Geotechnical Properties for Mixed Materials of Sludge, Crushed Concrete, and Incineration Ash

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Abstract: *An effective use of limited space in existing waste disposal sites is highly needed due to the difficulty in constructing new facilities in Japan. The control of compaction and consolidation properties of waste materials is important to reduce disposal space. Correspondingly, studying on shear strength properties is essential in order to take precautionary measures against potential failures such as slope instability. In this study, geotechnical properties such as maximum dry density, compression index, and friction angle were investigated for mixed waste materials of sludge (D<2.0mm), crushed concrete (2.0mm<D<9.5mm), and incineration ash (D<2.0mm) with different mixing proportions. Mixed samples of sludge and crushed concrete and/or incineration ash showed almost same compaction characteristics and friction angle. However, completely different results between the mixed samples of sludge and incineration ash and the mixed samples containing crushed concrete were observed. The compression index was significantly decreased with decreasing the mixing proportion of sludge in case of adding the crushed concrete. Therefore, it is highly important to mix the crushed concrete for increasing the strength of waste materials.*

Keywords: *Sludge, Crushed concrete, Incineration ash, Mixed waste materials, Compaction, Consolidation, Triaxial compression*

1. INTRODUCTION

Waste disposal sites are essential infrastructure facilities for human and industrial activities. However, it is difficult to construct new disposal facilities due to the lack of land in Japan. Therefore, an effective use of limited space in existing waste disposal sites is highly needed. The control of geotechnical properties such as compaction and consolidation of waste materials are important to reduce disposal space. Shear strength properties also play a key role in determining a safe slope. Therefore, in this study, geotechnical properties including maximum dry density, compression index, cohesion, and friction angle were investigated for mixed waste materials of sludge, crushed concrete, and incineration ash with their different mixing proportions.

2. METHODOLOGY

Waste materials of sludge (D<2.0mm), crushed concrete (2.0mm<D<9.5mm), and incineration ash (D<2.0mm) were used in this study. Sludge was taken from Chiba prefecture in Japan. Crushed concrete and incineration ash were collected from Saitama prefecture in Japan. The waste materials were mixed with various proportions based on mass ratio. The basic physical and chemical properties are reported in Hashimoto et al. (2016).

Compaction test, consolidation test, and triaxial compression test were carried out for mixed samples of waste materials. The details of experimental procedures for the standard proctor compaction test and consolidation test are presented in Hashimoto et al. (2016).

2.1. Triaxial Compression Test

Consolidation-Undrained triaxial compression test ($\overline{CU}$) was carried out for specimens of 10 cm in diameter and 20 cm in height according to JGS 0523 with some modifications using the apparatus shown in figure 1. More than 90% Degree of Compaction was achieved by adjusting the moisture content based on compaction curves presented in Hashimoto et al. (2016). Specimens were consolidated under 50, 100, and 150kPa confining stress conditions in order to obtain the failure envelope using Mohr Coulomb method. The strain rate of 0.1% per minute was used to measure the pore water pressure. The schematic diagram of triaxial compression system is presented in figure 2.

