

# Long-term settlement of the Pleistocene deposits due to construction of KIA

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## ABSTRACT

A series of elasto-viscoplastic finite element analyses is performed to assess the stress and deformation of the marine foundation due to construction of Kansai International Airport (KIA) fill. The foundation is modeled by following the stratification at offshore reclamation site. A new concept in terms of occurrence of viscoplastic behavior even in the quasi-overconsolidated region is incorporated into finite element code in order to simulate the long-term deformation of the Pleistocene clay deposits in Osaka Bay. Attention is also paid to the modeling of permeability for Pleistocene sand gravel layers considering the sedimentation environment because the performance of excess pore water pressure is strongly dependent on the extent as well as the change in thickness of those permeable sand gravel layers. The mechanism for the propagation of excess pore water pressure is also discussed. It is very important to know how far the excess pore water pressure generated due to reclamation propagates for assessing the effect of adjacent reclamation on the existing reclaimed land. From those findings on the performance of excess pore water pressure, the mode of advance in settlement of Pleistocene deposits is discussed.

## 1 INTRODUCTION

The outstanding development of coastal areas has recently been accomplished in Japan. A large-scale offshore reclamation in Osaka Bay is accompanied with large and rapid settlement of deep Pleistocene clay deposits (Mimura et al., 2003). Akai and Tanaka (1999) reported that large and rapid settlement has been preceding without significant dissipation of excess pore water pressure in the Pleistocene clay and sand gravel deposits in the foundation ground of Kansai International Airport (KIA) construction site. The phenomena taking place due to the reclamation is far from the conventional concept of consolidation in which deformation advances associated with the dissipation of excess pore water pressure.

Ito et al. (2001) summarized the distribution of sandy deposits in Osaka Bay using the data from elastic wave exploration and in-situ boring logs. It has been showed that the distribution of sandy deposits is different in each deposit subjected to the difference of sedimentation environment. The most serious problem originating from sandy deposits is permeability that controls the rate of consolidation of sandwiched Pleistocene clays. The quantitative contribution of the Pleistocene sand gravel layers to the long-term settlement of the Pleistocene deposits was shown by Jang and Mimura (2005). The Pleistocene clays have distinguished structure due to long term effect of diagenesis. The compression behavior of this kind of clay has a strong resemblance to that of Canadian Clay with highly developed structure (Leroueil et al., 1985) where no linear relationship is found between void ratio and the logarithm of applied overburden within the range of virgin compression. On the basis of these findings, Mimura et al. (1994) proposed the tri-linear compression model for the Pleistocene clays of KIA site. This modeling provided the rapid advance in settlement without significant dissipation of excess pore water pressure that has actually occurred in the field. Mimura and Jang (2004) proposed a new concept of compression in which viscoplastic behavior is assumed to occur even in the quasi-overconsolidated region less than  $p_c$  for the Pleistocene clays in Osaka Bay. The procedure has been found to be versatile to describe the long-term settlement monitored in the reclaimed islands in Osaka Port (Mimura and Jang, 2005).

In this paper, long-term settlement of the Pleistocene deposits of KIA is investigated through an elasto-viscoplastic finite element analyses together with the performance of excess pore water pressure propagation in the Pleistocene deposits. The mass permeability of Pleistocene sand gravel deposits is selected as one of the parameters controlling the deformation of the foundation ground. It is of importance to know how far the generated excess pore water pressure will propagate in permeable sand gravel layers because it directly influences the performance of the adjacent structures. The effect of the existence of excess pore water pressure in the permeable Pleistocene sand gravel layers on the subsequent advance in settlement of the Pleistocene deposits is of great concern for predicting the long-term settlement of the offshore-reclaimed marine foundations. Based on the trial calculation, the authors show how to assess the actual behavior of the foundation ground that is taking place in the case of large-scale offshore reclamation such as KIA.

## 2 ELASTO-VISCOPLSTIC FE FORMULATION

The elasto-viscoplastic constitutive model used in this paper was proposed by Sekiguchi (1977). Sekiguchi et al. (1982) modified the model to a plane-strain version. The viscoplastic flow rule for the model is generally expressed as follows:

$$\dot{\epsilon}_{ij}^p = \Lambda \frac{\partial F}{\partial \sigma_{ij}} \quad (1)$$

in which  $F$  is the viscoplastic potential and  $\Lambda$  is the proportional constant. Viscoplastic potential  $F$  is defined as follows:

$$F = \alpha \cdot \ln \left[ 1 + \frac{\dot{v}_0 \cdot \mathbf{t}}{\alpha} \exp \left( \frac{\mathbf{f}}{\alpha} \right) \right] = v^p \quad (2)$$

in which  $\alpha$  is a secondary compression index,  $v_0$  is the reference volumetric strain rate,  $\mathbf{f}$  is the function in terms of the effective stress and  $v^p$  is the viscoplastic volumetric strain. The concrete form of the model is shown in the reference (Mimura and Sekiguchi, 1986). The resulting constitutive relations are implemented into the finite element analysis procedure through the following incremental form: