Effects of Soil Grain Size on Pile Bending Moment Under Cyclic Lateral Loading in One Layered Sandy Soil

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1. Introduction

Conventional bridges are usually designed with elastomeric bearing to allow the superstructure displacement due to environmental conditions and this elastomeric bearing needs to be maintained periodically. Nowadays, integral abutment bridges are becoming popular because the elastomeric bearing are eliminated, which reduce the construction and maintenance costs. This system causes the girder displacement due to environmental thermal forces was directly restrained by the substructure. Previous researchers have proposed a system to increase the flexibility of pile foundation using a pre-bored hole that filled with elastic materials as shown in Figure 1. However, soil behavior due to this system are not clearly reported. In this study, the effectiveness of filler material properties such as grain size and density was proposed to effectively reduce the pile cracking possibility. Soil material characteristic on cyclic laterally loaded pile are also investigated. The behavior of a pile can be analyzed by using Winkler's model which is given by Equation 1.

$$\frac{d^4y}{dx^4} + \frac{p}{EI} = 0 \qquad (1)$$

Where, E = modulus of elasticity of pile, I = moment of inertia of pile section, p = soil reaction which is equal to ($k_h y$).

2. Experimental setup

Macro-scale testing was performed to determine soil behavior due to cyclic lateral loading and to evaluate the effectiveness of this system. Figure 2 shows the experimental test setup which is used in this study. An experimental study was performed using pile test model in non-uniform and uniform sand that have different soil grain size. Three different pile slenderness ratio of 10, 20 and 30 were used and lateral cyclic displacement was applied on the pile head. Index properties of the soil are given in Table 1. Relative density of soil was achieved using multiple sieving pluviation (MSP) method (Miura and Toki, 1982).

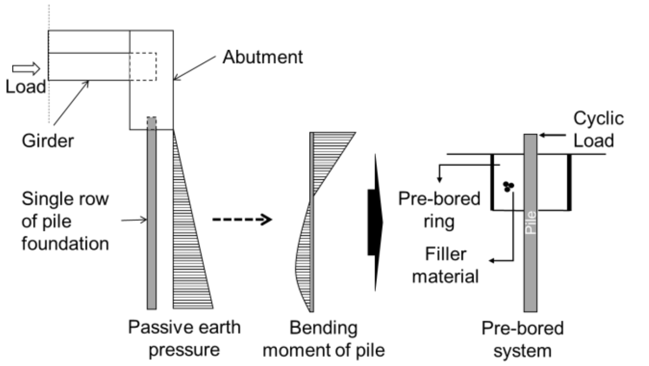

Figure 1 Integral abutment bridge with pre-bored hole

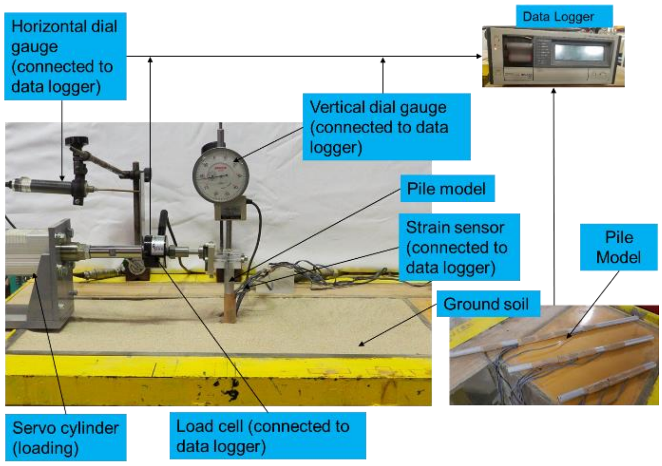

Figure 2 Testing scheme

Table 1 Index properties of ground soil

Soil properties	K-7	K-4	Toyoura (Awad-Allah, 2015)
D_{50} (mm)	0.17	0.75	0.18
Uniformity coef. (U_c)	2.96	1.24	1.4
Max. dry density	1.51	1.48	1.6
Min. dry density	1.18	1.24	1.31

3. Results

The main focus of this experiment is the pile bending moment which are periodically measured using attached strain gauges along the pile. Then, those measured values were analyzed and the maximum measured value (M_m) was normalized against the yielding moment (M_y). Normalized bending moment, which is the ratio of measured bending moment to the yielding moment of pile material (M_m/M_y), were estimated.

