Laboratory model experiments on pile embankments with geo-synthetics

A. Lee Kwang Wu
Korea Institute of Construction Technology, Republic of Korea (kwangwu@kict.re.kr)
B. Lee Il Hwa
Korea Railroad Research Institute, Republic of Korea (iwlee@krri.re.kr)
C. Ryu Jeong Ho
Korea Institute of Construction Technology, Republic of Korea (ryujeongho@kict.re.kr)
D. Choi Chung Rak
Pyunghwa Engineering Consultants, LTD, Republic of Korea (cclak@nate.com)
E. You Seung Kyung
Department Civil Engineering, Myong ji College, Republic of Korea (yousk@mjc.ac.kr)

ABSTRACT:
Laboratory model tests were performed to investigate the vertical loads transferred on the piles by mobilizing soil arching in pilesupported sand fills. In the model tests, model piles were inserted through the holes in a steel plate, which could be operated up and down. Geosynthetic reinforcement was laid on the pile caps below sand fills. The settlement of soft ground was simulated by lowering down the plate after final sand filling. The soil arching was mobilized in the embankments when the plate was lowered down. The loads acting on pile cap and the tensile strain in geosynthetics were measured by data logging system. Model tests showed that the loads transferred on pile caps by soil arching increased with settlement of the soft ground rapidly. In cases of without geosynthetics, the loads acting on pile caps dropped to the residual value after reaching peak value, whereas loads on pile gradually increased to constant value in cases of piled embankment with geosynthetics. Also the tensile strain in geosynthetic increased with the increase in the displacement of soft ground simulated by the settlement plate.

Keywords: Piled embankment, Geosynthetics, Model test, Soil arching

1 INTRODUCTION

For decades, piled embankments have been widely used for transportation such as high-speed railway and expressway to support bearing capacity and reduce settlement on soft subsoil. This method also leads to cost savings due to shorter construction periods. The fundamental mechanism on geosynthetic reinforced and pile supported embankment system (GRPS) is load redistribution by soil arching. The research and development program on GRPS includes laboratory tests aimed at improving the soil arching mechanism, investigating the factors of and established design codes on GRPS.

This paper presents and analyses the results of two series of laboratory model tests. Several researchers have carried out experimental research on piled embankments in the past. As most of previous researches, this paper focuses on a static and vertical load conditions such as the case without a slope that results in horizontal loads or the loads with time history as seismic load.

2 TEST SETUP AND TESTING PROGRAM

2.1 *Test set-up*

2 series of laboratory model test were conducted to investigate soil arching under static and vertical load. Each test model could be distinguished whether geosynthetic reinforced or not. The tests were conducted using the test set-up as shown below (Fig. 1). The soil container includes the movable plate vertically which could be simulated settlement on the subsoil. For a series of model testing with various center-to-center distances on pile group were conducted with various-sized top cap of each pile which ha been fastened with movable plate.

Figure 1: Test set up for laboratory model test (front view, side view, plan view from the left to right)

2.2 *Instrumentation*

There are two parts of the instrumentation for laboratory model test. The load cells on the head of each pile are as shown below (Fig. 2). Redistributed loads on a pile cap were measured. Since the settlement of subsoil in the model test would be under control, no need to measure the settlement of subsoil. To measure the tensile behavior of geosynthetics, strain gauge was used with adhesion (Fig. 3, Cho et al., 2012).

