A CONFIRMATION TEST RESULT OF THE MODULUS OF GROUND REACTION OF THE COVER MATERIAL FOR A LEACHATE COLLECTION FACILITY

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SUMMARY: This paper presents results of a confirmation test of the modulus of ground reaction of cover material for leachate collection pipe and drainage pipe which are installed at the bottom of waste disposal sites. To design buried pipes under large vertical load properly, it is important to confirm how much ground reaction can be expected from the cover material which has not been fully compacted. This paper presents the experimental results of a large-scale tri-axial compression test to confirm the modulus of deformation of the cover material which has not been fully compacted. As the result of study, it was found that the deformation of buried pipes was influenced by both properties of cover material and the degree of compaction. Since it is difficult to fully compact cover material in order to avoid damage to liner work, design of buried pipes should be conducted with great care for waste disposal sites with large waste height.

1. INTRODUCTION

It becomes more difficult year by year to find a new site for waste disposal sites in Japan, and thus, it becomes common to construct waste sites in valleys and mountain streams in mountainous area. At those sites, thickness of landfill layers is inevitably designed as thick as possible in order to maximize the disposable waste volume. Under these circumstances, large vertical load due to thicker waste depth can cause problems for leachate collection/drainage

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pipes (JWMA, 2001).

At waste disposal sites, leachate collection facilities are installed as a part of seepage control work and its purpose is to drain waste leachate smoothly from the bottom of waste body. Leachate collection facility consist of collection pipes and drainage pipes and cover materials, such as crushed stones or cobble stones, which are laid around those pipes for protection. Recently, because of its easy handling and connectivity, it becomes common to use high density polyethylene pipes for the leachate collection pipe and drainage pipes. The strength of these flexible conduits relies on the restriction of their deformation by the ground reaction from cover material. However, since cover materials could not be fully compacted to avoid damages to liner work, horizontal reaction for those pipes may not provide sufficient restriction for them.

In this study, we conducted some laboratory tests in order to confirm how much ground reaction can be expected from cover material (crushed stone) which has not been fully compacted. Firstly, density tests were conducted in order to confirm how density of cover material is chnaged depending on different laying methods of the material. Density test specimens were prepared by putting crushed stones into test mould by free-falling from different height so that those specimens have different degrees of compaction. Secondly, large-scale tri-axial compression test was conducted using several specimens under K_0-pressure (hereafter, referred as K_0-compression test). The compression test specimens were conducted using specimens having different degrees of compaction based on density test results.

We also discuss design approach for buried pipes under large waste load based on the laboratory test results.

2. TEST METHODS

2.1 Material Properties

M-40 single-sized crushed stone, which is commonly used as cover material for bottom pipes at waste disposal sites, was used for laboratory test. Particle distribution curve of M-40 crushed stone is presented in Figure1.

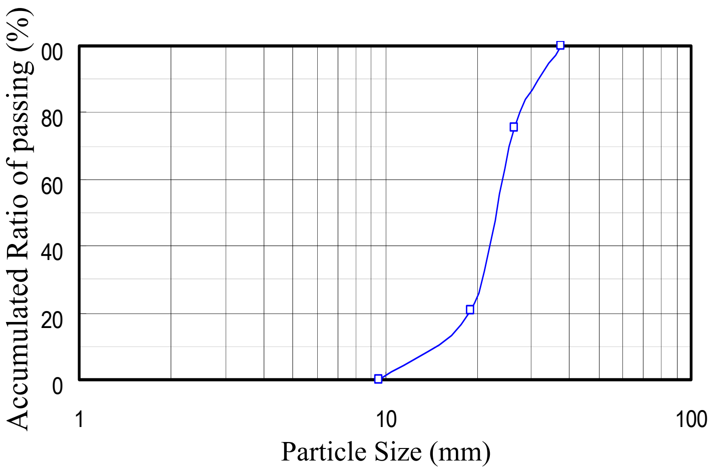

Figure 1. Particle Size Distribution of M-40 crushed stone

2.2 Density Test

2.2.1 Minimum and Maximum Density Test

Minimum density of M-40 crushed stone was obtained by ‘scoop method’. Materials were settled into ϕ30cm-mould by handy scoop (See Figure 2) and its hegight was measured. Measurement was conducted ten times and average density was regarded as ‘minimum density’.