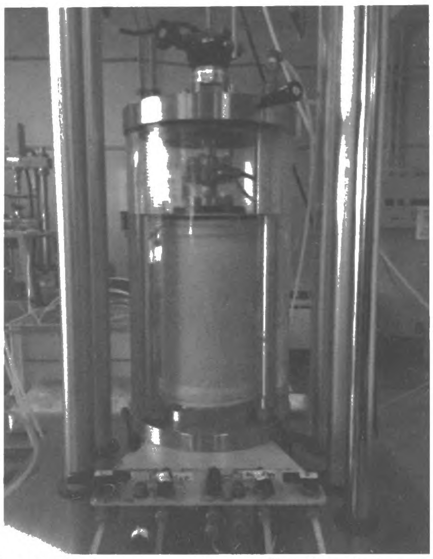


Figure 1 Experimental apparatus of triaxial compression test

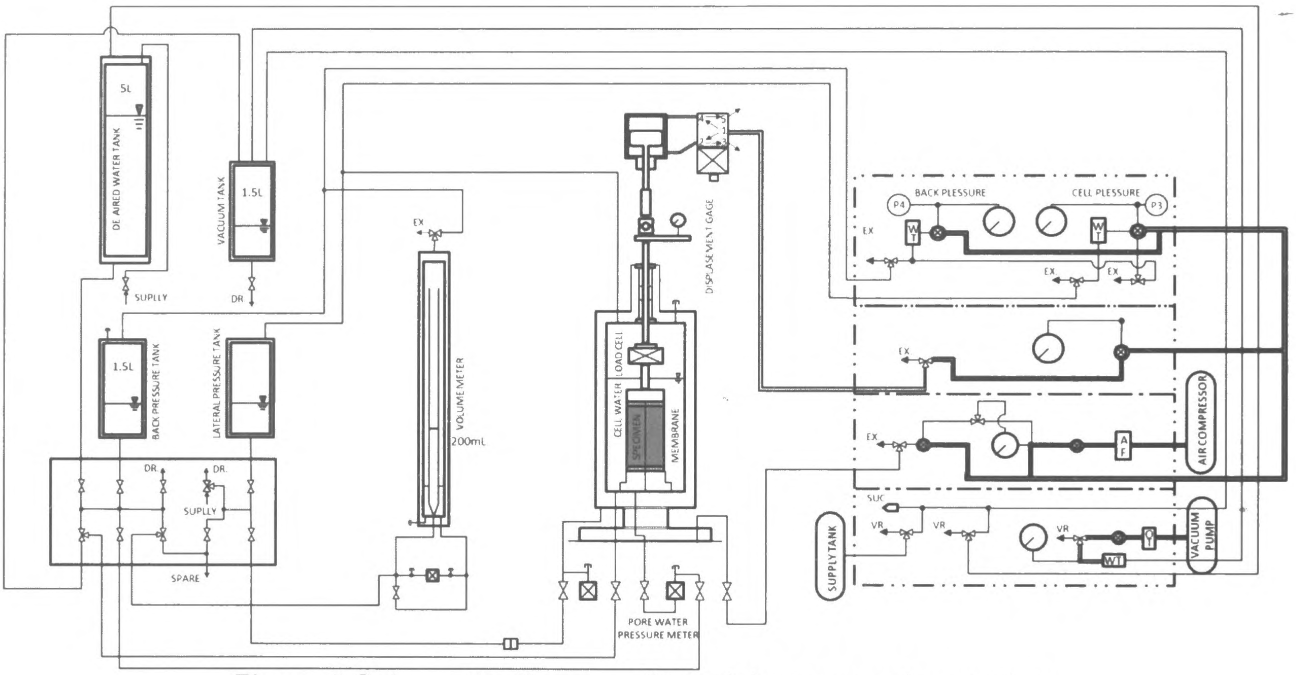


Figure 2 Schematic diagram of triaxial compression system

3. RESULTS AND DISCUSSION

3.1. Compaction Characteristics of Waste Materials

Based on compaction test results, the following equations (1) and (2) were proposed to estimate maximum dry density and optimum moisture content with each mass ratio as an input parameter. The coefficients were determined based on least square method of solver. Figure 3 presents relationships between estimated values from the proposed equations and actual measured values for maximum dry density and optimum moisture content. The 95% confidence intervals were also showed in the figure.

$$\rho_{dmax} = 0.73\alpha + 1.65\beta + 1.72\gamma \ (r^2 = 0.93) \quad (1)$$
$$w_{opt} = 69.7\alpha + 10.3\beta + 10.7\gamma \ (r^2 = 0.94) \quad (2)$$

α,β and γ are mass ratio of sludge, crushed concrete, and incineration ash, respectively. $\alpha + \beta + \gamma = 1$

