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Test Equipment and Application of Compression Properties of MSW

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ABSTRACT: In order to study the compression characteristics of municipal solid waste (MSW), a set of test device was independently developed. Five kinds of loading methods were analyzed, and the physical loading method using two levels of levers was selected. The experimental methods and operation process of the device were introduced. The laboratory test of compression characteristic of MSW by using self-developed device was carried out. Test application results show that the device can realize all pre-designed functions, and have the advantages of convenient operation, stable loading and small occupied floor space. As the stress is 100 kPa, 200 kPa, 300 kPa, 400 kPa, the strain of MSW is 42.4%, 49%, 54.1% and 59.25% respectively. The compression amount of the first 6 days reaches about 80% of the total compression. The compression amount of the pre-test specimen increases with the increase of the pressure, while the deformation rate of the later stage decreases. The instantaneous strain of MSW is basically linear to the pressure. The research results enrich the experimental equipment for studying the compression characteristics of municipal solid waste so as to provide data support for the subsequent research on the settlement model of landfill.

KEYWORDS: MSW, Compression properties, Test equipment, Laboratory test.

1. INTRODUCTION

Sanitary landfill is a comprehensive and effective way of dealing with MSW because of its simple operation, large capacity, low investment (Chen et al., 2009, Zhang et al., 2010, Tinet and Oxarango, 2010).The deformation settlement of MSW is great significance for the design, construction and operation of landfill (Fei and Zekkos, 2013), which is one of the main environmental geotechnical engineering problems involved in landfill (Babu et al., 2011).Landfill settlement research may provide a scientific basis for the prediction of landfill volume, increase of storage capacity, failure of cover-covering system cracking, design and maintenance of gas-liquid drainage system and site reuse (Hettiarachchi et al., 2007, Elagroudy et al., 2008, Liu et al., 2011).

The compression characteristics of MSW are significantly different from that of normal soil (Hettiarachchi et al., 2009). At present, many scholars have independently developed experimental instruments and carried out relevant research. Xie et al.(2007) used self-made creep compression tester to study the creep characteristics of MSW by loading respectively, which the sample diameter is 100 mm and the height is 235 mm. Chen et al.(2009) developed a solid waste compression tester which is composed of a cylindrical compression chamber, compression observation, data processing systems, loading platforms, concrete blocks and other components. Most of the above literature choose to use stack-loading method, which the pressurization operation is troublesome. When the load is larger, the weight or concrete block is added excessively, and the concrete block is prone to tilt. As a result, the stress on the specimen may be uneven and the accident may occur. What's more, the creep model of MSW is still needs to be developed.

The main contents of this study comprise the following three parts: (1) summarized the disadvantages of the equipment introduced in the above literature, and developed a set of test equipment for MSW compression characteristics independently; (2) introduced the construction, loading method, technical parameters, test method of the self-developed compression equipment; (3) carried out the laboratory test of compression characteristics of MSW, and discussed the change rule of deformation of MSW.

2. INTRODUCTION TO TEST EQUIPMENT

Both MSW and soil have typical solid, liquid and gas phases composition, but MSW itself has significant difference of organic matter degradation. The settlement of MSW consists of physical and mechanical compression, mechanical creep and organic matter degradation (Babu et al., 2010). Therefore, the compression apparatus of MSW should have the function of pressurization, sealing and gas-liquid collection. The methods of sealing and gas-liquid collection are similar, and the main difference is the way that the sample is pressurized.

2.1 Loading Method

The following several pressurized ways of test apparatus are considered: 1) oil pressure system, using manual pressure pump and voltage stabilizer. But the method of oil pressure system has the disadvantages of difficult pressure regulation control, expensive voltage stabilizer and excessively high equipment cost. 2) air pressure system, which it is realized by the combination of air compressor and pressure regulating valve. But the method of air pressure system has the shortcoming of not being able to power off. 3) jack and counterforce stents and holding ring, which is a passive loading method. The load is transferred to the MSW sample by the reaction device using the oil pressure of the jack. It is difficult to operate and is not suitable for long-term pressure. 4) heap load type pressurization, which is difficult to operate. When the load is large, too many weights or concrete blocks are added, and incline and safety accidents are easy to occur. 5) leverage, poise and screw jack combination, which the load to the sample is applied by using the lever principle, and the screw jack is used to adjust the lever balance.

