DEFORMATION AND STRENGTH CHARACTERISTICS OF LIGHTWEIGHT GEOMATERIAL MIXED WITH EPS BEADS FOR SUBGRADE

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ABSTRACT

The lightweight geomaterial mixed with EPS beads (abbreviated hereafter as LWGME), a mixture of superlight EPS beads and normal geomaterial, is one of the geoform. LWGME can use construction generated soil as base material. Therefore, construction generated soil leads to restraint and reuse of construction generated soil which is a problem in recent years. However, LWGME contains EPS beads of high compressibility, it is pointed out that is shows different mechanical characteristics from normal geomaterials. Therefore, grasp of mechanical characteristics is one of the important index for safer designs and constructions. This study, as a part of our studies to make clear the design parameter and the prediction equation of LWGME used for subgrade, to find out the mechanical characteristics of LWGME, conducts the unconfined compression test, the unconsolidated undrained shear test, the resilient modulus test.

Keywords: Composit material, EPS beads, subgrade soil, resilient modulus

INTRODUCTION

The lightweight geomaterial mixed with EPS beads (abbreviated hereafter as LWGME), a mixture of superlight EPS beads and normal geomaterial, is one of the geoform. LWGME can use construction generated soil as base material. Therefore, construction generated soil leads to restraint and reuse of construction generated soil which is a problem in recent years. A lightweight banking method with LWGME is also expected to reduce loads on the base ground by cutting down the weight of the bank, and to shorten construction periods and exceed in economic efficiency by reduction of the soil improvement range.

However, LWGME contains EPS beads of high compressibility, it is pointed out that it shows different mechanical characteristics from normal geomaterials. Therefore, grasp of mechanical characteristics is one of the important indices for safer designs and constructions.

Preceding study (Mori et al. 1993 and Minegishi & Makiuchi 2006) showed that constructing road embankment with cement stabilizer rate at 7% confirmed the improvement of stability of road embankment. However, the study on design parameter and the prediction equation in using LWGME for subgrade and filled up ground is not in advance. For the subgrade design, the pavement design method is utilized. The tendency of a pavement design method changes from the experiential to the theoretical with multilayer elasticity theory. The multilayer elasticity theory utilizes the deformation modulus and Poisson's ratio. This modulus is known to be affected by various factors and show different values. Therefor it is necessary to grasp the accurate modulus in order to prevent error in designing pavement structures. The resilient modulus used in multilayer elasticity theory is calculated from a relational expression E=10CBR with design CBR. But, application of this relational expression to LWGME is not clear.

This study, as a part of our studies to make clear the design parameter and the prediction equation of LWGME used for subgrade, to find out the mechanical characteristics of LWGME, conducts the unconfined compression test, the unconsolidated undrained test, the resilient modulus test.

SPECIMENS AND EXPERIMENTAL PROCEDURES

The base material in this study is volcanic cohesive soil (abbreviated hereafter as Kanto loam) collected in Funabashi, Chiba (VH_2, ρ_s=2.83g/cm^3,

Table 1 Combination condition of specimen

Test	EPS bead %	Cement stabilizer %	Wet dencity g/cm^3
Unconfined compression test	1.7	7	1.1
	2.01	25	
	2.04	30	
	2.07	35	
Unconsolidated undrained test	1.7	7	1.1
	2.01	25	
	2.04	30	
	2.07	35	
Resilient modulus test	0	18	1.4
		25	
		30	
		35	
	10	18	1.3
		25	
		30	
		35	
	30	18	1.1
		25	
		30	
		35	

