Preliminary analysis of the bio-mechanical characteristics for High-kitchen Municipal Solid Waste

He. Li [1]*, Jian.Guo. Zhang [2], Ji.Wu. Lan [1], Haijie He[1]

1 MOE Key Laboratory of Soft Soils and Geoenvironmental Engineering，Zhejiang University，Hangzhou，Zhejiang 3 10058，China,
2 Shen Kan Engineering & Technology Corporation, MCC(SKET)

*E-mail: lihe2404@126.com

Abstract: Degradation of Municipal Solid Wastes (MSW) results in a change in solid skeleton, particle size and pore structure, inducing an alteration of compressibility and liquid/gas conductivity of the wastes. To investigate the complicated biological, hydraulic and mechanical coupled processes of the MSWs, a pilot-scale experimental device which is consist of waste column container, environment regulation system, vertical loading system and measuring system for liquid/gas conductivity is built. With the experimental systems, long-term tests were set up to investigate the biological, hydraulic and mechanical behaviour of the High-kitchen Municipal solid waste with high organic content and high water content. Different values of vertical stress and different degradation conditions (micro-aerobic and anaerobic) were simulated. Throughout the experiments, the changes in total volume, degree of saturation, leachate quantity and chemistry, LFG generation and composition, liquid and gas conductivity were measured. The experimental results will provide solid data for a development of the Bio-Hydro-Mechanical coupled characteristics for High-kitchen Municipal solid waste.

1. Introduction

Municipal Solid Wastes (MSWs) contain biodegradable component, which results in the difference in engineering property between MSWs and traditional soil (Chen, 2013). The biodegradation of MSW is a complicated Bio-Hydro-Mechanical coupled process, which results in the decrease of solid phase and the variation on skeleton, particle size and pore structure of the MSWs.

Lots of experiment devices imitating the soil test apparatus have been designed to study the geotechnical properties for MSW with different degradation degree (Landva and Clark, 1990; Wall and Zeiss, 1995; Hossain, 2003; Reddy et al., 2009a,b; Bareither, 2012). The scale effect has an important influence on the mechanical and biodegraded properties of MSW (Hossain et al., 2009; Bareither et al., 2012), so the measured results by imitating-soil-test device can not be used to accurately estimate the behavior of the field-scale landfill. Currently, there was only a few equipments with large dimension (diameter is more than 30 cm) and bioreactor functions which can measure the variation of geotechnical properties for MSW during bio-degradation process (Beaven, 2000; Ivanova, 2007; Olivier et al., 2007; Reddy et al., 2009c).

In this paper, a pilot-scale experiment apparatus is developed, which can simulate the complicated landfill environment (different buried depth and varied liquid-gas pressure) and measured the geotechnical and biochemical parameters (compression, water content, leachate production and chemistry, LFG generation and composition, liquid and gas conductivity) of the MSWs. The objective of the study baesd on the pilot-scale experimental apparatus is to analyze the changes in MSWs geotechnical properties with waste decomposition and provide reliable data for development of mathematic relationship between time-dependent model property parameters and the degree of degradation (C/L) to describing the coupled behaviour of the MSWs.

2. Pilot-scale experiment apparatus and landfilled waste

The pilot-scale experiment apparatus is consist of waste column container, hydraulic loading system, heating device, measuring system for liquid/gas conductivity and monitoring system.

Synthetic MSW sample was prepared according to the reported composition of fresh MSW by World Bank (2005) for China. As shown in Table 1, degradable matter in MSW is mainly food waste, accounted for 50.0% (wet basis), which has a water content of more than 90%. High water content and high organic matter were the impressive characteristics for the MSW generated in China. The initial physical parameter for landfilled waste is given by Table 2. The experiment was conducted for 200 days.

Table 1. Composition of MSW

Component	Food waste	Dust, Cinder	Paper	Textile	Plastics	Metal	Glass	Wood	Total
Data(%)	50.0	15.5	13.0	2.0	14.0	1.5	2.0	2.0	100

Table 2. Characteristic parameter of MSW sample

Parameter	Cell 1
Total weight(t)	0.200
Initial Water Content(%)	66.5
Height (m)	1.12
Density (t/m3)	0.725

3. Results and discussion

The variation of cumulative LFG production for Cell 1 in 200 days was shown in Figure 1(a). Cell 1 was sealed at the 11d after landfilling finished, so there was no data for LFG production in the first 10days. The largest LFG production rate appeared between 10 d and 30 d, with the value of 16.83 L/d (0.250$Ld^{-1}kg^{-1}$-dry-waste). Then the LFG production rate decreased from 4.70L/d (0.070 $Ld^{-1}kg^{-1}$-dry-waste) to 3.00L/d (0.045 $Ld^{-1}kg^{-1}$-dry-waste) during 30 d to 180 d. 180 days later, the LFG production rate ceased gradually and the average value was only 0.94 L/d (0.014 $Ld^{-1}kg^{-1}$-dry-waste). The totel LFG production was 735 L (10.97 L/kg-dry-waste).