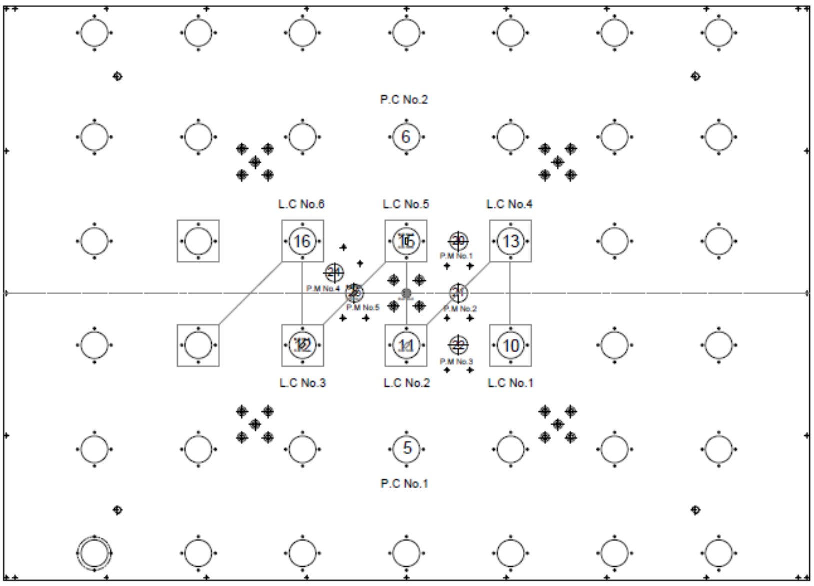
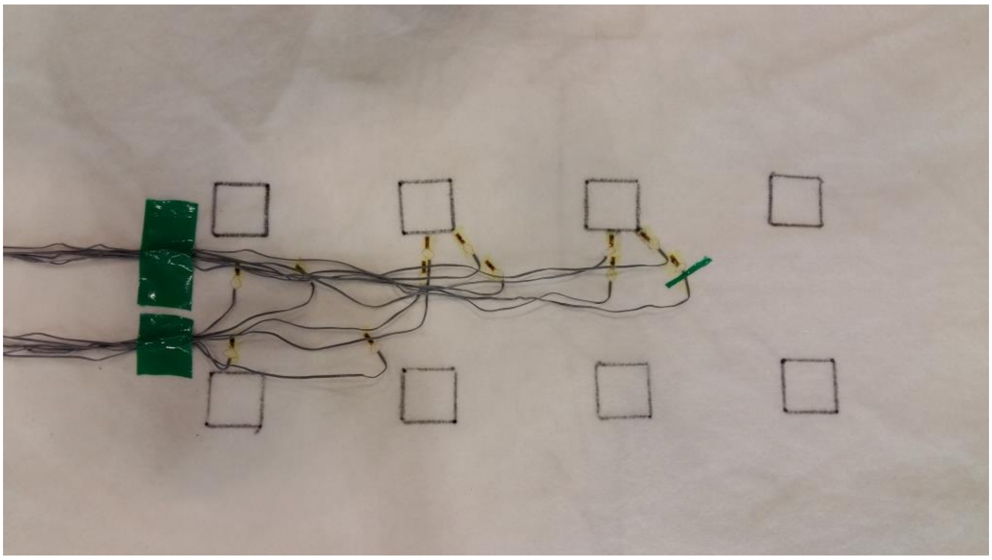


Figure 2: Instrumentation: Plan view



2.3 *Figure 3: Instrumentation: Strain gauge on the geosynthetics by adhesion*Test procedure

Each series of test procedure consists of 3 steps; set-up, measurement and analysis of measured data (Fig. 4). A set-up includes piled-movable plate installation, instrumentation and placement of surcharge material on the piled-movable plate to simulate embankment construction. Table 1 summarizes the properties of embankment material on laboratory model tests.