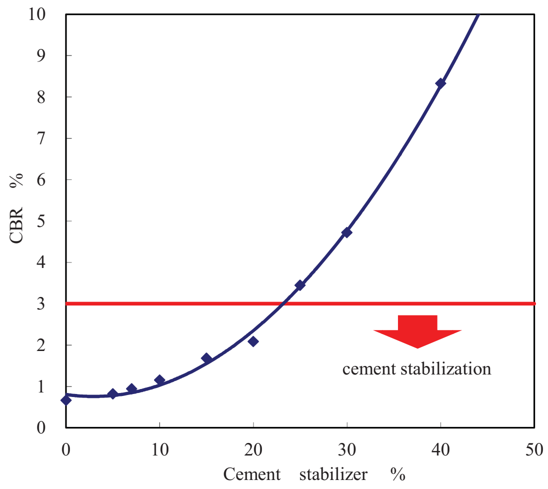


Fig. 1 Relation between cement stabilizer and CBR

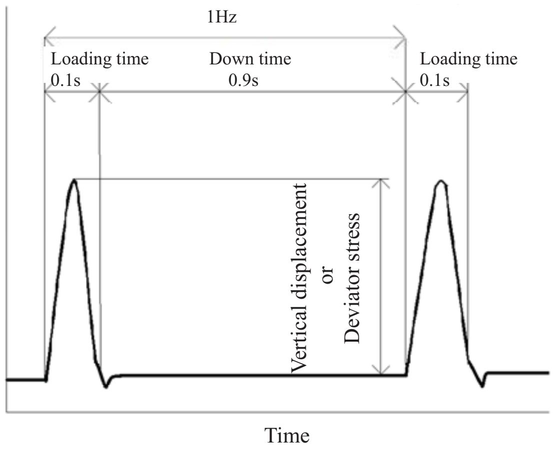


Fig. 2 Haver sine wave

w_L=149.2%, I_P=44.4), which is dried in laboratory until its moisture content becomes around 90% and is sifted in 2mm. EPS beads (ρ=0.033g/cm^3, D_{50}=1.47mm) are used as the lightweight material and cement stabilizer (ordinary portland cement) as the stabilizer. Water is also added to the moisture content of 120% where, according to our previous study (Minegishi et al. 2008), the beads could mix uniformly. Each combination condition of specimens are shown in Table 1. The mixture rates of cement stabilizer in the unconfined compression test and the triaxial compression test are set to 7%, 25%, 30% and 35% for the dry mass of Kanto loam. As this research focuses on the application to the subgrade and filled-up ground, the latter three, calculated through the preliminary experiment setting CBR to 3% and over (Fig. 1), are mainly examined; 7%, which was introduced to investigate the applicability to road embankment in our previous study, is dealt with so as to compare. In accordance with the these rates, the mixture rates of EPS beads turns to be 1.7%, 2.01%, 2.04% and 2.07% so that the wet density remains ρ_t=1.1g/cm^3. The mixture rates of EPS beads in the resilient modulus test are set to 0%, 10% and 30% for the volume of specimen. The mixture rates of cement stabilizer are set to 18%, 25%, 30% and 35% for the dry mass of Kanto loam. The specimen of the each test is compacted with a rammer of 2.5 kg at 5 blow / layer to 3 layers using a cylindrical plastic mold of 5 cm diameter. Compaction energy is based on Type-a (Ec=551.3 kJ/m^3) of JIS A 1210. After each

Table 2 Load condition of the resilient modulus test

Loading condition	Confining pressure σ_r (kN/m^2)	Deivator stress σ_d (kN/m^2)	Vertical stress θ kN/m^2	Load number
Preliminary load	41.4	27.6	151.8	1000
1	41.4	13.8	138.0	100
2	41.4	27.6	151.8	100
3	41.4	41.4	165.6	100
4	41.4	55.2	179.4	100
5	41.4	68.9	193.1	100
6	27.6	13.8	96.6	100
7	27.6	27.6	110.4	100
8	27.6	41.4	124.2	100
9	27.6	55.2	138.0	100
10	27.6	68.9	151.7	100
11	13.8	13.8	55.2	100
12	13.8	24.8	66.2	100
13	13.8	37.3	78.7	100
14	13.8	49.7	91.1	100
15	13.8	62.0	103.4	100

*Japan Road Society. (2007) A manual of pavement investigation and test method.

Table 3 Test result of unconfined compression test

Strength parameter	Value							
Sample	LWGME				Kanto Loam (Unmixed)			
Cement stabilizer (%)	7	25	30	35	7	25	30	35
Unconfined compression strength q_u (kN/m^2)	66.6	167.9	192.6	240.7	62.8	260.1	283.1	340.3
Angle of shear resistance φ_u (°)	17.9	46.9	48.4	39.0	47.8	39.2	37.1	29.1
Cohesion c_u (kN/m^2)	33.8	44.9	49.1	75.7	10.3	49.9	65.6	100.8
Deformation modulus E_{50} (%)	2.8	6.2	8.4	11.8	10.3	17.8	27.7	36.2

specimen is compacted, they are cured in the laboratory for 7 days before the tests. The testing criteria are as follows: JIS A 1216 for the unconfined compression test, JGS 0521 for the triaxial compression test. The resilient modulus test is conducted on the condition shown in Table 2. The waveform used haver sin wave shown in the Figure 2. Resilient modulus obtained from the resilient modulus test was calculated using the Eq. (1).

