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

Masao Kuroiwa
Environmental Technology Department, Civil Engineering Technology Division
Obayashi Corporation
Shinagawa Intercity Tower B, 2-15-2, Konan, Minato-ku, Tokyo, 108-8502 Japan

Osamu Nahata
Environmental Engineering Division, Kokusai Kogyo Co., Ltd.
5 sanbancho, Chiyoda-ku, Tokyo, 102-0075 Japan

Sunao Ogino
Design Department, Civil Engineering Division, TOA CORPORATION
5,Yonban-cho,Chiyoda-ku,Tokyo,102-8451 Japan

Satoshi Nakajima
Civil and Structural Engineering Department, Civil Engineering Division HAZAMA CORPORATION
5-8 Kita-Aoyama 2-chome,Minato-ku,Tokyo 107-8658,Japan

Masami Fujita
Environmental Department, Kankyogiken Consultants Co.,Ltd.
3-14-4 Miyako-cho,Chuo-ku,Chiba-city,Chiba,260-0001 Japan

ABSTRACT

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 at 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.

INTRODUCTION

It becomes more difficult year by year to secure sites for waste disposal sites. Thus, it becomes common to construct waste sites in mountainous area, such as valleys and mountain streams. At such sites, thickness of landfill layers is 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 pipes (JWMA, 2001).

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

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.

We studied design approach for buried pipes under large waste load as follows, especially focusing on compaction of cover material.

1) Measurement of modulus of deformation of cover material which has not been fully compacted. Large-scale tri-axial compression test using samples consolidated by K_0-pressure (hereafter, referred as K_0-compression test) was conducted.
2) Calculation of deflection of buried collection pipes or drainage pipes under vertical load caused by large waste height using Tohda's theory (Tohda et al., 2002), which was recently proposed for design method of buried pipes under large soil weight. His proposal is based on FEM analysis and experimental results under high pressure condition obtained by centrifuge model test.

MESUREMENT OF MODULUS OF DEFORMATION OF COVER MATERIAL

Material

Since large particle material cannot be used for tri-axial compression test device, M-40 single-sized crushed stone was used for the test. Properties of the crushed stone are presented in Table 1 and Fig.1.

Table 1 PROPERTIES OF M-40 CRUSHED STONE

Item			Results
Specific Gravity in S.S.D.C	Ga	(g/m^3)	2.649
Specific Gravity in A.D.C	Gb	(g/m^3)	2.630
Absolute Specific Gravity	Gg	(g/m^3)	2.681
Ratio of Water Absorption	Q	(%)	0.73
Maximum Particle Size	D_{max}	(mm)	37.5
Median Particle Size	D_{50}	(mm)	23.1
Coefficient of Uniformity	Uc		1.64
Coefficient of Curvature	Uc'		1.21
Fraction of Stone (75mm~)		(%)	0
Fraction of Gravel (2~75mm)		(%)	100
Fraction of Sand or Finer (~2mm)		(%)	0

A.D.C. = Absolute Dry Condition
S.S.D.C. = Saturated Surface-Dry Condition

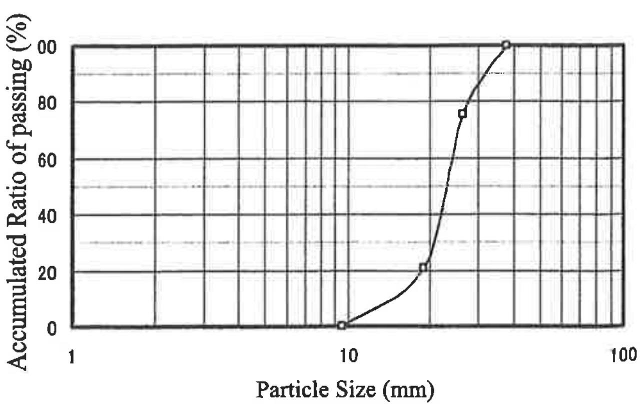


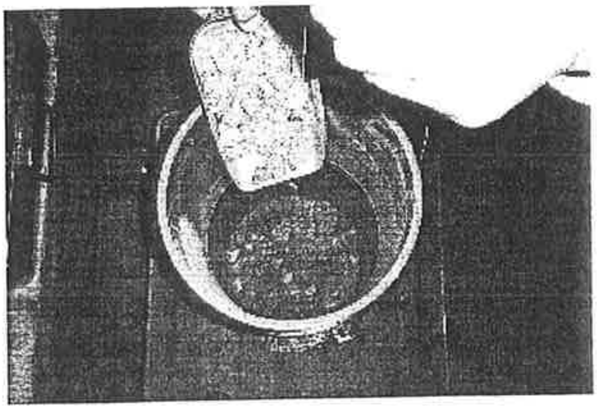
Fig.1 PARTICLE SIZE DISTRIBUTION OF TEST MATERIAL (M-40)

Test Methods

Density of Cover Material:

Density of cover material particles was measured for the specimen without compaction, i.e., the material was freely dropped into test piece mould (Photograph 1). Dry density increased as falling height increased. However, when the falling height reached 90cm, particles bounced out and the density decreased.