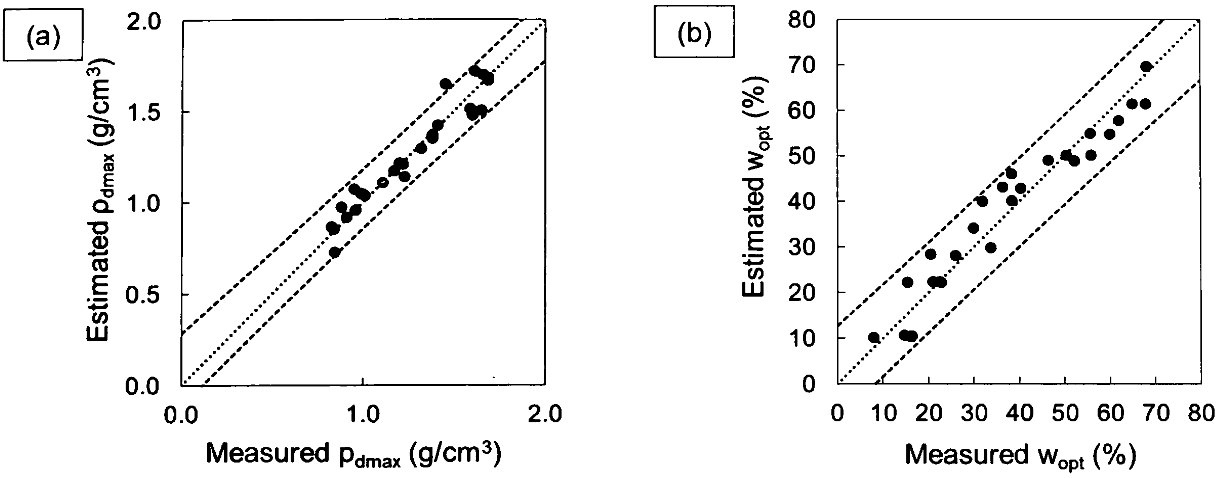


Figure 3 Relationships between estimated values from the proposed equations and measured values for (a) maximum dry density and (b) optimum moisture content. The broken lines show 95% confidence intervals

3.2. Consolidation Characteristics of Waste Materials

Figure 4 shows relationships between (a) initial void ratio (e_i) or (b) compression index (c_c) and mixing proportion of crushed concrete and/or incineration ash to sludge. Initial void ratio showed strong negative linear relation (r^2=0.87) with the mixing proportion of sludge. Compression index was generally decreased with decreasing the mixing proportion of sludge. Especially for the compression index, completely different trends between the mixed samples of sludge and incineration ash and the mixed samples containing crushed concrete were observed as shown in figure 5 (b). Therefore, the compression index drastically decreased in case of adding crushed concrete to sludge and/or incineration ash.

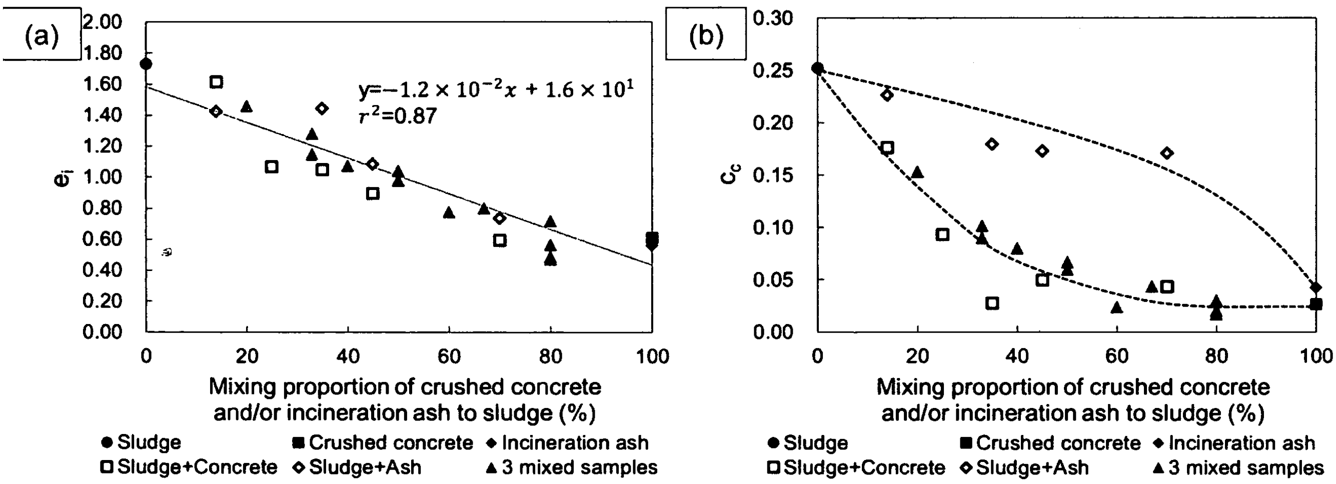
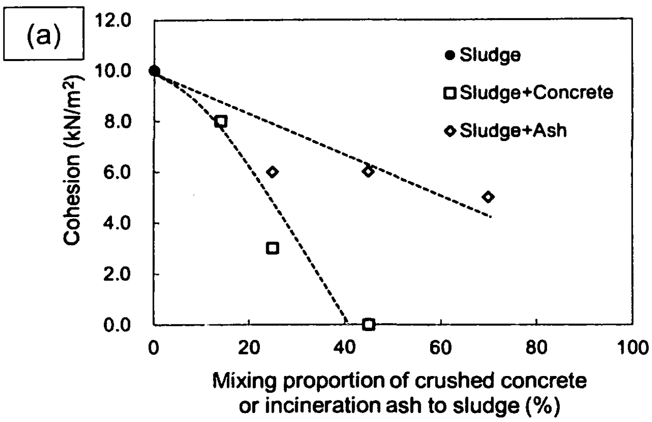