Maximum density of the material was obtained by compacting the material using vibrator. M-40 crushed stone was put into ϕ30cm-mould. Vibrator was applied for 600 seconds on the surface of every 6cm-layer of the material (See Figure 3). Measurement was conducted five times and average density was regarded as ‘maximum density’. Density was also measured for the specimen compacted by 4.5kg-rammer for comparison.

2.2.2 Density Test by Free Falling Method

Since cover material of buried pipe at the bottom of landfill site is hardly compacted in order to avoid damage to the pipe, cover material such as gravel or crushed stone is usually dropped by free falling and not compacted. Therefore, ‘free falling density test’ was conducted for M-40 crushed stone. The crushed stones were dropped into ϕ30cm-mould from different height (10cm, 30cm, 60cm and 90cm) and density was measured for each specimen. See Figure 4.

Figure 2. Minimum Density Test
(Scoop Method)

Figure 3. Maximum Density Test
(Scoop Method)

Figure 4. Free Falling Test

2.3 Large-scale Tri-axial Compression Test

2.3.1 Test Device

Large-scale tri-axial test was conducted using large-scale tri-axial compression test device shown in Figure 5 and Figure 6. Compression test was conduced under K_0-condition, i.e., axial strain was controled so that no radial deformation is caused during the test.

2.3.2 Test Conditions

Conditions for large-scale tri-axial compression test and measured items are shown in Table 1. Four specmens with different degree of compaction were used for the test and their initial density was set based on the results of density tests.

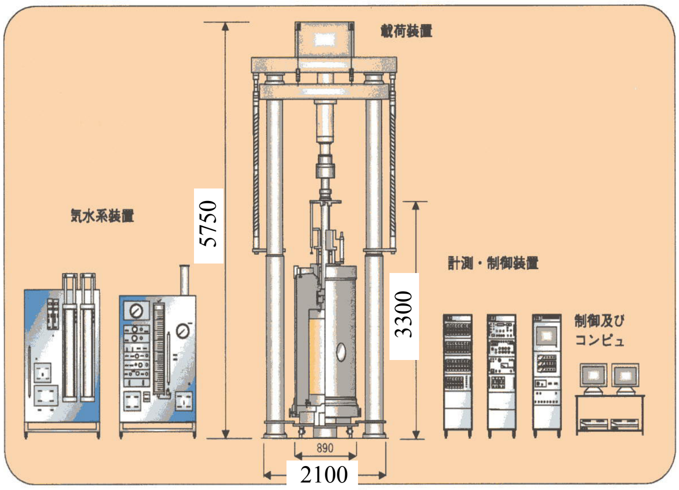

Figure 5. Large-Scale Tri-Axial Compression Test Device

Figure 6. Large-Scale Tri-Axial Compression Test Device

Table 1. Compression Test Conditions

Material	M-40 Single-sized Crushed Stone
Test Piece	ϕ300mm x h600mm
Initial Density	4 cases (set based on density test results. See 3.2.1)
Saturation	Saturated
Load	Maximum Load 1000 (kN/m^2)
Measured Items	Vertical Load Horizontal Pressure Water Pressure, Axial Displacement Volume Change

3. TEST RESULTS

3.1 Density Test

The results of minimum and maximum density tests are shown in Table 2 and the results of free falling tests are shown in Figure 7 with those results of minimum/maximum density tests. Dry density obtained by free falling test increased as falling height increased. However, when the falling height reached 90cm, particles bounced out and the density decreased.

Table 2. Results of Minimum/Maximum Density Tests

Test	Dry Density(g/cm^3)	Porosity
Minimum Density Test by Scoop Method	1.306	1.014
Maximum Density Test by Vibrator	1.678	0.567
Maximum Density Test by Rammer (for comparison)	1.722	0.527