$$Mr = \frac{\sigma_d}{\varepsilon_a} \qquad (1)$$

where: Mr = resilient modulus (MN/m^2);
σ_d = deviator stress (kN/m^2);
σ_a = total stress (kN/m^2);
σ_r = confining pressure (kN/m^2);
ε_e = elasticity strain

TEST RESULTS

Unconfined Compression Test

Table 3 shows the result of the unconfined compression test. Along with the increase in the rate of cement stabilizer the unconfined compression strength, cohesion, and shear resistance angle showed an upward tendency, which clarifies a positive correlation rate of cement stabilizer and intensity. Comparing the test results of LWGME and unmixed soil indicates that LWGME possesses larger values in shear resistance angle. This is thought to be because EPS beads serve as the resistance elements to shear. But in terms of 35% the

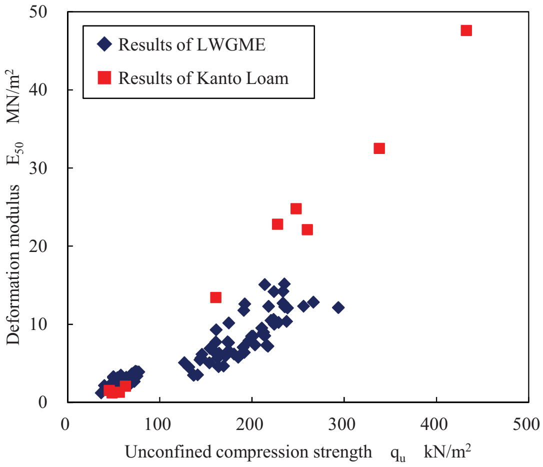


Fig. 3 Relation between unconfined compression strength and deformation modulus

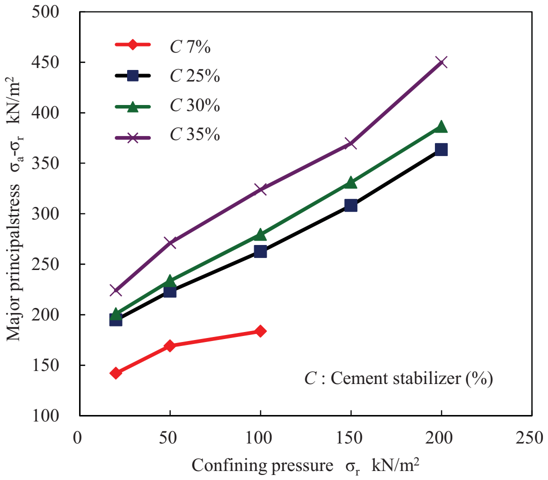


Fig. 4 Relation between confining pressure and major principal stress

Table 4 Test result of triaxial compression test

Cement stabilizer (%)	Confining pressure σ_r (kN/m^2)	Major principal stress difference σ_a-σ_r (kN/m^2)	Angle of shear resistrance ϕ_u (°)	Cohesion c_u (kN/m^2)
7	20	142.0	12.6	52.2
	50	169.1		
	100	183.6		
25	20	194.9	17.7	63.3
	50	223.3		
	100	262.5		
	150	308.1		
	200	363.3		
30	20	200.9	19.5	64.0
	50	233.7		
	100	279.5		
	150	331.1		
	200	386.5		
35	20	224.1	22.7	66.3
	50	271.1		
	100	323.9		
	150	369.6		
	200	450.0		

angle grows downward from 30%, which is due to the increase of the contact area among beads. Moreover, it turns out that the increasing amount of the unconfined compression strength and cohesion from 30 to 35% is much larger than that from 25 to 30%, which is because the decreasing rate of Kanto loam leads to reinforce the reaction of cement at a unit area and the action of the solidification material.

Figure 3 shows the relationship between the unconfined compression strength and the deformation modulus from the result of the unconfined compression test on both LWGME and the unmixed. At 7% of the cement stabilizer rate (less than 100 kN/m^2 in strength), LWGME and the unmixed Kanto loam show the similar data. Around 25% and over, the values are both in the upward tendency, but LWGME provides the lower result, which is caused for the reason that the affection to the mechanical characteristics by increasing the stabilizer rate is more prominent in the property of Kanto loam than that of the beads in specimens. Moreover, though the deformation modulus of LWGME at 7% lies within a certain extent, 25% or more show the random variation. This result is because EPS beads in specimens tend to be scattered heterogeneously as the mixing rate of EPS beads increases along with the increasing cement stabilizer rate.