Comparing the advantages and disadvantages of the five loading methods, the fifth loading method is finally chosen. The main reason is that the fifth loading method does not exist the disadvantage of power and pressure is difficult to control, which is based on the perspective of physics pressure. What's more, the cost of equipment production is relatively low, and can avoid the sample as the compression quantity too ambassador tilt lever.

2.2 Test Equipment

The schematic diagram of the self-developed compression creep test device is shown in Figure 1. The device consists of sample tube, pressure and balance system, sealing system, gas collection system, leachate collection and irrigation system, etc. The entity drawing of the test equipment is shown in Figure 2.

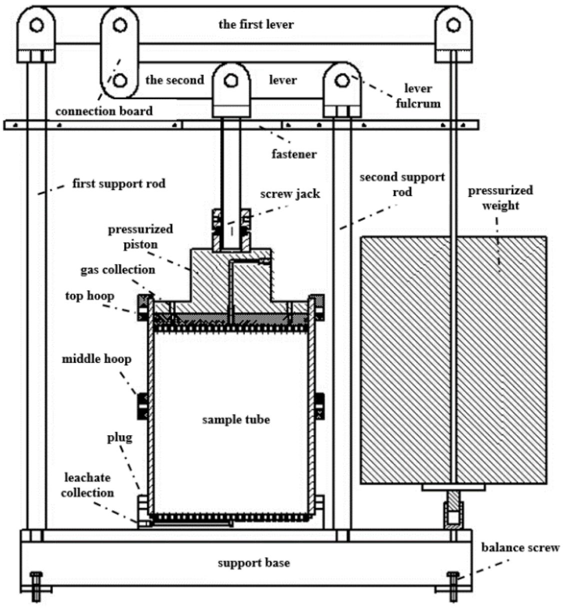

Figure 1 Compression instrument of MSW

Figure 2 Entity drawing of the test apparatus

2.3 Technical Parameters

The main technical parameters and the functions of each component are as follows.

The internal diameter of sample tube is 250 mm, height is 300 mm. Sample tube can provide a relatively sealed anaerobic environment for the MSW sample. The material for the sample tube is stainless steel. Although 316L stainless steel material has the advantages of strong corrosion resistance and high compressive strength, it is not chosen because of the disadvantages of expensive and difficult processing. The design drawing of sleeve is shown in Figure 3.

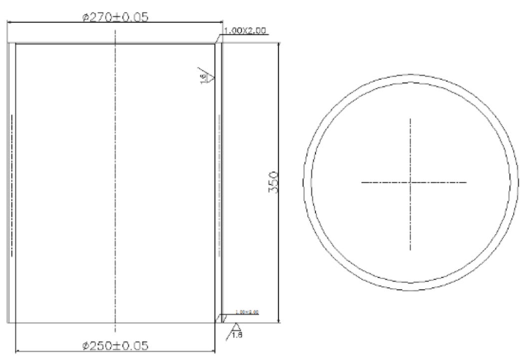

Figure 3 Design drawing of sleeve

Pressure and balance system is composed of two lever, weight, screw jack and pressurized piston. The leverage ratio at the first level is 1:5, and the second lever ratio is 1:2. The lab space can be saved through the two lever ratio of this loading method. The lower part of the first support rod and the second support rod is connected with the base of the support bracket by screws, and the upper part is respectively screwed with the first lever and the second level. The first support rod and the second support rod are made of 45# steel, and the materials used for the first-stage and second-stage levers are 20 mm thick 45# steel plate. The weight is converted to the quality of each piece by means of the load/pressure applied. The vertical load can be calculated by the leverage principle and the area of the sample.

