FILLING MATERIALS

In this study, our main purpose is to examine the relation between the mechanical property of the filling material and the mechanical property of the geocell structure that uses it in the cell. In this section, we perform the triaxial compression test (CD) for the sample used as a filling material in geocells to examine

Table 1. Fundamental properties of sample.

Sample no.	Collection point (material name)	Uniformity coefficient	Coefficient of curvature	Soil particle density (g/cm^3)	Minimum density (g/cm^3)	Maximum density (g/cm^3)
A	Gonohe, Aomori	5.14	1.38	2.711	1.254	1.522
B	Hachinohe, Aomori	2.42	1.23	2.671	1.635	2.007
C	Aomori, Aomori	3.36	0.95	2.705	1.423	1.727
D	(Silica sand No.5)	2.29	1.21	2.603	1.321	1.642
E	Kamo, Niigata	2.69	1.03	2.567	0.837	1.156
F	Inzai, Chiba	2.20	1.26	2.713	1.283	1.588
G	(Ferronickel slaggy)	28.9	0.75	3.232	1.543	2.246

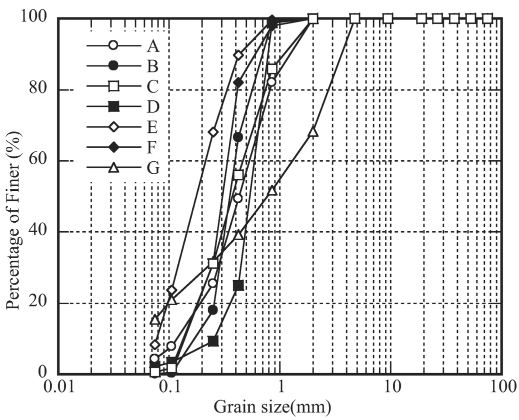

Figure 2. Grain size distribution curve.

internal frictional angle, cohesion, and deformation modulus. The triaxial compression test is one of the general shear tests. Triaxial compression test (CD) is on the condition without excess pore water pressure. Because the pore water is drained by the compression process, it is applied to the soil with a good permeability like sand.

2.1 *Outline of tests*

In this study, we use seven kinds of sandy materials, and Table 1 shows fundamental properties of these samples. Figure 2 shows grain size distribution curves of these samples. The distribution of the grain diameter is greatly different only sample G. Sample G is ferronickel slaggy, which is waste generated when the nickel alloy is refined. Moreover, the particle density of ferronickel slaggy is larger than general sand. While the one with a large grain diameter is chiefly used as aggregate for concrete effectively, it is hoped that ferronickel slaggy of the grain diameter at the sand level is used as geomaterials.

We perform the consolidated and drained triaxial compression tests (JGS 0524) for above-mentioned seven samples. Test conditions are shown in Table 2.

Table 2. Test conditions.

Sample	Pressure (kPa)	ρ_t (g/m^3)	ρ_d (g/m^3)	D_r(%)
A	100	1.510	1.455	85.0
	200	1.494	1.450	
	300	1.501	1.453	
B	100	1.902	1.879	85.0
	200	1.905	1.881	
	300	1.905	1.881	
C	100	1.679	1.671	85.0
	200	1.678	1.670	
	300	1.688	1.673	
D	100	1.597	1.584	85.0
	200	1.596	1.583	
	300	1.594	1.582	
E	100	1.144	1.090	85.0
	200	1.161	1.093	
	300	1.141	1.086	
F	100	1.567	1.533	85.0
	200	1.549	1.528	
	300	1.556	1.530	
G	100	2.104	2.088	85.0
	200	2.135	2.102	
	300	2.115	2.090	

The sample size is 5 cm in the diameter and 10 cm in height, and the relative density is about 85%.

2.2 *Results*

From the results, we calculate the internal friction angle and the cohesion of each sample. Moreover, we define the deformation modulus E_{di} (MPa) by the following expression as an index that shows the deformation property.

$$E_{di} = \sigma_d / \varepsilon_d \tag{1}$$

where the σ_d is half an axial stress of maximum axial stress, ε_d is the axial strain at ε_d and i shows the lateral pressure. Because deformation characteristics depends on the lateral pressure, we calculate the deformation moduli in each case of pressures.

Table 3. Mechanical properties of filling materials.