For the following K_0-compression test, test case was set as in Table 2 depending on falling height, in turn depending on the degree of compaction. Test was also conducted for material compacted by vibrator for comparison.



Photograph 1 'FREE-FALL MOULDING'

Table 2 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 Vibrated)	1.631	0.613	89.9	97.2

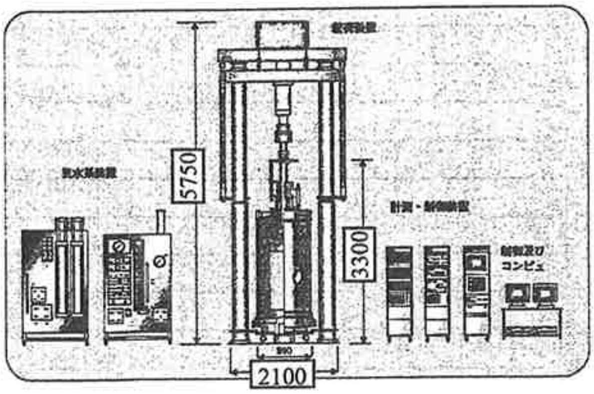


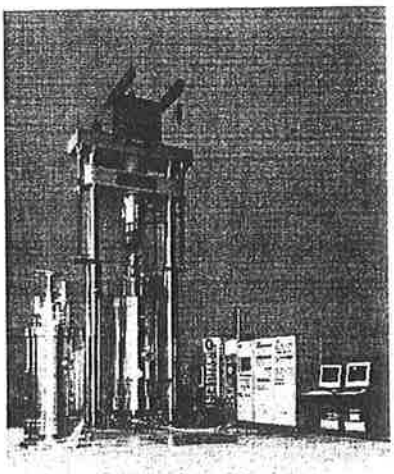
Fig.2 LARGE-SCALE TRI-AXIAL COMPRESSION TEST DEVICE

Modulus of Deformation:

Modulus of deformation of the test piece was measured using large-scale tri-axial compression test device shown in Fig.2 and Photograph 2. The test piece was consolidated at K_0-state before compression test. Test conditions for the compression test are shown in Table 3.

Table 3 Compression Test Conditions

Material	M-40 Single-sized Crushed Stone
Test Piece	ϕ300mm x h600mm
Saturation	Saturated
Load	Maximum Load 1000 (kN/m^2)
Measured Items	Vertical Load, Horizontal Pressure, Water Pressure, Axial Displacement, Volume Change



Photograph 2 LARGE-SCALE TRI-AXIAL

COMPRESSION TEST DEVICE

Test Results

The relationship between initial dry density (ρ_d) and modulus of deformation (Es), which was obtained by K_0-compression test, is shown in Fig.3. 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. Dependency on effective axial compression stress was not clearly observed in this test.

The relationship between the degree of compaction and modulus of deformation of the material (M-40) is shown in Fig.4 with Tohda's test data for crusher run (C-40). Modulus of deformation of M-40 is smaller compared with that of C-40. The degree of increase in the modulus for M-40 with the increase in degree of compaction is also relatively small compared with that observed for C-40.

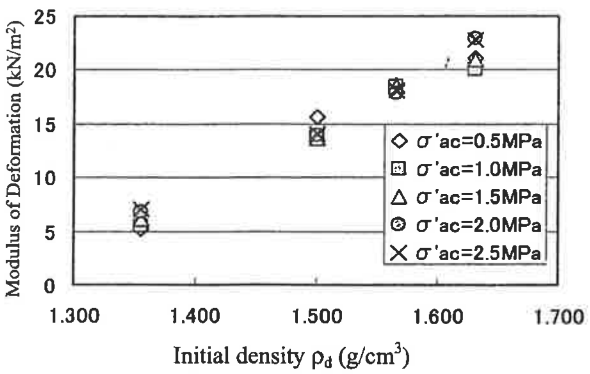


Fig.3 MODULUS OF DEFORMATION (M-40)

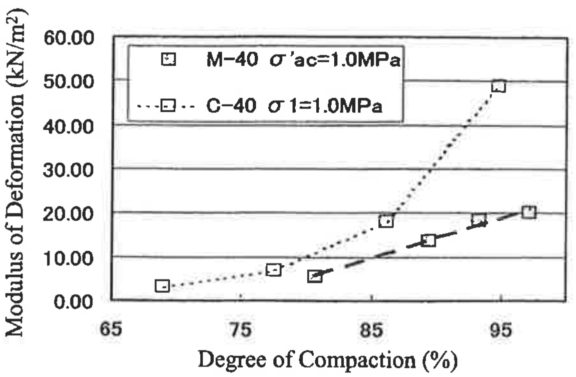


Fig.4 COMPARISON OF TEST RESULTS

OF M-40 AND C-40

DESIGN OF BURRIED PIPES UNDER LOAD CAUSED BY LARGE WASTE HEIGHT

Design approach for buried pipes under load caused by large waste height proposed by Tohda et al. (2002) is presented in flowchart in Fig.5.