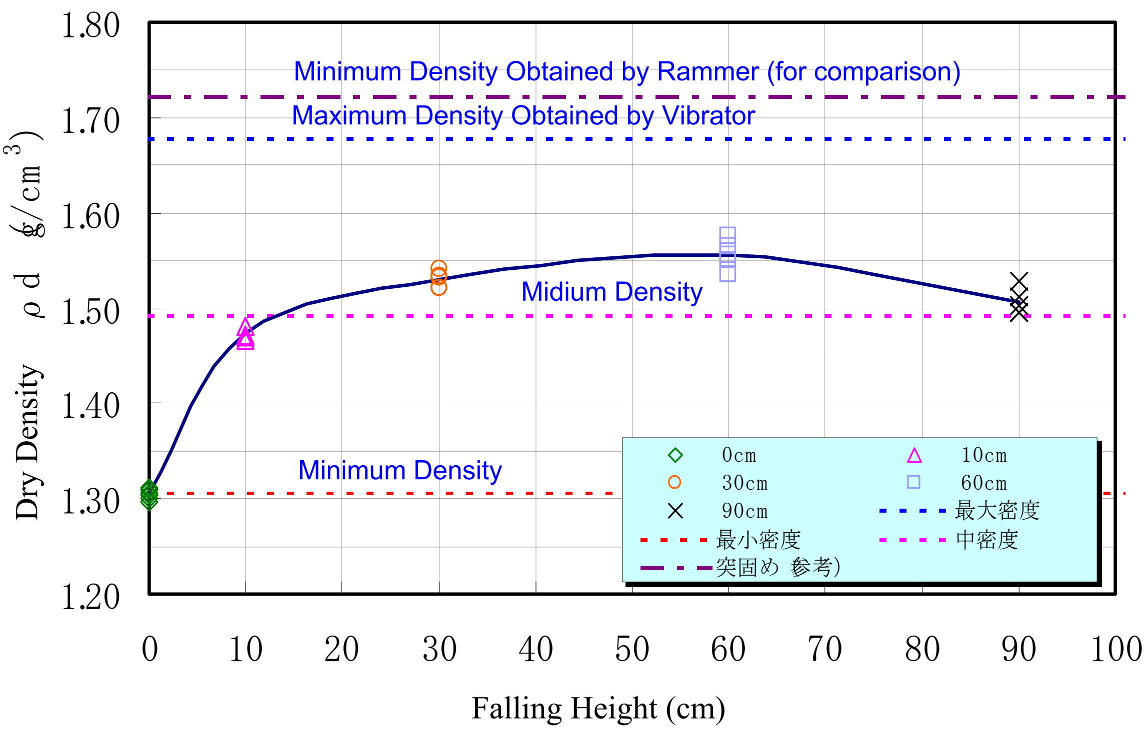

Figure 7. Relationship between Falling Height and Dry Density of M-40 Crushed Stone

3.2 Large-scale Tri-Axial Compression Test

3.2.1 Initial Density of Specimen

After free falling density test, test case for K_0-compression test was set as in Table 3 depending on three different falling heights, in turn depending on the degree of compaction (Case 1, 2 and 3). Test was also conducted for material compacted by vibrator for comparison (Case 4).

3.2.2 Relationship between Initial Dry Density and Axial Strain

The relationship between initial dry density (γd) and axial strain (ε) is shown in Figure 8.

Table 3. Test Case for K_0-compression test

Test Case	Dry Density (g/cm^3)	Void Ratio E	Relative Density Dr(%)	Degree of Compaction (%)
Case 1 (Falling Height = 0cm)	1.356	0.940	16.5	80.8
Case 2 (Falling Height = 10cm)	1.501	0.752	58.6	89.5
Case 3 (Falling Height = 60cm)	1.556	0.679	75.0	93.3
Case 4 (Compacted by Vibrator)	1.631	0.613	89.9	97.2

