

# Aging effects on the mechanical property of waste mixture in coastal landfill sites

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## Abstract

Coastal landfill sites not only offer an option for disposal but also create a new land space after the completion of landfilling. To perform proper design on settlement, stability, and/or bearing capacity at landfill sites, the geotechnical properties of the waste layer such as deformation and shear strength should be investigated. This research is focused on the mechanical properties of waste mixture sampled at a coastal landfill site including municipal solid waste incinerator ash, slag, soil and others, to provide useful information on geotechnical properties in utilizing coastal landfill sites after their closure. A series of triaxial consolidated undrained compression tests (CU) and hydraulic conductivity tests were carried out on the reconstituted waste samples before and after being cured in simulated leachate water in coastal landfill sites for different periods, to understand the aging effects on mechanical properties of waste mixture. It was shown that while curing results in an increase in the peak strength and deformation modulus, the residual strength was not affected by the curing periods. Scanning electron microscope observations and X-ray diffraction analysis on the waste samples after curing confirmed that the formation of ettringite and hydration products had a densification effect on the microstructure. The higher peak shear strength and lower hydraulic conductivity of the waste samples were attributed to this effect.

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**Keywords:** Waste layer; Curing time; Coastal landfill; Triaxial test; Mechanical property; Ettringite

## 1. Introduction

Coastal landfilling is an important method for disposal of municipal solid waste incinerator ash (MSWIA), slag, soil, and others in Japan. According to the Ministry of the Environment, Japan, approximately 20% MSW was disposed of in coastal

landfill sites, and the weight ratio of MSWIA in landfilled wastes reached almost 78% in 2003 (Shimaoka et al. 2007). In general, coastal landfill sites are located at strategic points in the port areas of Tokyo, Nagoya and Osaka with relatively easy access from the metropolitan areas. Coastal landfill reclamation is a key option considering the limited land available in Japan. For this reason, it is important to investigate the strength, bearing capacity, and deformation properties of the waste mixture layers deposited in the coastal landfill. However, limited research regarding the geotechnical properties of the waste mixture layers in coastal landfill sites has been carried out, and the engineering properties of waste mixtures, which include incinerator ash, slag, and surplus soil, remain largely unknown. However, studies have been carried out in

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the framework of the Osaka Bay Phoenix Project, which is an extensive coastal landfill project that started in 1990 and has 45 million m<sup>3</sup> of total capacity, geotechnical investigations were carried out for the MSW landfill zone at Amagasaki offshore disposal site to determine its physical and dynamic properties (Aburatani et al. 1996). This research concluded that the wet unit weight of the waste layer varied between 15 and 18 kN/m<sup>3</sup>, depending on the depth of waste layer, the internal friction angle ranged from 24.5° to 35°, and mechanical properties of the MSW-reclaimed layers were equivalent to those of loose alluvial sandy soil with an average SPT-N value of 4.5.

Another important but poorly studied aspect is the time dependency on the waste mixture properties, particularly the changes in geotechnical properties of the waste mixture with time in coastal landfill sites. Sato et al. (2001) conducted consolidated drained triaxial tests on MSW incinerator ash specimens, which were cured under three different conditions including dry, wet and submerged conditions. The results showed an increase in the strength of the MSW incinerator ash samples with the longer curing periods due to the hydration and pozzolanic reactions. An increase in the shear strength in the incinerator ash samples that were submerged in water was also reported by Itoh et al. (2005) and Towhata et al. (2010). These previous works indicated that reduction in the pore space and decrease in the hydraulic conductivity occurred by the curing effects. A study carried out on the MSWIA cured in a fully-sealed condition by Doi et al. (2000) showed that the unconfined compression strength increased with time, while hydraulic conductivity decreased by two orders of magnitude together with a reduction in the compressibility of MSWIA. The authors pointed out that ettringite generation and cementation with time influenced these mechanical properties.

Considering that MSWIA is a major landfilled waste in Japan, these previous studies suggest the importance of considering the aging effects on the geotechnical properties of waste mixtures submerged in landfill leachate or seawater. However, there have been few works that evaluate the shear strength and deformation properties of the waste mixture when it interacts with actual or simulated coastal landfill leachate for a long time. In this study, waste mixture immediately before being disposed of in a coastal landfill site was collected, and reconstituted specimens were cured in simulated leachate for different time periods to simulate the interactions with the leachate in a coastal landfill site. A series of triaxial consolidated undrained (CU) compression tests and hydraulic conductivity tests were carried out on the specimens before and after being cured. Scanning electron microscope (SEM) and X-ray diffraction (XRD) analyzes were also conducted to further understand of the changes in the microstructures of waste mixture. Based on these experimental results and observations, the aging effects on the mechanical properties and microstructures of the waste mixture reclaimed in coastal landfills were discussed.

## 2. Materials and methods

### 2.1. Material

The waste mixture used in this study was collected at a coastal landfill site in Osaka Bay area, Japan, immediately before reclamation. The composition of the waste mixture collected was approximately 50% of MSWIA, 30% of gravel materials like slags, and 20% surplus soil, based on the waste acceptance record. Approximately 200 kg of the wet waste mixture was collected and then air-dried in a laboratory at a constant temperature of 20 °C. After that, large pieces of debris such as glass and rocks were removed and the mixture was sieved with a 9.5 mm opening sieve. The sample after sieving was considered the mixture of MSWIA and soil containing small slags and gravels (Table 1).

Fig. 1 shows the particle size distribution of the waste mixture sample after sieving, determined according to JIS A 1204 (2009). The grain size distribution indicates this waste mixture is composed of 85.9 % sand fraction (> 0.075 mm), 8.1% silt fraction (0.005–0.075 mm) and 6.0% clay fraction (< 0.005 mm). The uniformity and curvature coefficients were 127.8 and 2.63, respectively. The material was well graded with a particle size distribution corresponding to SG-F (gravely sand with fine fraction), according to the JGS 0051 (2009). The specific gravity of the waste mixture sample was 2.67. The chemical composition of the waste sample determined by the X-ray fluorescence spectroscopy (XRF) is shown in Table 2. The XRF shows that calcium oxide is the main component (51.6% in CaO), which indicates a certain hydration ability of the sample. Fig. 2 shows the compaction curve of the waste mixture, according to the A–c method of Standard Proctor Compaction Test, JIS A 1210 (2009).

Table 1  
Chemical composition of the waste mixtures sample.

Chemicals	CaO	Fe <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	TiO <sub>2</sub>	SO <sub>3</sub>	K <sub>2</sub> O	ZnO	Others
Content (%)	51.6	20.4	9.1	4.3	3.3	2.8	1.7	1.9	4.9

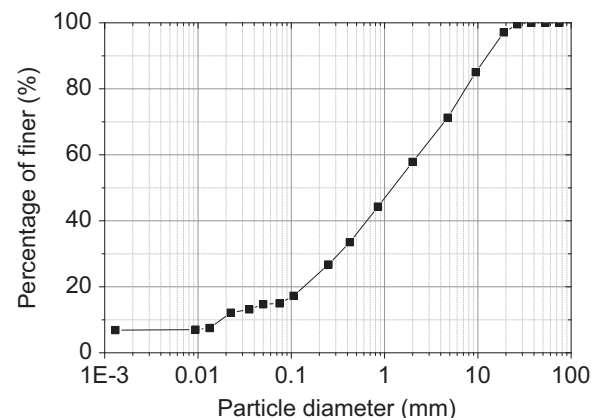


Fig. 1. Particle size distribution of the waste mixture sample after sieving.

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