Large scale plate loading tests of refuse soil

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Abstract. Refuse is a type of soil composed of domestic waste and filling soils. The chemical components of the refuse is extremely complex, and the mechanical parameters of the refuse is dependent on the local economic development, customs, climatic conditions and geological condition. In this condition, the field tests is required to obtain the mechanical parameters of the refuse. In this study the large scale plate loading tests were carried out on the refuse soils at the garbage landfill of China International Garden Flower Expo at Wuhan. Based on the tests results the influence sphere of refuse soil under 1200T is obtained. The tests results can provide reference and guidance for the similar projects.

1. Introduction
With the rapid development of economy, the continuous improvement of people's living standards and the change of life style, the amount of municipal solid waste (MSW) has increased dramatically. Many early simple landfills have already reached the designed landfill scale after years of operation. At the same time, the scale of the city continues to grow, the construction land is becoming increasingly tight, and the people's needs for the environment and other aspects are increasing in the new era. The landfill that has been saturated or overloaded is included in the urban construction planning land, and it is extremely urgent to reuse the sealed landfill. This requires in-depth study on the physical, chemical and mechanical properties of landfill waste soil.

Rubbish refers to the new special soil which is formed by mixing the municipal solid waste dumped in the landfill every day and its covering fill. The physical and chemical composition of these garbage soils is very complex, and is influenced by many factors such as local economic development level, customs, climatic conditions and geological conditions. Under normal circumstances, the content of organic matter is very high, and different degrees of physical, chemical and biological reactions occur with the length of garbage exposure time or landfill time.

At present, more and more in-depth researches have been made on the engineering properties of garbage soil, mainly focusing on the specific gravity, porosity, degradation of organic matter, gas and liquid production, settlement of garbage dump, indoor and in-situ mechanical properties of garbage soil, etc. [1-15]. However, due to the particularity of waste soil, there are great differences among different places, so it is necessary to conduct independent experimental research for each landfill. However, the tests done by predecessors are basically indoor tests. At present, there is no research on large-scale in-situ tests on garbage soil. There are many problems in indoor tests, such as sampling disturbance and size effect. Therefore, large-scale field tests will help to study the properties of garbage soil more...
accurately and deeply. In this paper, combined with the actual situation of Wuhan Expo project, in-situ field load test simulates the actual loading conditions of garbage soil, and makes exploratory research on its comprehensive stress and deformation characteristics, in order to provide reference and guidance for the design and construction of similar projects.

2. Testing program
The 10th China International Garden Expo, hosted by Wuhan, is located at the intersection of the ecological inner ring and Fuhe Green Wedge in the ecological framework of "two axes and two rings, six wedges and multiple corridors" in Wuhan. It is located in the west section of Zhanggongdi City Park under construction and the original site of Jinkou Garbage Dump. Jinkou domestic garbage dump covers an area of 768 mu, and engineers and technicians plan to adopt the world's advanced oxygen-consuming degradation technology to treat it without pollution. After the treatment, it will become a "pure land" without peculiar smell and sewage. After the treatment is completed, fill soil will be piled on the garbage soil to form the site of the 10th International (Wuhan) Garden Expo, and the waste land will be turned into treasure land. In order to understand the mechanical characteristics of garbage dump area, it is recommended to carry out large-scale plate load test with the load plate size of 6m×6m after expert argumentation. With the increase of loading, the depth of its stress is deepened, so as to truly understand the comprehensive stress and deformation characteristics of garbage soil.

In the load test, a series of in-situ tests and deformation monitoring were carried out. Five layered settlement holes, four deep displacement measurement holes and 16 surface deformation indicators were arranged at each load test point, and their arrangement is shown in figure 1.

Figure 1. Schematic diagram of monitoring point layout.
3. Test result analysis

3.1. P–S curve of measuring point

The P–S curve of deformation measuring point on large plate in plate load test is shown in figure 2. It can be seen from the Fig. that the settlement at the center of the plate is the largest, and the settlement deformation at the four horn points is the smallest. Through P–S curve, it can be concluded that the characteristic value of bearing capacity of garbage soil is 267kPa and the deformation modulus is 3.4MPa.