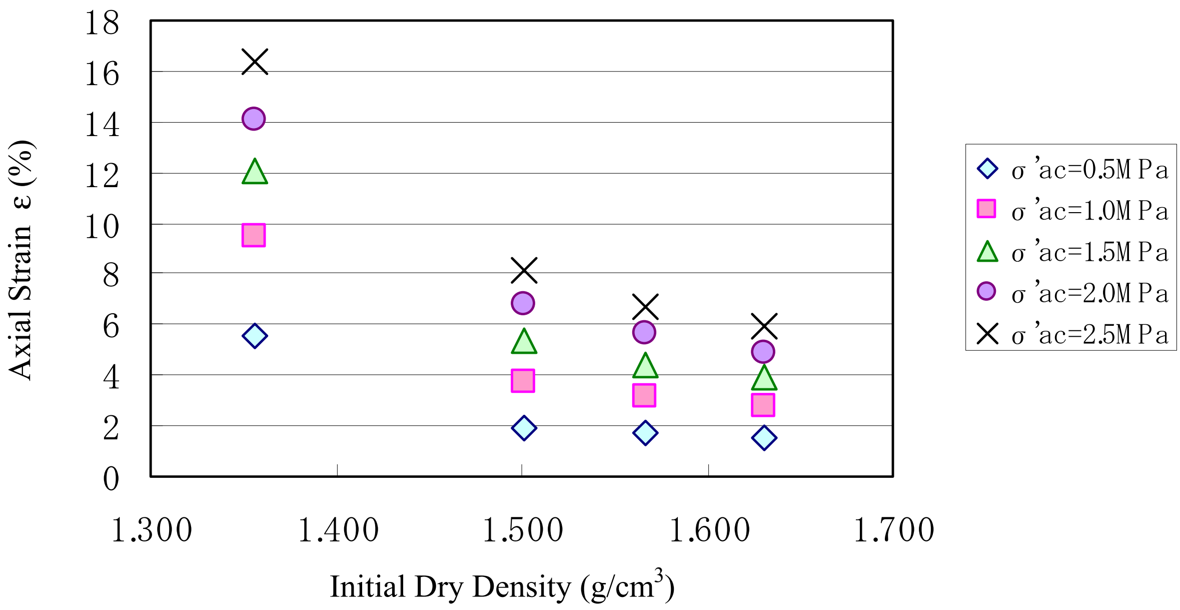

Figure 8. Relationship between Initial Dry Density and Axial Strain

3.2.3 Relationship between Initial Dry Density and K_0 Coefficient

The relationship between initial dry density (γd) and K_0 coefficient is shown in Figure 9.

3.2.4 Relationship between Initial Dry Density and Modulus of Deformation

The relationship between initial dry density (γd) and modulus of deformation (Es), which was obtained by K_0-compression test, is shown in Figure 10. Measured modulus of deformation tends to linearly increase with initial dry density and the largest measured modulus was four times larger than the smallest depending on the degree of compaction.