Pressurized piston seals the top of the sleeve by O-ring seal to ensure that the sample tube is not leaking air and no water leakage. Pressurized piston reserved the outlet hole for gas collection and leachate recycling. Nylon is used as the pressurized piston material because of its convenient drilling operation, cheap, good corrosion resistance and have a certain strength. Vertical load can be applied to the specimen by the screw jack on the groove of the pressure piston. The screw jack consists of a thrust ball bearing, a screw rod, a handle, a base, a top pad. The main functions of screw jack are to transfer the load provided by the lever to exert vertical pressure on the sample and adjust the lever balance during the experiment. Where in the bearing is a connecting part of the upper and lower screw sleeves to reduce the friction when rotating, and the handle can save labor when rotating the screw sleeve. The design drawing of pressurized piston is shown in Figure 4.

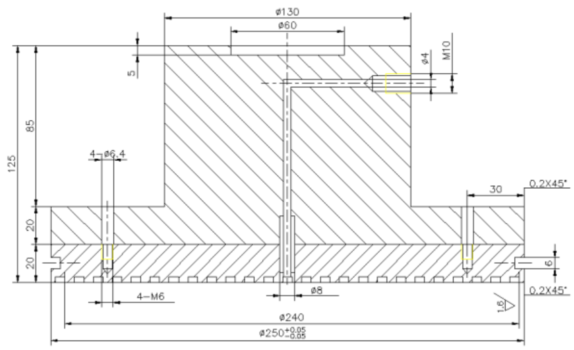

Figure 4 Design drawing of pressurized piston

The top hoop and the middle hoop can prevent lateral deformation and ensure that the specimen is deformed only in the vertical direction.

The top filter plate can be used to collect the gas generated by the sample under anaerobic conditions, and the vertical pressure can be transmitted evenly to the specimen. The leachate produced by the sample is collected through the perforated hole of the bottom filter board. The material of the filter plate is stainless steel. The design drawing of filter plate is shown in Figure 5.

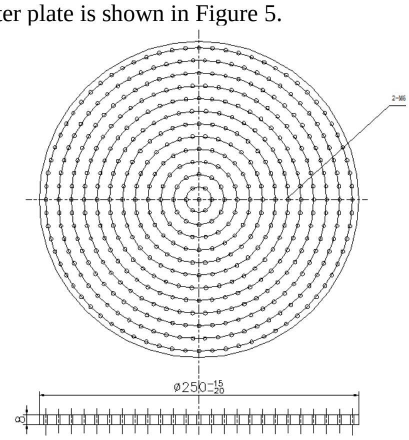

Figure 5 Design drawing of filter plate

The function of the bottom plug is to support the sleeve and fix it with the support base. The material of the bottom plug is stainless steel. The design drawing of bottom plug is shown in Figure 6.