![Figure 2. P–S curve of large load plate.](image)

(Note: Horn 1: southwest corner; Horn 2: southeast corner; Horn 3: northeast corner; Horn 4: Northwest Corner)

3.2. Surface subsidence deformation

The surface settlement and deformation curves of the east and west sides of the large plate are shown in Fig. 3, and the surface settlement and deformation curves of the north and south sides are shown in Fig. 4. It can be seen that the greater the load, the greater the settlement and deformation of foundation soil. When the load reaches 333.33kPa, the settlement deformation is close to 0, and the deformation is very small. At a distance of 7m from the load center, the settlement deformation is 9~17mm, and the settlement deformation is small. Based on this analysis, the deformation influence depth is 4~6m around the load plate.

![Figure 3. Settlement curve of foundation soil surface in east-west direction.](image)
Figure 4. Surface settlement curve of foundation soil in the north-south direction.

3.3. Inclinometer curve
Inclinometer pipes are buried on both sides of the large plate, and the depth of the inclinometer pipes exceeds the depth of the garbage soil layer. Data are collected according to one test point per m. See Fig. 5 for the inclinometer curves of E1, E2, W1 and W2. It can be seen from the inclinometer curve that under the same load, the horizontal displacement at the depth of 3m is the largest. The depth is 12~15m, the horizontal displacement is almost zero, and the depth of deep horizontal deformation is 12m.
3.4. Layered settlement and deformation
The layered settlement deformation curve of foundation soil around the center of large load plate is shown in Fig. 6. It can be seen that the maximum settlement of plate center is about 400mm, 180mm at 5m, 23mm at 7m, 128mm at 5m, 15mm at 7m. The influence depth of plate center deformation is about 12m, and the influence depth of plate periphery deformation is about 10m.
4. Application of test results
Duishan is a large area of heaped load, so the settlement is calculated by the method of unidirectional compression layered summation. The additional stress of foundation soil and the corresponding settlement are caused by the dead weight of Duishan. The calculation depth of foundation settlement can be d
determined by the ratio of vertical additional stress to the dead weight of soil. For general cohesive soil, when the ratio of additional stress to deadweight stress at a certain depth of foundation is not greater than 0.2, the depth is the calculated depth of foundation settlement. For soft clay, the thickness of compression layer is determined on the basis that the ratio of additional stress to dead weight stress is not more than 0.1. The Code for Design of Building Foundations (GB50007-2011) stipulates that the calculation should be continued when there is still soft soil layer at the lower part of the calculation depth. For this project, the relatively soft layer at the lower part of the formation in the heaped mountains area of Yuanbo Fair is the clay layer, and the compressive modulus of the gravel and the soil below it is high, and the settlement caused by heaped mountains is small, accounting for about 1% of the total settlement, which can be ignored. Therefore, the calculation depth is determined to the bottom of attending layer of soft soil.

For the settlement of foundation soil caused by the dead weight of heaped mountains, the layered summation method has certain errors, which need to be corrected. For the value of settlement correction coefficient, the analogy method of test value and calculated value is adopted.

For large-scale flat plate load test, the load plate adopts stepped integral cast-in-place concrete slab, with the area of the lower layer of 6m×6m and the thickness of 0.5m. According to the P–S curve of large-scale load plate test, the maximum value of heaped mountains is 15m, the filling weight of heaped mountains is 18.5kN/m³, and the overlying load is 278kPa. It can be seen from the P–S curve that under the action of 280kPa, the settlement at the center point of the corresponding settlement plate is 420 mm.

Using Lizheng geotechnical calculation software, the foundation size is 6m×6m, and the actual settlement calculation depth is 8.5m under the same geological conditions. When the settlement empirical coefficients are taken as 1.0 and 1.2, the calculation results are shown in Fig. 7. It can be seen that when the settlement empirical coefficient is 1.2, it is close to the load test value of large flat plate. Based on this, the settlement correction coefficient can be determined to be 1.2.
When the empirical coefficient of settlement is taken as 1.2, the maximum settlement in the main peak area (the height of heaped mountains is 15m) is 1788mm. This settlement analysis does not consider the self-degradation of garbage soil and the settlement caused by the landfill treatment of garbage soil, but only studies the settlement of garbage soil foundation caused by the large-area heaped mountain fill.