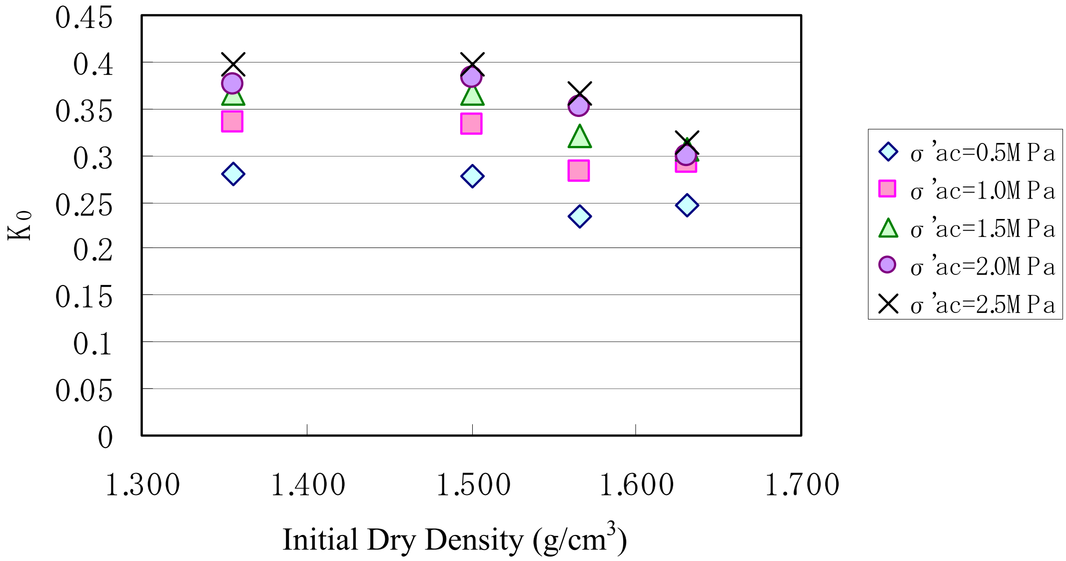

Figure 9. Relationship between Initial Dry Density and K_0 Coefficient

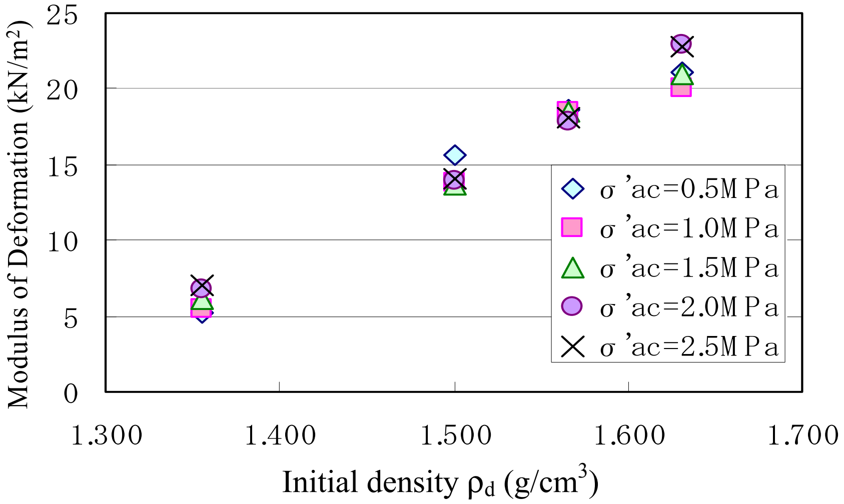

Figure 10. Relationship between Initial Dry Density and Modulus of Deformation

3.2.5 Degree of Compaction and Modulus of Deformation

The relationship between the degree of compaction and modulus of deformation of the material (M-40) is shown in Figure 11 with Tohda's test data for crusher run (C-40). Modulus of deformation of M-40 is smaller compared with that of C-40.

4. DISCUSSION : APPLYING TEST RESULTS TO DESIGN OF BURIED PIPE

Conventionally, flexible pipe such as high-density polyethylene pipe is designed based on Marston's theory, which estimate vertical load of soil column above pipe, and Spangler's theory, which calculate deflection of buried pipe under vertical load. These theories can be applied in case that the height of soil column, i.e., waste depth is 7 to 30m, depending on properties of the pipe, but there exists no specific design method for soil column larger than 30m.

Tohda et al. recently propsed a calculation method of deflection of buried collection pipes or drainage pipes under vertical load caused by large waste height (Tohda et al., 2002). His proposal is based on FEM analysis and experimental results under high pressure condition obtained by centrifuge model test. Design approach for buried pipes under load caused by large waste height proposed by Tohda et al. (2002) is presented in flowchart in Figure 12.

In this study, we used Tohda's method to calculte strain of burried high-density polyethylene pipe under different ground reactions which were set based on the results of tri-axial compression test. The calculation results are shown in Figure 13. It can be observed that strain ratio is large when the degree of compaction is low. In addition, strain ratio of pipes buried in M-40 is larger than that in C-40.