The variation of the LFG composition (CO_2 and CH_4) was given by Figure 1(b). After sealed at 11 d, the relative concentration of CO_2 reached peak value of 79.0%. Then the relative concentration of CO_2 decreased to 27.15% quickly at 47 d. Between 47 d and 105 d, the relative concentration of CO2 increased from 27.15% to 42.0%.The relative concentration of CO_2 dropped to 18% at 200 d. The production of CH_4 was firstly observed at 8 d and the relative concentration was 1.43%. Then the relative concentration of CH_4 went up to 36.86% with the degradation process during 8 to 105 d. At the end of the stage-A (200 d), the relative concentration of CH_4 increased to more than 40.0%.

Figure 1(c) and 1(d) provideed the change on the concentration of the pH and COD measured in effluent leahcate. The pH value remained between 5.26~6.26, that indicated the MSW cell was in acid environment. The COD concentration increased gradually from 18.31 g/L to maximum value of 47.75 g/L, due to rapid release and hydrolysis of complex organics from solid waste to the leachate, and then remained at a high level due to the accumulation of volatile fatty acid (VFA).

The bio-degradation process of MSW can be seperated into 5 stages (Ivanova, 2007): aerobic degradation, acidogenesis, acetogenesis, methanogenesis, aerobic. Referring to Olivier (2007), three successive stages of bio-degradation can be observed for stage-A: aerobic (0~11 d, not sealed for Cell 1), acidogenesis (12~105 d,with pH≈6.0, CO_2≥25%, CH_4≤40%), acetogenesis (105 ~200 d, with pH↑, 45%＞CO_2＞20%, 60%＞CH_4 ＞40%). The duration of stages 1~3 was almost same as that descrbed by Olivier (2007) (203 days).

Figure 1(f) showed the surface settlement of Cell 1. 5 days after landfilling, the accumulated settlement was 11 cm (corresponding strain is 0.098). At 61 d the settlement was developed to 14.2 (corresponding strain is 0.126). During 62 to 200d the settlement can be neglected, which was less than 1 mm.

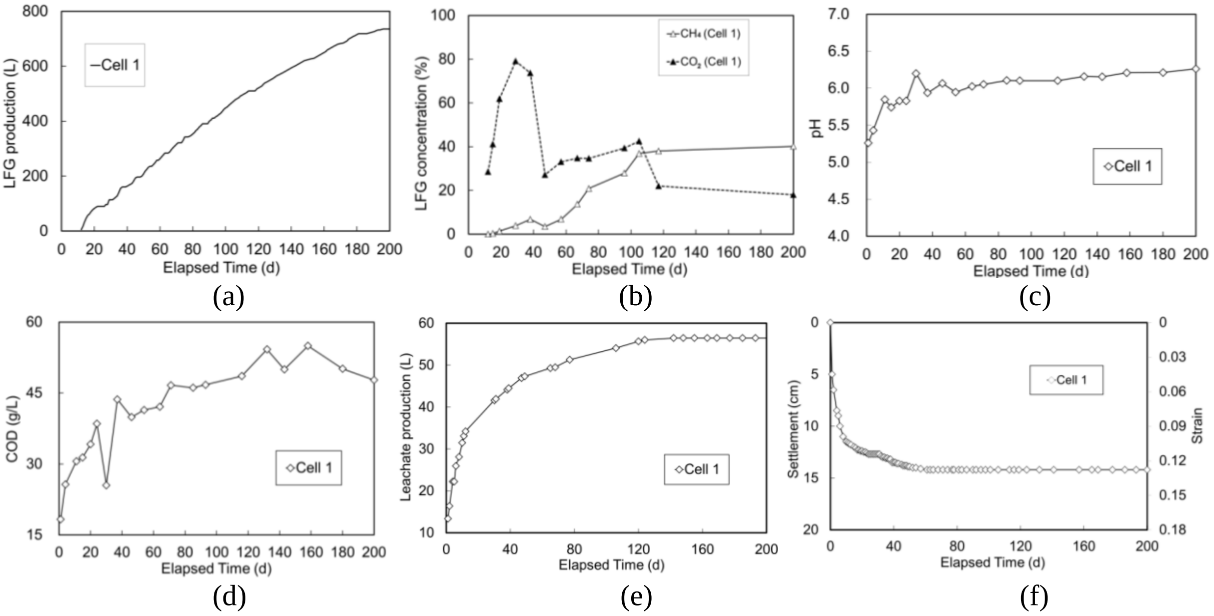

Figure 1. Characteristics of effluent leachate, LFG and settlement

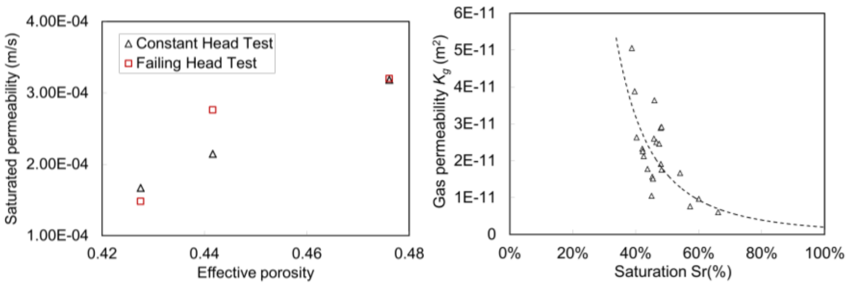

Figure 2. Saturated permeability and gas permeability

There was no vertical load applied on the MSW cell at the stage-A of experiment, so the settlement can be thought as the time-dependent biocompression induced by the rapid hydrolysis of the food waste and the release of the intracellular water. According to the C'_α model (Hossain and Gabr, 2005), the C'_α obtained for the biocompression in stage-A of Cell 1 was 0.054, that was closed to the $C'_{\alpha M}$ (0.020~0.056) calculated by Bareither (2012) based on laboratory compression experiments with different type MSWs.