Figures 3 illustrate the relationships between normalized bending moment and pile depth for single piles constructed into medium dense sand (D_r=50%) and dense sand (D_r=80%) on a static lateral loading. It is noticed that a higher density will provide a higher bending moment. The graded sand with high density provides 3 times higher bending moment value than the graded sand on medium density. While, the high density of uniform sand provides 1.5 times higher bending moment value than the uniform sand on medium density. It indicates that the potential increasing bending moment on the uniform sand is smaller than the graded sand. The maximum bending moment location was also changed on the different soil density. Figure 4 shows the effect of the soil grain size and soil uniformity. It shows that soil with the higher grain size (D_{50}) and lower uniformity coefficient (U_c) such as K4 sand provides a lower bending moment with the similiar soil relative density.

The cyclic lateral loading effect is shown in Figure 5. After 50 times of cyclic loading, there is no significant increase of bending moment on the uniform sand. It indicates that the there is a small densification effect due to the cyclic loading on the uniform sand. So the suitable pre-bored hole filler material is the uniform sand which performs better on maintaining bending moment due to cyclic lateral loading.

4. Conclusions

Bending moment of pile in graded sand is higher than uniform sand along the pile length and the potential increasing of pile bending moment on the uniform sand is smaller than the graded sand. Uniform sand provides better characteristic to be used as filler material in pre-bored pile foundation. It provides smaller bending moment value along the pile and performs better on maintaining bending moment due to cyclic loading.

5. Future plan

Experiment tests for 2 layered soil to determine the effective depth and dimension of pre-bored ring. Investigate the behavior of filler material inside pre-bored ring due to cyclic laterally loaded pile.

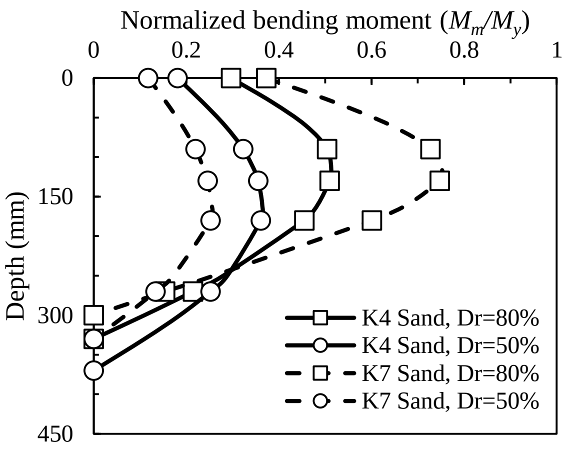

Figure 3 Effect of soil density on bending moment

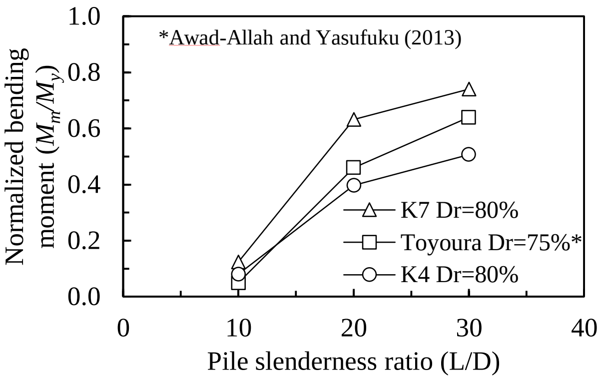

Figure 4 Effect of grain size due to the static lateral loading

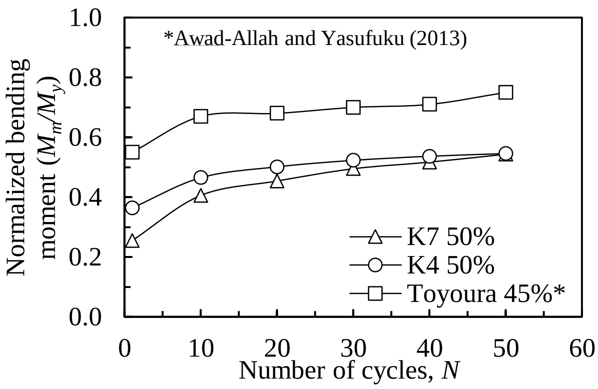

Figure 5 Effect of cyclic lateral loading on medium soil density

6. Reference

1) Miura, S. and Toki, S. 1982. A Simple Preparation Method and Its Effect on Static and Dynamic Deformation-Strength Properties of Sand, Soils and Foundations, 22 (1), pp. 61-77.

2) Awad-Allah, M.F. and Yasufuku, N. 2013. Performance of Pile Foundations in Sandy Soil Under Slow Cyclic Lateral Loading. The 5th International Geotechnical Symposium on Geot. Eng. For Disaster Prevention & Reduction, Incheon, pp. 291-300.