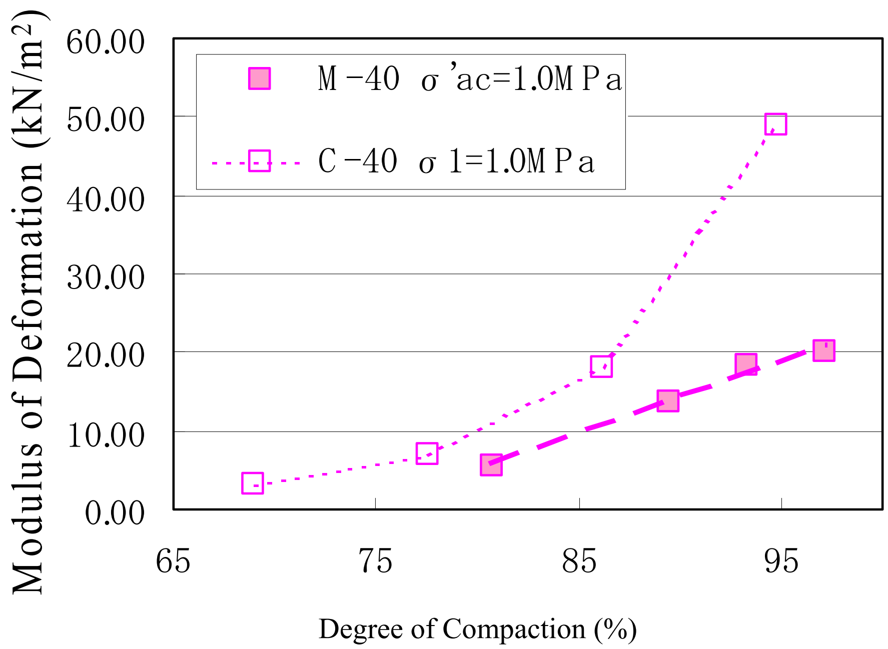

Figure 11. Relationship between Degree of Compaction and Modulus of Deformation

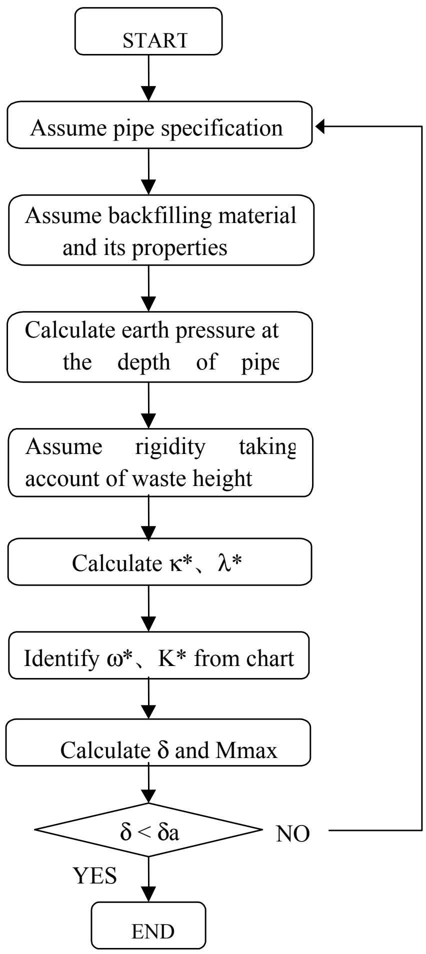

Figure 12. Design Approach for Buried Pipes under Load Caused by Large Waste Height

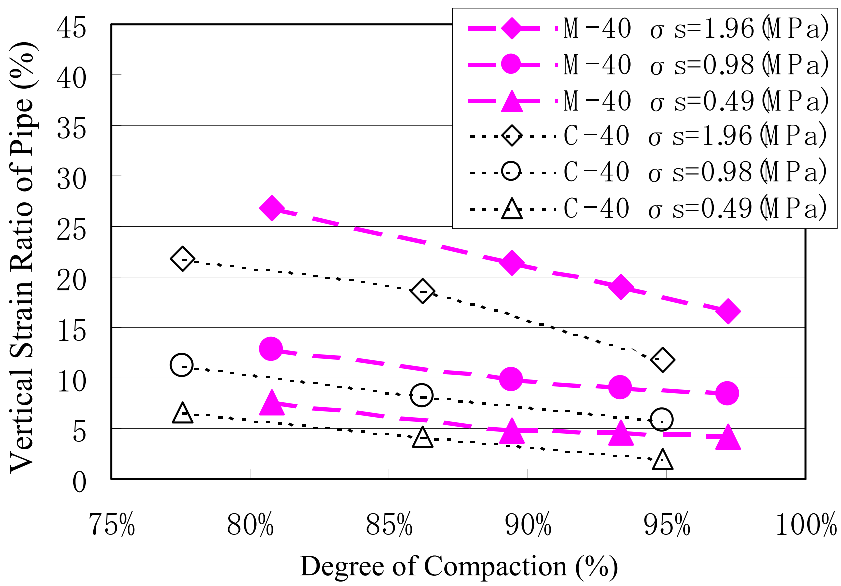

Figure 13. Relationship between Degree of Compaction of Cover Material and Strain of Pipe

In most cases, allowable vertical strain ratio is set as 10 to 15% for high-density polyethylene pipes and similar pipes (e.g., Mitsui Chemical Sanshi Co., Ltd, 1999). On the other hand, it can be read from Figure 9 that vertical strain ratio of pipe buried in M-40 could possibly exceed 10% with surcharge more than 0.98MPa, even if the degree of compaction is 97%. Assuming unit weight of waste is 17kN/m^2, the surcharge of 0.98MPa equals to waste of 59m height. Therefore, it can be said that there is possibility that the deflection of pipe could not be avoided by compaction effort in case that the waste height exceeds 50m.

5. CONCLUSIONS

As the result of large-scale tri-axial compression test, it was found that the deformation of buried pipes was influenced by both properties of cover material (e.g, the difference between C-40 and M-40 in this study) and their degree of compaction. Since it is difficult to fully compact cover material in order to avoid damage to liner work, design of buried pipes should be conducted with great care for waste disposal sites with large waste height.

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