	Cohesion c_d (kPa)	Internal friction angle ϕ_d (°)	E_{d100} (MPa)	E_{d200} (MPa)	E_{d300} (MPa)
A	16.1	39.0	7.8	10.7	12.6
B	6.8	36.3	16.2	25.9	36.1
C	3.5	40.3	10.8	15.4	48.4
D	12.8	37.5	14.1	20.9	25.5
E	2.7	31.1	2.8	4.8	7.1
F	12.0	32.3	5.7	8.8	11.6
G	9.9	43.4	12.1	24.4	26.9

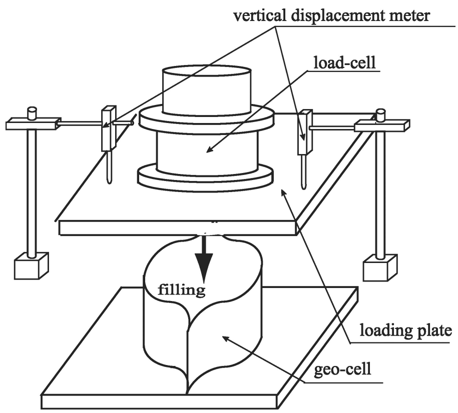

Figure 3. Compression test device.

The strength and deformation characteristics of all samples are shown in Table 3. Cohesion is very small value compared with the maximum principal stress difference, and we can consider almost 0.

3 COMPRESSION CHARACTERISTICS OF GEOCELL REINFORCED SAND

To use various materials as the filling in geocell, it is necessary to understand mechanical correlations between the filling and the geocell structural body. In this section, we examine the correlation between the deformation characteristics of fillings and the compressibility of geocell structure. We use seven kinds of above-mentioned sandy materials as the filling.

3.1 *Outline of compression test*

Figure 3 shows an outline of the compression test device. The filling materials are filled separately for the 3 layers in the cell. Each layer is compacted 25 times respectively so that the relative density might become constant. We use the unit geocell structure for the compression tests. The compression tests are performed by controlling the vertical

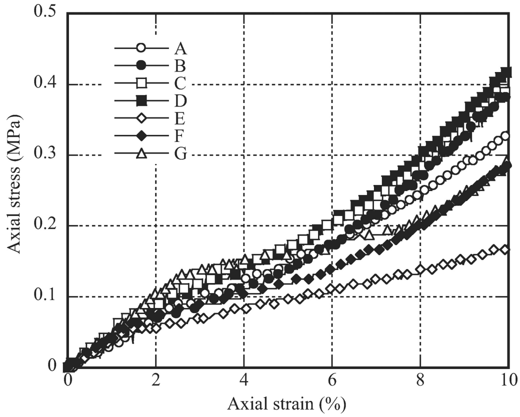

Figure 4. Stress-strain curves.

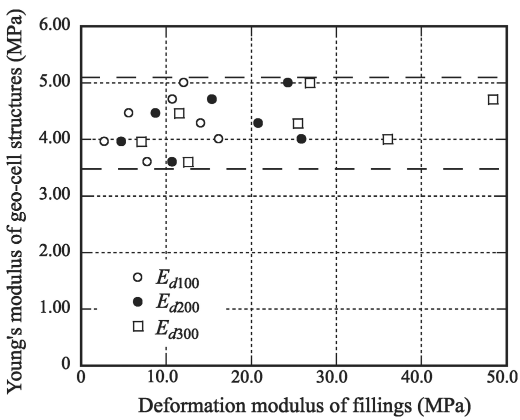

Figure 5. Relation between Young's modulus of geocell structure and deformation modulus of filling.

force (0.25 ton/minute). The vertical displacements are measured. The axial stress and the axial strain were calculated by the method similar to the compression test for the soil.

3.2 *Results and discussions*

Figure 4 shows the relation between the axial strain and the axial stress of the geocell structure obtained by the compression tests. Here, the results up to the axial strain 10% was shown. Even when the examination was continued up to about 30%, complete failure of the geocell structure was not seen. We can consider that it is not completely destroyed under a realistic loading condition. Therefore, it is important that we evaluate the mechanical properties of the geocell structure according to the deformation characteristics.

Figure 5 shows relation between deformation modulus of fillings and Young's modulus of geocell

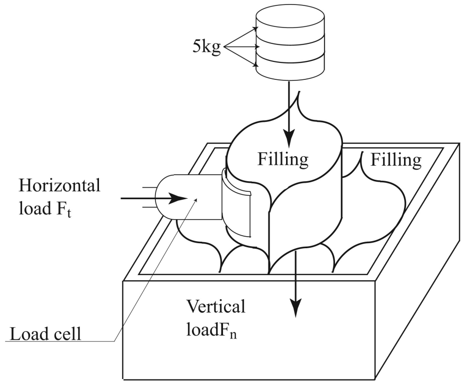

Figure 6. Shear resistance test device.

reinforced sand. In this study, we consider that the Young's modulus of geocell structure can be defined by the ratio of the axial stress and the axial strain in initial state of loading. As for Young's modulus of the geocell reinforced soil, it enters between 5MPa from 3MPa in all cases. The clear correlation between deformation modulus of the filling and Young's moduli of geocell strucutres can not be seen from Fig. 5. A similar deformation property is shown, when the sandy materials is used as the filling of the geocell structure. In the geocell method, it is guessed that there is hardly influence by the few difference of deformation property of the filling.

