Modeling of consolidation characteristics of clays for settlement prediction of Kansai International Airport

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ABSTRACT
The construction of Kansai International Airport is a large, unique project which involves building a man-made island 5 km offshore in Osaka Bay. The presence of soft clay layers under the construction site having a total thickness of several hundred meters suggested that large settlement might occur due to their consolidation. For the second phase construction project at the Kansai International Airport site, we developed two types of settlement prediction method based on experience in the first phase. With the first method, the DB model is used to predict settlement using a database of geotechnical information. The database contains three-dimensional distributions of soil sedimentation parameters and geotechnical parameters for geological layers under the Kansai International Airport site. The second method uses a nonlinear elasto-viscoplastic model. With this method, the strain is divided into elastic and viscoplastic components. To reproduce time-dependent settlement, the model assumes that the consolidation yield stress changes with the strain rate. Both methods were used to predict settlement on the first and second airport islands for comparison with measured settlement. The results showed that calculated values agreed favorably with measured values.

1 INTRODUCTION

The construction of Kansai International Airport is a large, unique project which involves building a man-made island 5 km offshore in Osaka Bay. The presence of soft clay layers under the construction site having a total thickness of several hundred meters suggested that large settlement might occur due to their consolidation. The prediction of such settlement was a major technological challenge, particularly that of highly compressive Pleistocene layers. There was an additional concern about the thickness of sand layers that alternated with clay layers, which suggested that these sand layers might not function sufficiently as drainage layers.

In the early stages of the first phase construction project that started with such uncertainties, original prediction was carried out changing consolidation parameters and drainage conditions. Thus, there was a lot of variability in the original prediction. As the construction work proceeded, settlement was measured at the pilot area where reclamation works were completed earlier than in other areas, and the results were used to modify original predictions. The measurements at the pilot area revealed that the measured settlement matched the largest values of original predictions. It was also confirmed that the excess pore water pressure built up in most sand layers. Original predictions were modified using these observations and the first phase reclamation works were completed.

For the second phase construction project, we developed two types of settlement prediction based on experience in the first phase. With the first method, the settlement of clay layers is calculated using the elasto-plastic model while the pore water pressure in sand layers is calculated by seepage analysis. The prediction model incorporates three-dimensional distributions of the properties of clay. To organize the data required for configuring the model, we developed a database of available geotechnical information. This prediction model, therefore, is called the DB (database) model.

The second method assumes that clay behaves as elasto-viscoplastic material. The pore water pressure in sand layers is calculated by the coupled analysis of clay consolidation and sand seepage. This model assumes nonlinear e-logp relationships for clay. This prediction model, therefore, is called the nonlinear model.

This paper outlines the geotechnical characteristics of the Kansai International Airport site and then describes the DB model and the nonlinear model. Subsequently, we compare observed settlements with prediction using two models.

2 GEOTECHNICAL PROPERTIES AT THE KANSAI INTERNATIONAL AIRPORT SITE

The Kansai International Airport, 5 km offshore in Osaka Bay, is an area of about 4 km square. However, the geotechnical characteristics vary a lot among this relatively small area. This section describes the main geotechnical characteristics at the site.

2.1 *Geological layer configuration*

Figure 1 shows 3D views of geological layers at the Kansai International Airport site. Figure (A) is a view from the south. And Figure (B) is a view from the western offshore side of second airport island. As shown in Figure (A), geological layers at the site have a downward inclination toward the offshore side. For example, the thickness of Ma13-Ma7 increases from 170m, under the first airport island, to 210m, under the second airport island. Furthermore, most of the sand layer are very thin. Only Ds1 and Ds10, which exist under Ma13 and Ma7 respectively, can function as a drainage layers in terms of the thickness and area. Other sand layers, particularly those that could drain water from Ma10 and Ma9, are quite thin; the layer thickness is almost zero at some locations.