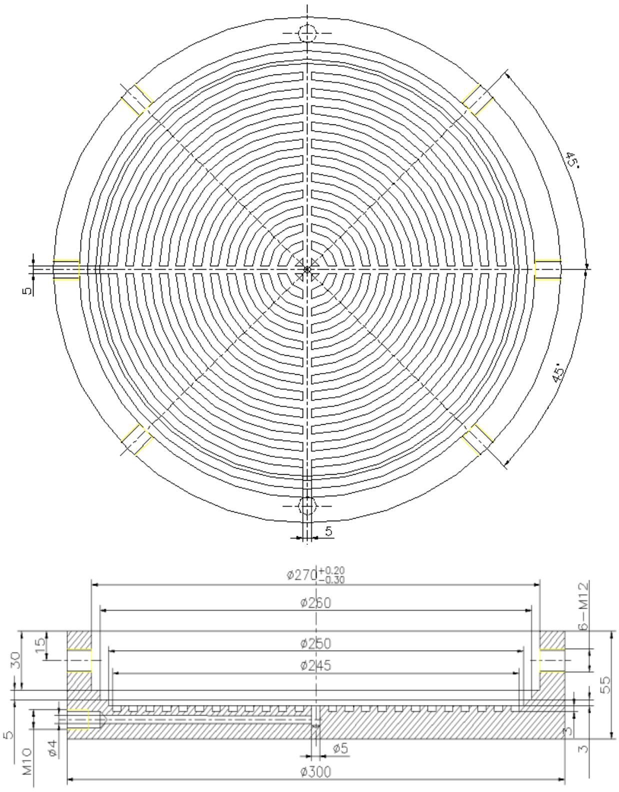

Figure 6 Design drawing of the bottom plug

The fastener is made of stainless steel, which can hold two support rods to prevent the stiffness of the support rod from being too high, and to avoid the support rod horizontally tilt due to excessive pressure. The design drawing of the fastener is shown in Figure 7.

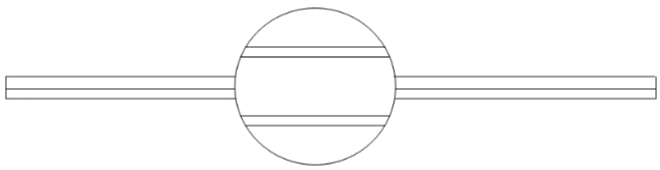

Figure 7 Design drawing of the fastener

3. LABORATORY TEST APPLICATION

3.1 Test Materials

The test materials are artificial, and the sample components and proportions are shown in Table 1. The physical properties of the MSW samples are shown in Table 2. The particle size of each component was artificially broken to less than 4 cm.

Table 1 Composition of waste samples

Composition	Kitchen waste	Muck	Paper	Plastic	Fabric	Wood
Ratio/%	50	26	15	3	3	3
Weight/kg	6.07	3.31	0.66	0.33	0.17	0.17

Table 2 Physical properties of waste samples

Moisture content	Wet density	Dry density	Void ratio	Organic matter
54.6%	0.9 g/cm^3	0.582 g/cm^3	2.196	57.2%

3.2 Test Method

The sample components of the waste soil were mixed evenly with the test plan, and then sealed and maintained 24h. The water of the sample was mixed evenly. Set up the sample tube and the base, and prepare the test preparation. In the sample tube, fill the sample with high layer and compaction layer by layer, and control the sample height of 250 mm.The compression creep characteristics of MSW were carried out by using separate loading methods at 100 kPa, 200 kPa, 300 kPa and 400 kPa last for 100 days. The test conditions were strictly controlled to minimize the influence of external factors on the test. Gas and leachate of samples in each phase were collected and the data of compression amount were recorded.

4. RESULTSANDANALYSIS

4.1 The Relationship between Strain and Stress

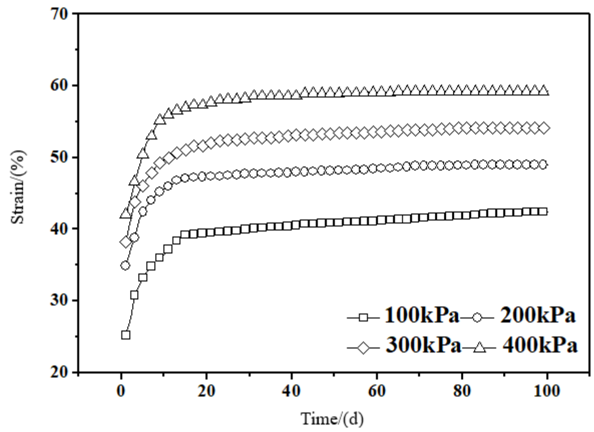

Figure 8 The strain of MSW under different pressure

From Figure 8, it could be seen that the sample compression volume of the pre-test (1~6d) was larger, which reached about 80% of the total compression volume. With the increase of vertical stress, the ultimate compression of MSW sample was 106 mm, 122.5 mm, 135.3 mm and 148.1 mm respectively, and the strain was 42.4%, 49%, 54.1% and 59.25% respectively. The greater the pressure applied, the larger the compression deformation in the early stage, but the lower the deformation rate in the later stage. This may be due to the reorganization of the pore structure, the movement and dislocation of the particles, resulting in the compression creep of the MSW sample.