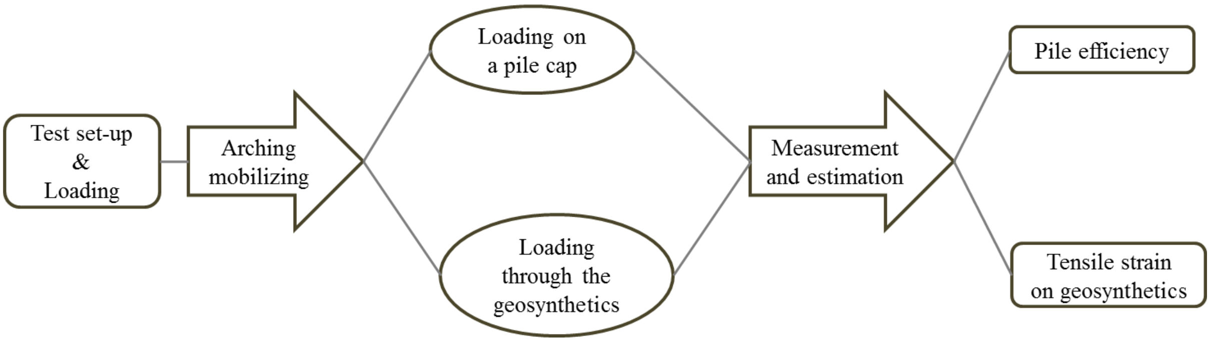


Figure 4: Laboratory model test procedure

Table 1. Material properties

Soil classification	Gs	$\gamma_{d_{max}}$ (kN/m3)	$\gamma_{d_{min}}$ (kN/m3)	e_{max}	e_{min}	Internal friction angle (deg) @ Dr=70%
Clean sand	2.64	15.96	13.04	0.986	0.623	39.3

3 TEST RESULTS

3.1 *Figure 5 and 6 show the load-displacement curve and pile efficiency at various interval ratio of the pile Load distribution on the pile by arching: no reinforcement*

In case of no reinforcement, loading behavior on pile cap shows the peak point clearly on the load-displacement curve as dense sand behavior. Viewing the case of the largest interval ratio of pile, the curve shows more clear peak and stiff slope to peak than other curves. Efficiency of pile from the test results shows a good agreement with BS 8006 (1995).

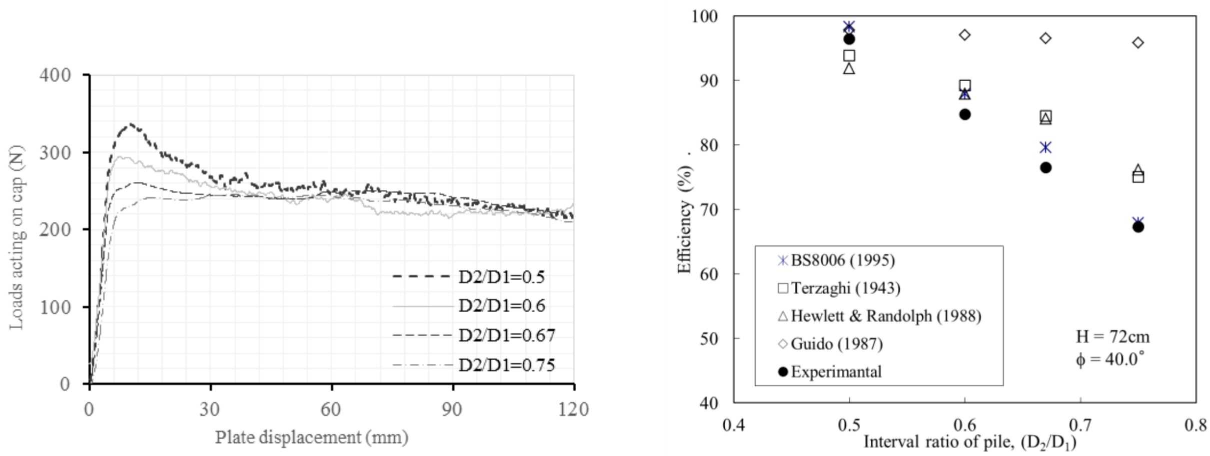
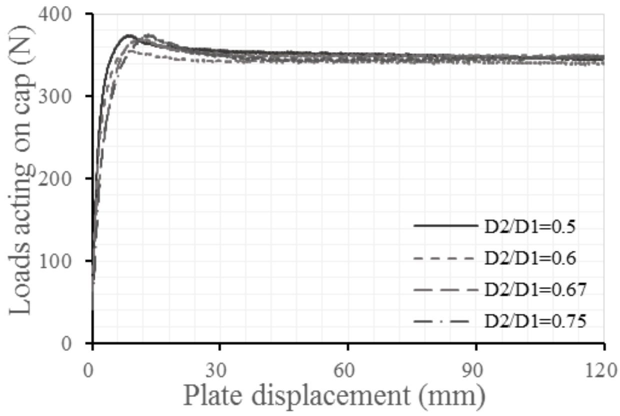