5. Conclusions
(1) When the deep soil at the bottom of the loading plate is loaded to 1200t, the deformation influence depth can reach about 10m.
(2) When the soil around the load plate is loaded to 1200t on the load plate, the deformation influence range can reach 4m ~ 5m around the plate, and the settlement is the main one without uplift.
(3) When the deep soil around the loading plate is loaded to 1200T on the loading plate, the deformation influence range can reach 3m~4m around the plate, and the influence depth decreases sharply with the increase of the plate edge distance.
(4) Under the upper load, the influence depth of garbage soil is deepening. Under the load of 1200T, the settlement can reach about 65cm, and the surrounding soil has no uplift deformation.

References
[1] JU Hong-yue, YIN Jun, ZHANG Wen-long. Research on plate loading test of soft soil foundation’s loading capacity under overload effect [J]. Shanxi Architecture, 2010, 36(20): 73-74.
[2] LEI Hua-yang, LI Hong-qf, WAN Zi-rui. Analysis of Field Test on a Large Construction Waste Accumulation [J]. Journal of Tianjin University, 2006, 39(11): 1310-1315.
[3] Wei Yuhang. Study on mechanical properties and constitutive model of Chengdu municipal solid waste soil[D]. Chengdu: Xihua University, 2016.
[4] Beaven., Richard., Powrie., et al (1996) "Determination of the hydrogeological and geotechnical properties of refuse in relation to sustainable landfill Municipal and Industrial Waste.". Proceedings of Annual Madison Waste Conference. University of Wisconsin-Madison/Extension, Madison, WI, USA, P 435-445.

[5] Liu Fengjun. Experimental study on the rubbish soil foundation of a simple waste landfill [D]. Shanghai: Tongji University, 2002.

[6] Yan Shu. Research on engineering properties of garbage soil[D]. Wuhan: Wuhan Institute of Rock and Soil Mechanics, Chinese Academy of Sciences, 2004.

[7] Ke Qiuju. Laboratory experimental research on engineering properties of waste soil and conceptual optimization design of zoning landfill [D]. Quanzhou: Huqiao University, 2010.

[8] JIANG Shan-chao, WEN Song-lin, REN Jia-li. Bearing Behavior of an Aged Municipal Landfill in Wuhan[J]. Soil Eng. And Foundation, 2016, 30(2):161-163.

[9] YAN Shu, WU Wen, XU Song-lin, FENG Qi-lin, BAI Si-wei. Study of deformation curve of municipal domestic refuse in Wuhan [J]. Rock and Soil Mechanics, 2004, 25(12):2017-2022.

[10] XIE Qiang, ZHANG Yong-xing, ZHANG Jian-hua. Experimental Study on the Compressibility of Stale Waste[J].Journal of Chongqing Jianzhu University, 2003, 25(4):18-22.

[11] Gao Wen-yin, Tu Fan, Xiao Zhao-yun, Ke Qiu-ju, Xie Zhong-ming. Experimental study on repeated direct shear of municipal solid waste from different depth of landfill [J]. Chinese Journal of Environmental Engineering, 2010, 4 (5):1171-1176.

[12] ZHANG Bing-yin, JIE Yu-xin. Strength and deformation characteristics of municipal solid wastes [J]. Engineering Mechanics, 2006, 23:14-22.

[13] LUO Xing-wen, YANG Ming-liang, YAO Hai-lin, GU Zhi-meng. Experimental study on engineering mechanical properties of stale refuse [J]. Chinese Journal of Geotechnical Engineering, 2006, 28(5):622-625.

[14] LIU Rong, SHI Jian-yong, PENG Gong-xun. Experimental studies on mechanical behavior of refuse samples [J]. Rock and Soil Mechanics, 2005, 26(1):108-112.

[15] LI Xiu-lei, LI Jin-feng. A study of deformation and strength properties and stress-strain model for municipal solid waste (MSW)[J]. Hydrogeology & Engineering Geology, 2016, 43(5):70-86.