4.2 The Relationship between Immediate Deformation and Stress

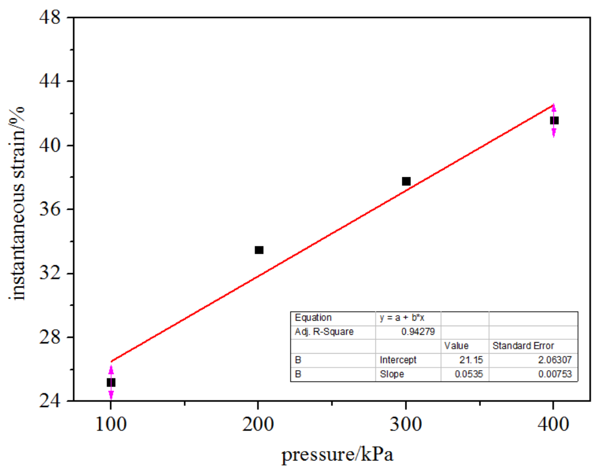

Figure 9 Change rule of porosity of MSW

It can be seen from the Figure 9 that the instantaneous strain of MSW is basically linear to the pressure.

4.3 The Relationship between Porosity and Stress

The void ratio of the sample at any time can be calculated by eq. (1).

$$e_t = \frac{(h_0 - h_t)A}{V_{st}} - 1 \quad (1)$$

In the formula, e_t is the void ratio of the sample at time t , h_0 is the initial height of the sample, h_t is the height of the sample at time t, A is the cross-sectional area of the sample, and V_{st} is the volume of solid particles in the sample at time t.

The change curve of porosity at different times of MSW sample is shown in Figure 10.

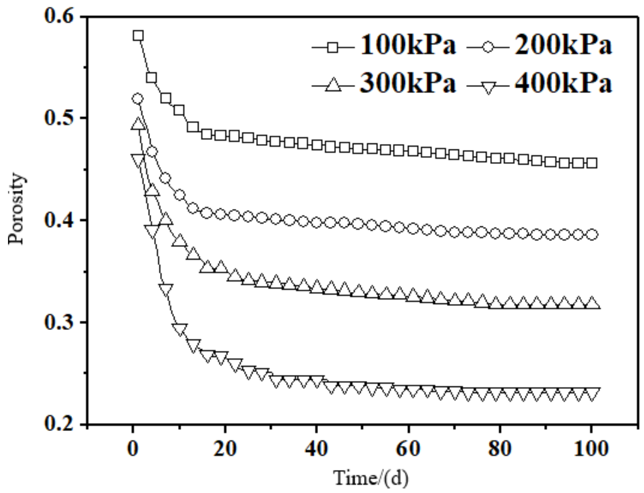

Figure 10 Change rule of porosity of MSW

As can be seen from Figure 10, the porosity variation of the sample is basically similar to that of the strain. The porosity of the sample decreases with the increase of the pressure, and decreases sharply in the early stage and gradually changes in the later stage. With the increase of pressure, the porosisty is 0.457, 0.386, 0.318 and 0.232 respectively, which is 33.5%, 43.8%, 53.7% and 66.2% lower than the initial porosity.

5. CONCLUSION

The paper independently developed the compressive creep test device of MSW, carried out indoor creep property test of manually prepared garbage samples, and established the M-2K extended Burgers creep model based on the creep component characteristics. The main conclusions are as follows.

(1) Self-developed MSW compression creep test device has the advantages of convenient operation, stable loading and small area. The preliminary application results show that the instrument can meet the lab-test of creep characteristics of MSW and can provide data support for the subsequent research on the settlement model of landfill.

(2) The final strain of MSW samples were 42.4%, 49%, 54.1% and 59.25% respectively at pressures of 100 kPa, 200 kPa, 300 kPa and 400 kPa.The porosisty is 33.5%, 43.8%, 53.7% and 66.2% lower than the initial porosity.

(3) The instantaneous strain of MSW is basically linear to the pressure.

6. ACKNOWLEDGMENTS

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