SCALE EFFECTS ON THE SHEAR STRENGTH OF WASTE IN OSAKA COASTAL LANDFILL SITES

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Summary: *In Japan, a significant volume of municipal solid waste incinerator ash (MSWIA), slag and soil are disposed in coastal landfill sites located in Tokyo and Osaka bay. Future reclamation of these final disposal sites is an important goal. Thus, it is relevant to understand the shear strength properties of the waste layers in coastal landfill sites to utilize the land after closure. However, there is no available research on the effects of oversize particle on the shear strength of waste samples in coastal landfill sites. Therefore, this paper presents the results of larger triaxial test (150 mm x 300 mm) for waste samples. In the large triaxial test, the pore water pressure generated is higher compared to the results obtained for small samples. The smaller values of shear strength for large samples are also related to the crushability of large particle size. Thus, the frictional angle of large specimens is slightly smaller than that of small ones for this material.*

Keyword: *ash, curing time, coastal landfill, large triaxial test.*

I. INTRODUCTION

In Japan, a significant volume of municipal solid waste incinerator ash (MSWIA), slag and soil are disposed in coastal landfill sites located in Tokyo and Osaka bay. Future reclamation of these final disposal sites is an important goal. Thus, it is relevant to understand the strength properties of the waste mixture layers in coastal landfill sites to utilize the land after closure. However, the particle size distribution of the waste mixture ranges from fine-grained to coarse-grained (gravel, glass, etc.) affecting the estimation of the strength properties of the waste mixture sample in coastal landfill sites. Generally, the strength properties of a sample material is investigated by a triaxial test. When triaxial tests are run, the maximum particle size of the samples must be less than one-sixth of the diameter of the specimen. Therefore the standard triaxial test, with a specimen of 50 mm in diameter, cannot be used if the diameter of the waste mixture sample is larger than 9.5 mm. Numerous research studies have attempted to increase the maximum particle size of the specimens tested by increasing the size of the testing apparatus in order to accurately measured the mechanical behavior of geomaterials (Holtz &J. 1956, Hennes 1952, Simoni et al. 2006). Previous studies have investigated the effect of large particles on shear strength of soil by using large triaxial test and reported that the increase in gravel content decreases the density and shear strength of the material (Fragaszy et al. 1992, Fragaszy et al. 1990). Kirkpatrick (1965) studied the Leighton Buzzard sand with uniform particle sizes using triaxial tests; the results showed a reduction in friction angle as the mean particle size increased while the porosity was kept constant. Other researchers concluded that the shear strength of mixture (soil and gravel) increases with gravel content.

However, there is no available research on the effects of large particle on the shear strength of waste mixture samples in coastal landfill sites. Therefore, in this research, large-scale (150 mm x 300 mm) and small-scale (50 mm x 100 mm) triaxial tests were carried out on waste mixture samples to study the effect of specimen size on the shear strength of the samples. The experimental work was conducted in Kyoto University, Japan. This paper deals with the effects of particle size and confining pressure on the shear strength of waste mixture samples.

II. MATERIAL AND METHODS

2.1. Material

The waste samples employed in this study were obtained from the coastal landfill site in Osaka Prefecture. The waste samples were collected before being disposed at the coastal landfill site. Approximately 200 kg of wet waste sample include incinerator ash; slag and surplus soil, etc. were collected and then dried in a room with an average temperature of 20°C. For conducting small specimen, large pieces such as glasses or rocks were removed and the sample was sieved with 9.5mm opening sieve and set aside until use. For large specimen, all large pieces were used except pieces larger than19mm. The maximum diameter of waste mixture for small and large triaxial test is 9.5mm and 19 mm, respectively. Figure 1 shows the particle size distribution for small and large samples, determined according to JIS A1204. The specific gravity of the waste sample was 2.67.

X-ray florescence Spectroscopy (XRF) was performed to determine the chemical composition of the waste samples. The chemical composition of the sample is shown in table 1. The main components of the sample are CaO; Fe_2O_3 and SiO_2. The XRF shows that lime (CaO) is the main component of the sample (51.6 %).

