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Prediction of the stress state and deformation of soil deposit under vacuum pressure

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ABSTRACT

Stress state and deformation of a clayey deposit under vacuum pressure has been investigated using field data as well as laboratory vacuum consolidation test results. The field vacuum consolidation project was conducted in Saga, Japan for a clayey deposit with prefabricated vertical drain (PVD) installation. Laboratory tests were conducted under triaxial condition using undisturbed soil specimen with a mini-vertical drain inserted in the center to simulate PVD induced consolidation. By comparing the field and laboratory test results, it has been found that the effective confinement from the surrounding soils to the vacuum treated area is close to active earth pressure for a zone about 5 m depth from the ground surface, and below it is between active and at-rest states. A scaling factor has been derived to convert consolidation time in laboratory to the field case. It has been shown that with the scaling factor, the results of laboratory vacuum consolidation test under triaxial condition can be used to predict field settlement curves for vacuum loading.

Introduction

Preloading a soft clayey deposit using vacuum pressure has been widely used to improve the strength and stiffness of soft grounds, mostly for the projects of constructing transportation infrastructures (e.g., Tang and Shang, 2000; Chai et al., 2005; Mesri and Khan, 2012). Vacuum pressure will induce isotropic consolidation stress increment in a deposit, and result in settlement as well as inward (toward the center of a treated area) lateral displacement (Chai et al., 2005; Imai, 2005). Due to the inward lateral displacement, the earth pressure in the treated area will be changed also. The results of vacuum consolidation under odometer condition show that horizontal effective confinement from the consolidation ring reduced during the vacuum consolidation process, and even causing separation of the soil sample and the ring when the initial vertical effective stress (surcharge load) in a soil sample is low (Chai et al., 2005, 2009). However, odometer condition is different from the field condition. To calculate/predict vacuum consolidation induced ground deformation, understanding the effective stress state in a soil deposit is essential, but there are very limited laboratory or field data on this aspect.

In this study, a vacuum consolidation project conducted in Saga, Japan (Chai et al., 2006), is briefly described first. Then laboratory vacuum consolidation tests under triaxial stress condition and with a vertical drain at the center of the specimen were conducted using the undisturbed Ariake clay samples. The effect of confining (cell) pressure on the deformation characteristics of the soil specimens has been investigated. By comparing the laboratory and the field measured values, possible effective stress state in the deposit under vacuum consolidation has been

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evaluated. The laboratory test results have been also used to predict the settlements of the field soil strata at the site of the field vacuum consolidation project.

Vacuum consolidation project in Saga, Japan

From June 2003 to March 2004, a field vacuum consolidation was carried out at a site in Saga, Japan for a road construction project (Chai et al., 2006). The location of the site is shown in Fig. 1 as "Test site". The total improved area was about 1 km long and 16–18 m wide. The area was divided into 7 Sections and Section-4 with a length of 187 m was instrumented with settlement gauges, excess pore water pressure gauges and an inclinometer casing. The soil profiles at Section-4 are shown in Fig. 2 (data from Tanabashi et al., 2004; Chai et al., 2006). It can be seen that the soft clayey soil layer is about 11 m thick.

At Section-4, the construction of the sand-mat about 1.0 m thick commenced on 20 May, 2003 and followed the installation of prefabricated vertical drains (PVDs). PVDs were installed to a depth of 10.5 m from the ground surface and they were arranged in a square pattern at 0.8 m spacing. For this case, only about 0.5 m clayey layer was left at the bottom of the clayey deposit without PVDs. In addition, prefabricated strip drains (0.3 m wide and 4.5 mm thick) were laid on the top of the sand-mat with a horizontal spacing of 0.8 m to ensure adequate horizontal drainage capacity (Chai et al., 2006). During the sand-mat construction, the settlement at the ground surface was monitored. Just before the commencement of vacuum consolidation, the measured settlement was 112 mm. In this study, it is assumed that the sand-mat induced settlement was finished before the commencing of vacuum consolidation, and the settlements considered are the increments after the application of the vacuum pressure.

Vacuum pressure was applied using air sealing sheet method (Chai and Carter, 2011), and the sheet used for this project was a 0.5 mm thick polyvinyl chloride (PVC) membrane. At the site the groundwater level was about

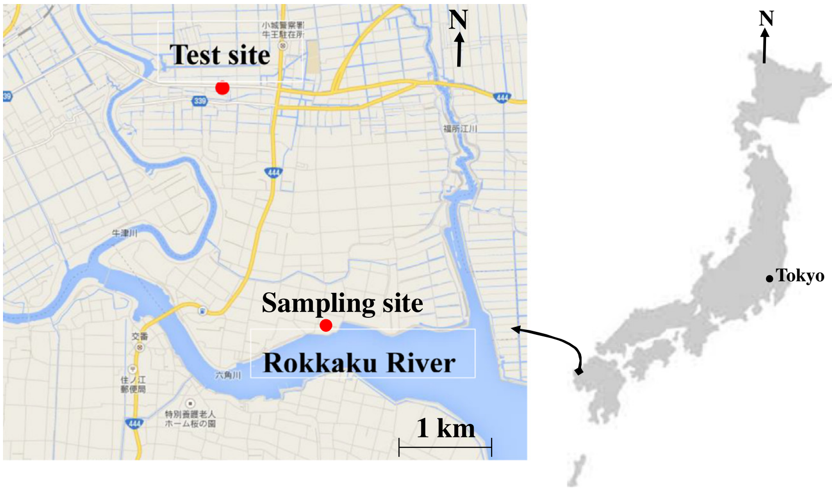

Fig. 1. Locations of test and sampling sites.

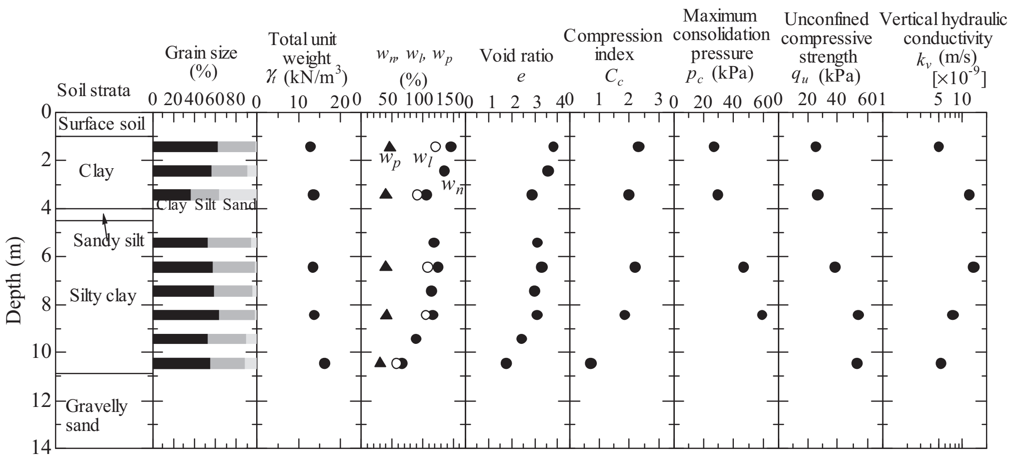

Fig. 2. Soil profiles and some physical and mechanical properties at the test site.