Unconsolidated Undrained Shear Test

Figure 4 and Table 4, generated from the results of the triaxial compression test, confirm the increasing major principal stress along with the increase of the confining pressure as well as that of the stabilizer rate. It also turns out that the increase in the cement stabilizer rate makes the shear strength increased alongside. Compared to the disparity at 25-30% of the stabilizer rate, 30-35% shows a larger gap as in the unconfined compression test, which results from the increasing amount of the stabilizer per unit area of Kanto loam.

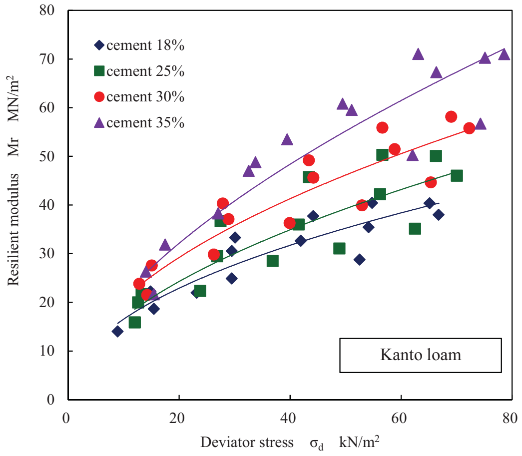
Resilient Modulus Test

Figure 5a, b, c shows the relationship between the resilient modulus and the deviator stress from the result of the resilient modulus test. As shown in Fig. 5(b), (c), the resilient modulus shows the downward tendency as the mixture rate of EPS bead in each cement stabilizer rate increases. This result shows the same tendency as deformation modulus obtained from the unconfined compression test, the unconsolidated undrained shear test. The resilient modulus of the Kanto loam in Fig. 5a shows an upward tendency as cement stabilizer increases. In contrast, cement stabilizer rate 25%, 30% and 35% of LWGME (Fig. 5c) showed the same value when the mixture rate 30% of EPS beads rate is made to mix. The mixture rate 10% of EPS beads showed the same tendency as the mixture rate 30% of EPS beads. This result, it is thought that elastic deformation of each load level does not change.

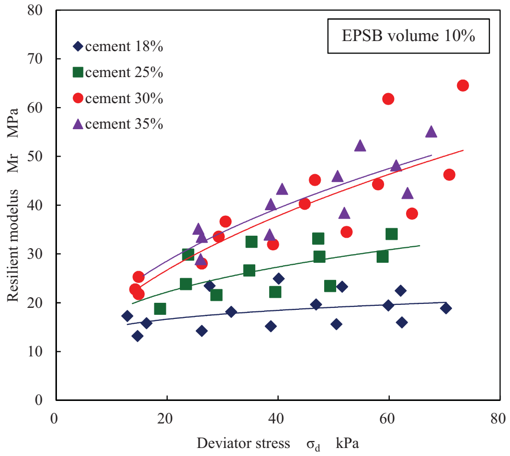
CONCLUSIONS

The main conclusions obtained from this study are as follows:

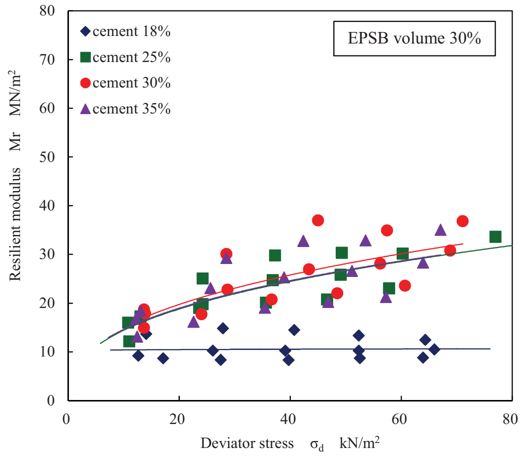
1) The deformation modulus of LWGME, through the unconfined compression test, shows the almost same tendency as the unmixed Kanto loam, when the amount of cement stabilizer is small.
2) Within the range of the mixing condition of this study, the strength and the cohesion of LWGME depends on the mixing rate of cement stabilizer, and the angle of shear resistance is dependent on the mixing rate of EPS beads.
3) The resilient modulus of LWGME is affected by the mixture rate of EPS bead. Therefore, even if the mixture rate increases, the resilient modulus shows a fixed value.



(a) Kanto loam



(b) EPSB volume 10%



(c) EPSB volume 30%

Fig. 5 Relation between the resilient modulus and the deviator stress

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