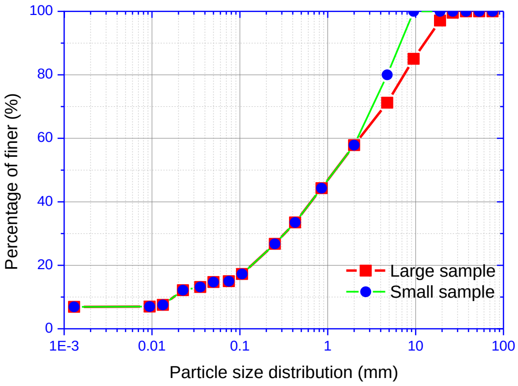

Figure 1. *Particle size distribution of waste mixture samples for small and large triaxial tests*

Table 1. *Chemical composition of waste sample (%)*

CaO	Fe_2O_3	SiO2	Al_2O_3	TiO_2	SO_3	CuO
51.61	20.40	9.11	4.28	3.30	2.77	0.52

2.2. Method

In this study, small specimens were prepared by compacting 5 layers of waste in to a split cylindrical mold (50 mm diameter and 100 mm in height) 80% of maximum dry density (1.28 g/cm^3) with optimum water content of 34.5% according to the value obtained from the Standard Proctor Compaction Test.

For large CU triaxial test, specimens were prepared by compacting 5 layers of waste mixture in to a split cylindrical mold (150 mm diameter and 300 mm in height) with the same maximum dry density and optimum water content as small specimens. In this test, D/d_{max}= 15/1.9 = 7.89 (where D is diameter of specimen in large triaxial test and d_{max} is the maximum particle size of waste mixture).

Small and large CU triaxial tests were carried out on waste mixture specimens following the same procedure. These specimens were saturated by applying a vacuum procedure (Rad and Clough, 1984). The samples were consolidated with an effective confining pressure of 50, 100 and 150 kPa and sheared at a constant strain rate of 0.5%/min until 15% of axial strain was reached. The initial conditions for large and small triaxial test are shown in table 2.

Table 2. *Initial condition of waste mixture samples*

Type of Triaxial test	Confining pressure (kPa)	Dry density after consolidated (g/cm^3)	Void ratio (after consolidated)
For small triaxial test (50mm x 100 mm)	50	1.02	1.62
	100	1.02	1.62
	150	1.02	1.62
For large triaxial test (150mm x 300 mm)	50	1.02	1.61
	100	1.03	1.56
	150	1.06	1.53

III. RESULTS AND DISCUSSION

3.1. CU test for small triaxial test

Figure 2 shows the stress-strain curves for small samples. Generally, the deviator stress increases dramatically from 0 to 2 % of axial strain and reaches a peak after 6% of axial strain. After that the deviator stress reaches a constant value until 15% of axial strain. The stress-strain curves illustrate the strain hardening behavior of waste mixture samples.

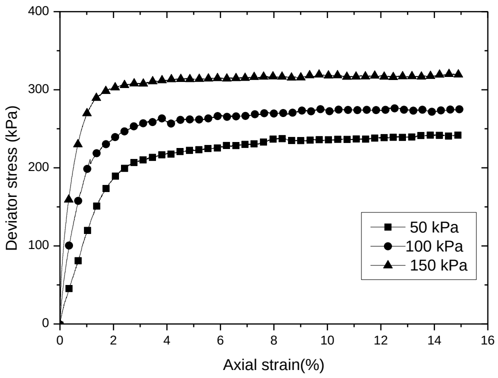

Figure 2. *Stress-strain curves for small samples*

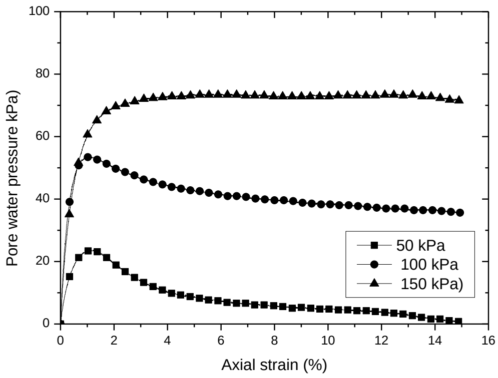

Figure 3. *Pore pressure results versus axial strain for small triaxial test*

Figure 3 shows the pore pressure results versus axial strain. For samples under a confining pressure of 50 kPa, the pore water pressure shows an increase trend at the initial stage until it reached a peak value of about 20kPa and then it is reduced steadily to nearly zero at 15% of axial strain. Pore water pressure generated in samples that sustained 100 kPa confining pressure, showed a similar trend than samples under 50 kPa but reaching a pore pressure peak value of about 50 kPa and then reducing steadily until reaching about 35 kPa. However, for samples under 150 kPa, pore water pressure increases and reaches a peak at 2% and then keeps a constant value until an axial strain of 15% is reached. The samples under initial conditions in small triaxial test showed a contractive behavior in shearing process due to the positive value of the pore water pressure when the axial strain increased from 0 to 15 %.

