Experimental study on the behaviors of floating-type improved ground during consolidation

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1 INTRODUCTION

For soft soil engineering, in many cases, the foundation directly on natural ground cannot satisfy the requirement. In the case of constructing superstructures such as embankment on deep soft clay layer, application to the floating type friction piles can reduce the construction cost. Consequently, a technology of combining the floating type cement-treated columns and surface stabilization has been developed, which is perceived as one of the effective and acceptable methods for improving the soft clay ground.

For this structural form, it is important to predict the total settlement of the ground in relation to the important factors. During consolidation, the skin friction between the piles and soft clay will occur, which plays an important role in reducing ground settlement.

Fig. 1 shows the concept of floating type ground improvement. As shown in Fig. 1, this type of technique can be useful for deep soft soil layer considering that it can reduce the settlement.

In previous studies, several investigations for considering the influence of the improvement parameters have already been conducted by Miki et al. (2004) and Ishikura et al. (2006), (2013). A method for predicting the total settlement of this improvement ground has already been proposed by Ishikura et al. (2009).

In this paper, in order to evaluate consolidation settlement in consideration to time-dependent skin friction characteristics, a loading model test under two conditions (unimproved condition and 1 floating pile improved condition) was performed for observing the settlement process. Based on the experiment results, some characteristics of this technology were discussed.

2 LABORATORY MODEL TEST

2.1 Test set-up and procedure

Figure 2 shows the apparatus used in the model test under the plane strain condition. The test is comprised of two parts. Firstly, the specimen was prepared under a pre-consolidation pressure of 40kPa using a bellofram cylinder until the end of primary consolidation. For unimproved condition, the vertical pressure will be added to final pressure of 80kPa continued. While for improved condition, a model pile which is composed of aluminum and have 30 mm in wide D, 100mm in depth and 200mm in length H_1, was inserted in the model ground for the consolidation settlement test.

As shown in the Figure 2, the apparatus consists of a box-shaped cell, loading plates and loading device. Perforated acrylic plates were used as drainage condition at the bottom

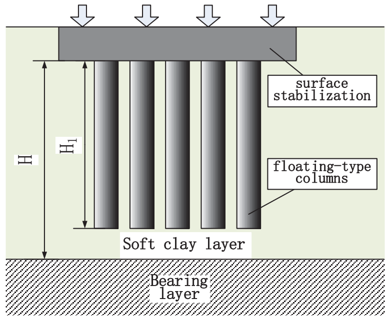

Fig. 1 Concept of floating type ground improvement

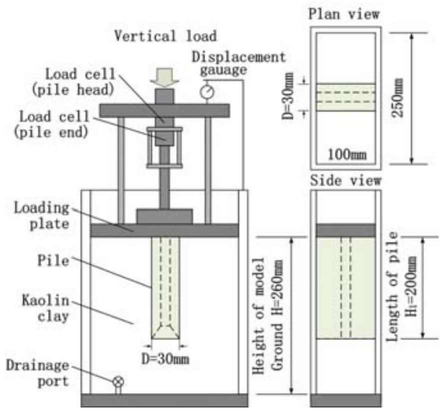

Fig. 2 Loading model test under the plane strain condition

and the top of the model ground. A rubber membrane was covered on the inside wall for reducing the wall friction. The model ground was prepared by using Kaolin clay, which was remolded in a slurry condition with water content of about 80%. Then the slurry was poured into the mould layer by layer, until up to a depth of about 350mm. After the loading system was set up, a pre-consolidation pressure was applied using a bellofram cylinder, from 5kPa to 10kPa, 10kPa to 20kPa, 20kPa to 40kPa, until the end of primary consolidation. And the compression index c_v and coefficient of volume compressibility m_v were obtained when the pre-consolidation was finished. During the test, the settlement at the top of the model ground and the pre-consolidation pressure were monitored. Then, for improved condition, a groove was cut for insetting the model pile. After insetting the model pile, the model ground was prepared.

The test was carried out with double drainage at the upper and lower surface. The pressure of 40kPa was applied firstly to ensure firm contact between the model pile and the surrounding soil and to bring the model ground to a normally consolidation state, and then the pressure was increased stepwise from 40kPa to 80kPa, 80kPa to 160kPa using a bellofram cylinder. During the test, the settlement at the top of the model ground, the vertical load and the resistant at the pile head and pile end were monitored.