The leachate production of MSW in Cell 1 was shown in Figure 1(e). From 0 to 60 day, the accumulated leachate production accounted for 87.33% of the totel leachate production (56.472 L). It indicated that at the beginning of degradation the settlement was affected directly by the leachate production.

The measured saturated permeability was shown in Figure 2. By immersion/drawdown cycles, the effective porosities for Cell 1 at different time were 0.427, 0.476 and 0.442 respectively. The saturated permeabilities were 1.67×10^{-4}m/s, 3.18×10^{-4}m/s and 2.15×10^{-4}m/s respectively. The gas permeability decreased from 5.06×10^{-11}m^2 to 6.04×10^{-12}m^2, while the degree of saturation varied from 38% to 66%.

4. Conclusions

In pilot-scale MSW model experiments, the following observations were found:

1) Under anaerobic environment without vertical additional stress, three successive stages of bio-degradation for Cell 1 can be observed during the first 200 days: aerobic (0~11 d, not sealed for Cell 1), acidogenesis (12~105 d,with pH≈6.0, CO_2≥25%, CH_4≤40%), acetogenesis (105 ~200 d, with pH↑, 45%＞CO_2＞20%, 60%＞CH4 ＞40%).

2) It indicated that at the beginning of degradation the settlement was affected directly by the leachate production;

3) The saturated permeabilities for Cell 1 ~ 3 were 1.67×10^{-4}m/s, 3.18×10^{-4}m/s and 2.15×10^{-4}m/s respectively with the method of constant head test. The gas permeability decreased from 5.06×10^{-11}m^2 to 6.04×10^{-12}m^2, while the degree of saturation varied from 38% to 66%.

Acknowledgment

Financial support for this work was provided by the National Basic Research Program of China (973 Program) via Grant No.2012CB719801 & No.2012CB719802.

Reference

[1] Chen Y. M., Zhan L. T., Xu X. B., Liu H. L. (2013). Geo-environmental problems in landfills of MSW with high organic content. In Proc., 18th int. conf. on soil mechanics and geotechnical engineering, Paris, France (Vol. 1, pp. 3009-3012).
[2] Wall D. K., Zeiss C. (1995). Municipal landfill biodegradation and settlement. Journal of Environmental Engineering, 121(3), 214-224.
[3] Hossain M. S., Gabr M. A., Barlaz M. A. (2003). Relationship of compressibility parameters to municipal solid waste decomposition. Journal of Geotechnical and Geoenvironmental Engineering.
[4] Reddy K. R., Gangathulasi J., Parakalla N. S., Hettiarachchi H., Bogner J. E., Lagier T. (2009a). Compressibility and shear strength of municipal solid waste under short-term leachate recirculation operations. Waste Management & Research, 27(6), 578-587.
[5] Reddy K. R., Hettiarachchi H., Parakalla N. S., Gangathulasi J., Bogner J. E. (2009b). Geotechnical properties of fresh municipal solid waste at Orchard Hills Landfill, USA. Waste Management, 29(2), 952-959.
[6] Bareither C. A., Benson C. H., Edil T. B. (2012). Compression behavior of municipal solid waste: immediate compression. Journal of Geotechnical and Geoenvironmental Engineering, 138(9), 1047-1062.
[7] Hossain M. S., Gabr M. A., Asce F. (2009). The effect of shredding and test apparatus size on compressibility and strength parameters of degraded municipal solid waste. Waste management, 29(9), 2417-2424.
[8] Beaven R. P. (2000). The hydrogeological and geotechnical properties of household waste in relation to sustainable landfilling. (Doctoral dissertation, University of Southampton).
[9] Ivanova L. K. (2007). Quantification of factors affecting rate and magnitude of secondary settlement of landfills. (Doctoral dissertation, University of Southampton).
[10] Olivier F., Gourc J. P. (2007). Hydro-mechanical behavior of Municipal Solid Waste subject to leachate recirculation in a large-scale compression reactor cell. Waste Management, 27(1), 44-58.
[11] Reddy K. R., Hettiarachchi H., Parakalla N., Gangathulasi J., Bogner J., Lagier T. (2009c). Hydraulic conductivity of MSW in landfills. Journal of Environmental Engineering, 135(8), 677-683.
[12] Hossain, M. S., Gabr, M. A. (2005). Prediction of municipal solid waste landfill settlement with leachate recirculation. In Proceedings of the Sessions of the Geo-Frontiers 2005 Congress. Austin, Texas, USA: ASCE.