3.2. CU test for larger triaxial test

Figure 4 shows the stress-strain curves for large samples. The deviator stress increases dramatically from origin to reach a peak value at about 2% of axial strain. After that, the deviator stress decreases steadily until 15% of axial strain and the stress-strain curves illustrate the strain softening behavior of waste mixture samples. This behavior significantly change compare with the results for small samples.

Figure 5 shows the pore water pressure versus axial strain. For specimens that sustained 100 and 150 kPa of confining pressure, the pore water pressure increases dramatically from 0% to 2% of axial strain and from 2% to 15% it has a mild but steady increases. In the case of specimen that sustained 50 kPa of confining pressure, pore water pressure has a constant value from 2% to about 15% axial strain.

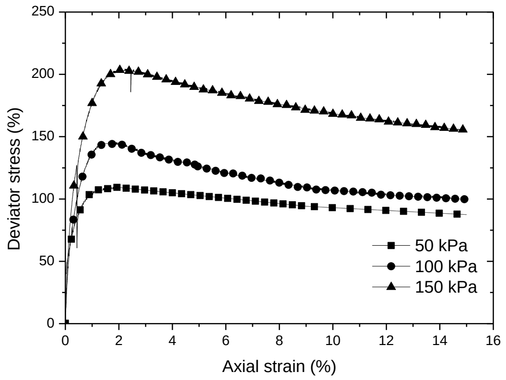

Figure 4. *Stress-strain curves for large samples*

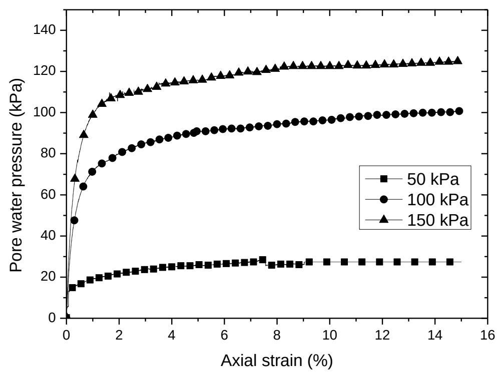

Figure 5. *Pore pressure results versus axial strain for large triaxial test*

3.3. Effect of particle size on shear strength of waste mixture sample

In order to compare the peak strength envelopes and the shear strength parameters for large and small samples, the shear strength parameters are determined using a linear interpolation. Figure 6 shows the peak strength of small samples and large samples.

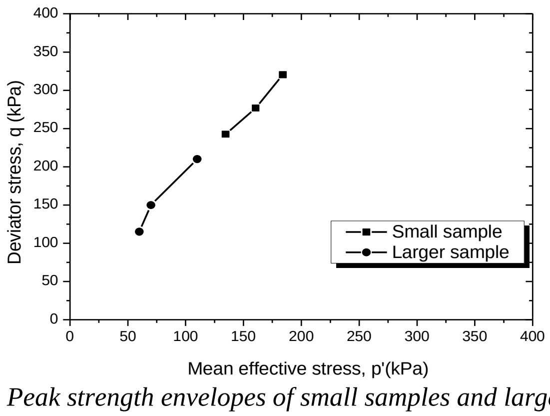

Figure 6. *Peak strength envelopes of small samples and large samples*

The cohesion and angle of friction obtained are 0 kPa, 46.7° for small sample, and 2.8 kPa, 44.78° for large sample, respectively. The direction of peak strength envelope for samples and larger samples is similar. Thus, the strength parameters results are almost no change. The most important reason for the change in shear strength is related to pore water pressure generated. In the large sample, due to large diameter of mixture waste and large specimen the pore water pressure generated are higher compare to those in small samples. The change in pore water pressure contributed to the change in shear strength of large sample compare with small samples. Thus, most important reason for the change in shear strength is related to pore water pressure generated. In the large sample, due its the large diameter, the pore water pressure generated is higher compare to the results obtained for small samples. The change in pore water pressure contributed to the increased in shear strength for large sample compare with small samples.

IV. CONCLUSION

Based on the experimental results, the following summarizes about the scale effects of specimens on the mechanical properties of waste mixture in Osaka coastal landfills:

1. In this research, the particle size of the larger samples for large triaxial test 150mm x 300mm is larger than 9.5mm. In the large triaxial test, the pore water pressure generated is higher compared to the results obtained for small samples

2. The value of shear strength obtained from the triaxial tests for large samples are smaller than with the results obtained for small samples that affect stress paths and that in turn reduce in the strength of large samples. The smaller of the shear strength for large samples are also related to the crushability of large particle size. Thus, the frictional angle of large specimens is slightly smaller than that of small ones.

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