2.2 Test results and discussions

Figure 3 shows the relationship between normalized settlement S/D and elapsed time during consolidation process under two types of test conditions. Figure 4 shows the relationship between normalized settlement S/D, normalized incremental averaged skin friction $\Delta f/\Delta\sigma$ and elapsed time during consolidation process under improved test condition. The load was applied by step loading, the next loading was applied after the consolidation that was caused by the previous loading was complete. As shown in Fig. 3, normalized settlement S/D increased and then converged to the constant value. The settlement of case 2 is smaller than that of case 1 obviously. The consolidation settlement was mainly completed in a relatively short period when the pressure was just applied. Meanwhile, in Fig. 4, incremental averaged skin friction Δf is the value that divides the load difference between the pile head and pile end by the surface area of the model pile. As shown in this figure, with the time increased, incremental averaged skin friction Δf initially increased just applying on the vertical pressure. However, after reaching the peak, it began to decrease with time and later converged to the constant values. It is static between pile surface and soil when the averaged skin friction increased, while static friction reached the ultimate value, the relative slide between pile surface and soil or soil interior occurred. After that, sliding friction decreased and later converged to the constant value.

Figure 5 shows the relationship between the normalized settlement S/D and normalized skin friction $\Delta f/\Delta\sigma$ under 80kPa and 160kPa. It is considered that incremental skin friction is mobilized by acting relative displacement between the pile and soft clay around the surface of the pile end during consolidation process. With the vertical load increased (80kPa to 160kPa), the value of incremental averaged skin friction $\Delta f/\Delta\sigma$ became small.

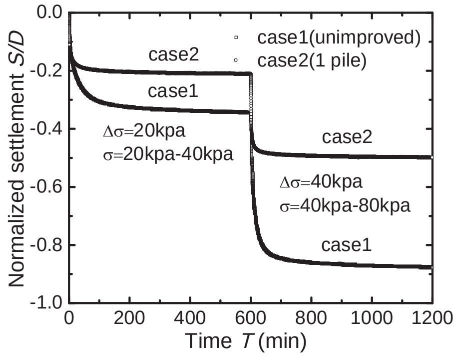

Fig. 3 Relationship between settlement and elapsed time

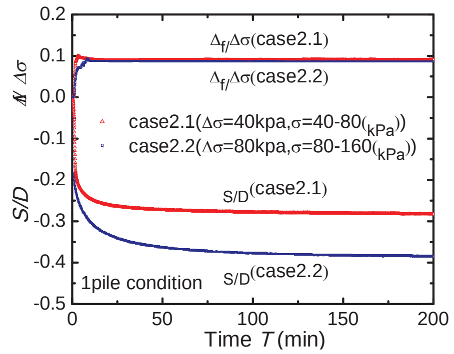

Fig. 4 Relationship between settlement, skin friction and elapsed time

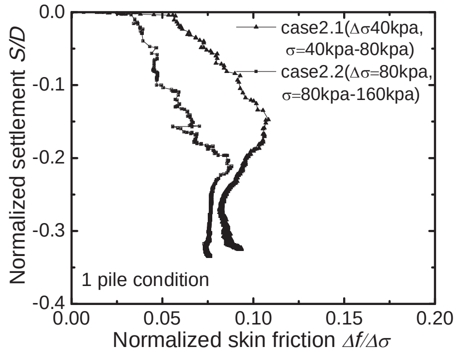

Fig. 5 Relationship between settlement and skin friction

3 CONCLUSIONS

This article presents the laboratory model test for investigating the settlement behavior and skin friction of floating type improved ground with shallow stabilization during consolidation. The following conclusions can be derived from this study.

(1) The results under two test conditions were obtained and compared, the settlement of improved condition was smaller than that of unimproved condition, and consolidation settlement was mainly completed in a short time.

(2) It was clarified that skin friction applied on the pile during consolidation initially increased with an increase of normalized settlement and after reaching the peak, it began to decrease with time and later converged to the constant values, and the value of incremental averaged skin friction became small while the vertical load increased.

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