Figure 5: Load-displacement curve and Efficiency curve: no reinforcement

3.2 *Load distribution on the pile by arching: reinforced with the geosynthetics*

In case of reinforcement piled embankment, loading behavior on pile cap shows no peak point on the load-displacement curve. Most of cases show t
point of curves. Efficiency of pile-reinforcement has hi



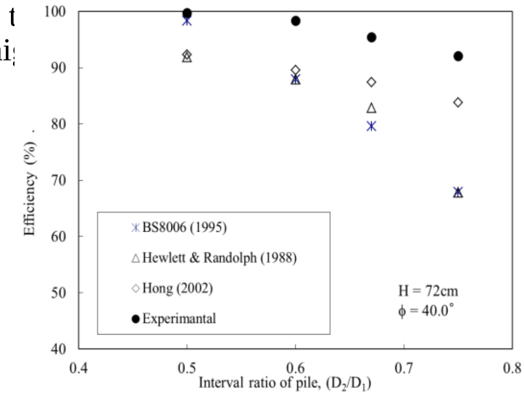


Figure 6: Load-displacement curve and Efficiency curve: reinforcement case

3.3 *The strain of the geosynthetics due to arching*

Since measured values from strain gauges are attached to geosynthetics, particularly nonwoven textile which was used this study, the correction of the values on the strain gauges are needed. The correction chart is used to modify the reading value on the strain gauge (Cho et al., 2012). According to the chart shown below, the correction factor for strain gauge on the nonwoven textile is 10.0, approximately.

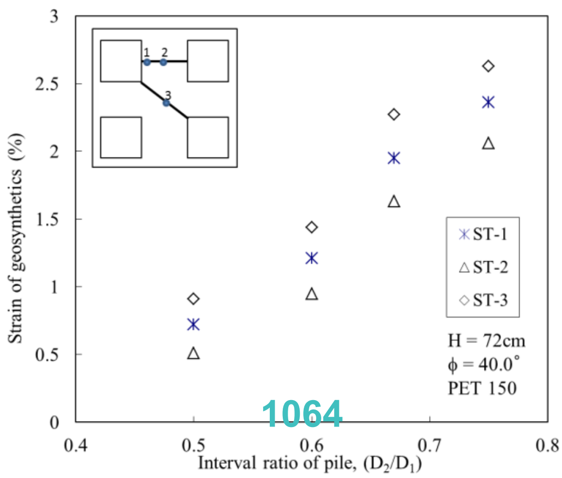


Figure 7: The strain of geosynthetics on the edge of pile cap and center of arching

Figure 7 shows that tensile strain of nonwoven textile (PET150)at various interval ratio of pile. The tensile strains of PET150 increased with the interval ratio of pile proportionally. Since the test model for this study consists of isolated pile cap, the tensile strain at the diagonal pile to pile center (ST-3) has the largest value of 2.6%. This value is within the design criteria for geosynthetic reinforcement – piled embankment as BS8006, i.e. 6.0%.

4 CONCLUSION

This paper presents and analyses the results of two series of laboratory model tests to investigate the difference in behavior on pile embankment between geosynthetic reinforcement and no reinforcement under vertical and static load only.
According to the load-displacement curves, loading behavior on pile cap without reinforcement shows the peak clearly on the load-displacement curve as dense sand behavior. The behavior of curve on pile-reinforced cap, however, shows no peak and stiffer initial slope of curve than load-displacement with no reinforcement pile cap.
According to these test results, the load on the reinforced piled embankment system might be transferred to pile cap and geosybthetics synchronizely when the capacity of pile reached a yield point within a stable tensile strain on the geosynthetics (PET150) as 2.6%.
The pile load efficiency and tensile strain behavior on geosynthetics in the model test results was in accordance with the theoretical value on the specific design code as BS 8006 well.

Acknowledgements

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