4 SHEAR RESISTANCE OF GEOCELL REINFORCED SAND

As for the geocell reinforced soil, there are a lot of cases vertically using the cell repeatedly. In general of these cases, because upper and lower cells are not connected and each step is independent, shear resistance between upper and lower cells is important. In this section, the correlation between internal frictional angle ϕ_d of the filling and the shear resistance between geocell structures is examined.

4.1 *Outline of shear resistance test*

Figure 6 illustrates an outline of the shear resistance examination between cells. Lower two geocells with filling are set in the box. We put an upper geocell with filling on the lower cells. The weight is put on the upper cell to change the vertical force F_n. The one side center of the upper geocell is horizontally pushed at 2 mm/min by the hydraulic lifter. Horizontal reaction forces and horizontal displacements are measured.

4.2 *Results and discussions*

First of all, the results of the case of sample A is shown in Fig. 7 as an example. We can say from this figure

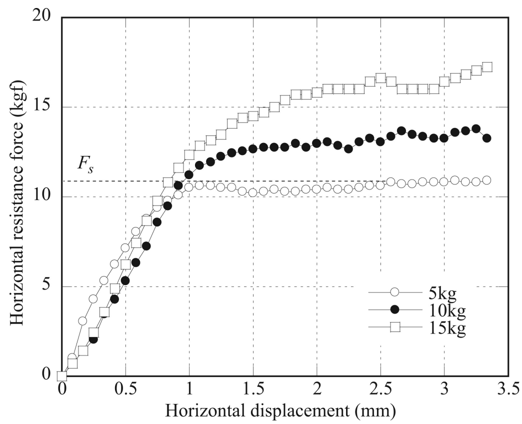

Figure 7. Relation between horizontal displacement and horizontal load (sample A).

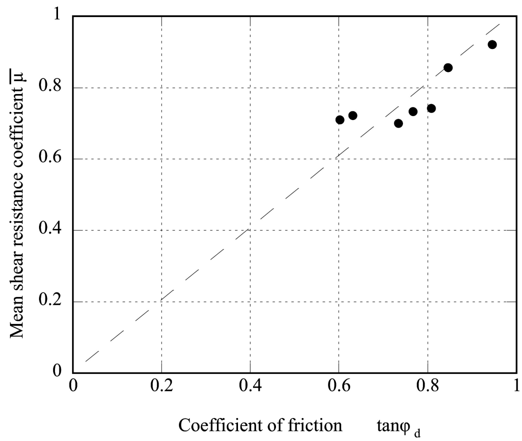

Figure 8. Relation between internal friction coefficient and mean shear resistance coefficient.

that in the first stage of the horizontal loading, the horizontal reaction forces increase linearly. When the horizontal reaction forces reach a maximum value, slippage occurs. We assume the maximum value as shear resistance force F_s. The shear resistance coefficient μ, which is so called static friction coefficient, is calculated as follows.

$$\mu = F_s/F_n. \tag{2}$$

Moreover, we calculate the mean shear resistance coefficient $\bar{\mu}$ by averaging the results of the three cases of tests, which change vertical force, in each filling material. Fig. 8 shows the relationship between the internal friction coefficient $\tan\phi_d$ of filling material and the mean shear resistance coefficient between geocells $\bar{\mu}$. As can be seen from this figure, $\bar{\mu}$ grows by ϕ_d large and it is almost linear relationship.

5 SUMMARY

In this study, to develop the geocell construction method by using the local generation soil effectively, we performed some experiments and we discussed the relationships between the mechanical properties of filling materials and the mechanical property of the geocell structures. The results of our experiments are shown as follows, When we use the sandy materials as the filling in the geocells, Young's modulus of the unit geocell structures is from 3MPa to 5MPa. In the geocell method, the few difference of deformation characteristics of the filling hardly influence the compressibility of the geocell structure. When we use sandy materials as filling, the mean shear resistance coefficient between cells grows by the internal friction angle of the filling large and it is almost linear relationship. As the next task, it will be necessary to make the same investigation when the clay soil is used as a filling.

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