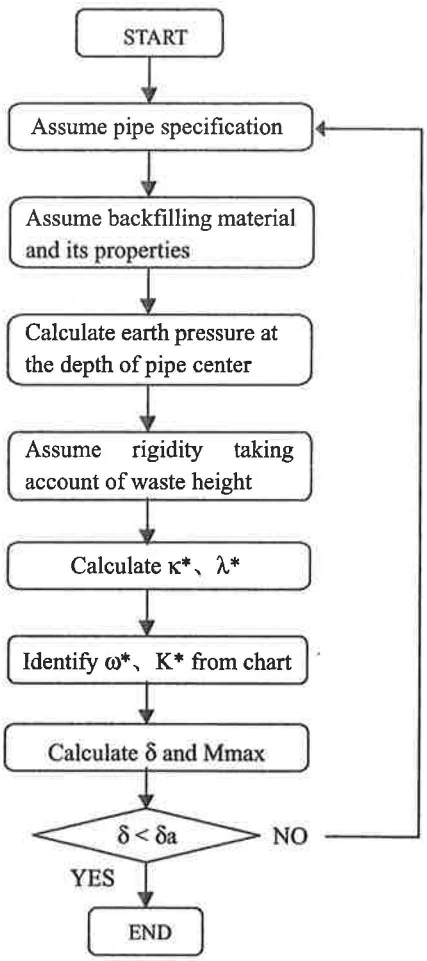


Fig. 5 DESIGN APPROACH FOR BURIED PIPES UNDER LOAD CAUSED BY LARGE WASTE HEIGHT

Tohda et al. reports only the calculated results for those pipes supported by base concrete. However, it has been confirmed that the strain of buried pipes directly set on ground is approximately 1.25 times larger than that supported by base concrete. Since it is not common at waste disposal site to set base concrete under collection/drainage pipes, it was decided to apply the safety factor of 1.25. The vertical strain ratio of buried high-density polyethylene pipes calculated by above approach is shown in Fig.6.

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.

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 Fig.6 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.

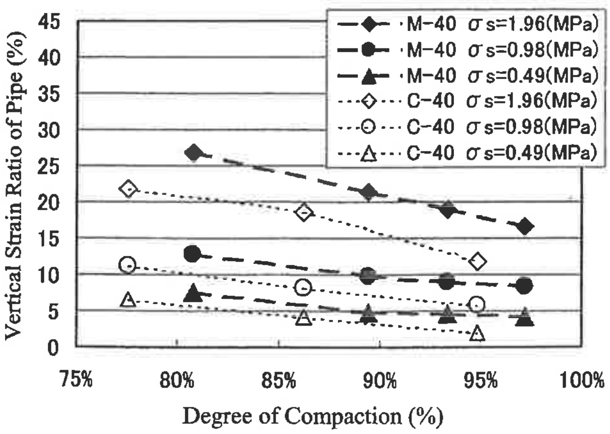


Fig.6 THE RELATIONSHIP BETWEEN DEGREE OF COMAPACTION AND VERTICAL STRAIN RATIO OF PIPE

CONCLUSION

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 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.

This study was carried out by 'Working Group for Site-Oriented Design Method for Waste Disposal Site Facilities' in NPO 'LS Research Association'. The working group has studied refined design method taking account of the difference in site conditions and focused on the topic 'problems related to design of collection/drainage pipes under large waste height'.

ACKNOWLEDGEMENT

We appreciate Mr Hinobayashi (Environmental Engineering Material Supply Department, TAKIRON Co., Ltd.) who provided us with valuable advice about the design method of buried pipes under large waste depth.

REFERENCES

Japan Waste Management Association (JWMA) (ed.) (2001) "Planning and Design of Waste Disposal Site Construction", pp.309-323

Tohda, J., Hinobayashi, J., Yoshimura, H., Hudo, M., and Kanchiku, H. (2002) "A New Design Method For Drainage Pipes Buried Under High Fills", Proceedings of JSCE, No.701/Ⅲ-58263-268, 2002.3, pp.263-281

Mitsui Chemical Sanshi Co., Ltd (1999), "Technical Information for Mitsui Howell Pipe" (brochure)