Figure 4 Relationships between (a) initial void ratio or (b) compression index and mixing proportion of crushed concrete and/or incineration ash to sludge

3.3. Consolidation-Undrained Shear Characteristics of Waste Materials

Figure 5 presents relationships between (a) cohesion (c') or (b) friction angle (φ') and mixing proportion of crushed concrete and/or incineration ash to sludge. For the mixed samples of sludge and incineration ash, cohesion showed negative linear relations with increasing the mixing proportion of incineration ash. On the other hand, the mixed samples of sludge and crushed concrete showed different results, it rapidly decreased and became almost zero value with increasing the mixing proportion of crushed concrete. For the mixed samples of sludge and crushed concrete or incineration ash, measured friction angles showed positive linear relations with increasing the mixing proportion of crushed concrete or incineration ash irrespective of different particle size distributions for crushed concrete and incineration ash.



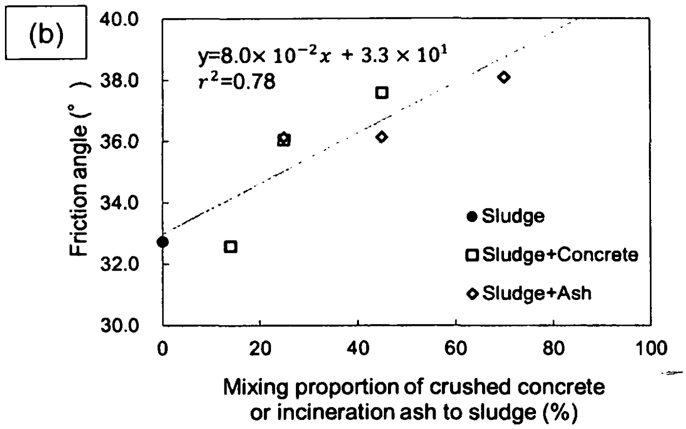


Figure 5 Relationships between (a) cohesion or (b) friction angle and mixing proportion of crushed concrete or incineration ash to sludge

4. CONCLUSIONS

In this study, geotechnical properties such as maximum dry density, compression index, and friction angle were investigated for mixed waste materials of sludge (D<2.0mm), crushed concrete (2.0mm<D<9.5mm), and incineration ash (D<2.0mm) with their different mixing proportions. Based on compaction test results, the equations were proposed to estimate maximum dry density and optimum moisture content with each mass ratio as an input parameter. Measured friction angles showed positive linear relations with increasing the mixing proportion of crushed concrete or incineration ash irrespective of different particle size distributions for crushed concrete and incineration ash. On the other hand, for compression index, completely different results between the mixed samples of sludge and incineration ash and the mixed samples containing crushed concrete were observed. The compression index was significantly decreased with decreasing the mixing proportion of sludge in case of adding the crushed concrete. Therefore, it is highly important to mix the crushed concrete for increasing the strength of waste materials.

5. ACKNOWLEDGEMENTS

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