Simplified Deformation Analysis of Embankment Foundation Using Soil Parameters Estimated by Plasticity Index

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ABSTRACT

This paper describes a simple procedure for evaluating deformation behavior of clay foundation under embankment, using a soil-water coupled finite element method based on finite deformation with elastoplastic model, and a simplified method for determining the soil parameters and ground modeling estimated by liquid limit, plasticity index and natural water contents. Reasonable agreements have been obtained between measured and computed values for vertical and horizontal deformations of the well documented case history of the Kurashiki trial embankment built on soft ground. Finally, the analytical results obtained by the present methods are found to be reasonable in the preliminary design, considering the idealized assumptions made and uncertainties in the data.

KEY WORDS: plasticity; finite deformation; soft ground; settlement; lateral flow

INTRODUCTION

Vertical and horizontal deformations for foundation under embankment are often large and potentially damaging to structures. The embankment fill applies vertical load to the foundation surface in combination with an outward shear stress caused by the horizontal stresses in the fill. Evaluating their magnitudes, and the rate at which they will occur, plays an important part in many geotechnical engineering projects. In addition, deformation analysis of the clay foundation under embankments is one of the necessary steps in embankment design. This deformation analysis becomes increasingly important when embankments are constructed over weak (normally consolidated cohesive stratum) significantly.

It has been a few decades since geotechnical researchers developed theoretical soil mechanics, sophisticated laboratory, in-situ testing devices and finite element method (FEM) with the powerful computers. Most researchers who are familiar with them developed the complementary approaches to performance for predicting prototype mechanical behavior with any real confidence. Ladd et al. (1977) stated that a prediction capability consists of three components: 1) a model to describe soil behavior, 2) suitable methods to evaluate the required soil parameters, and 3) computational procedures for applying the model to practical problems. The key to the success of this sort of deformation analyses largely depends on the above factors.

It was also found that the computed deformations are governed by selected soil parameters for constitutive equations and ground modeling. It appears, however, that in practice, the selection of soil parameters and ground modeling (ex. modeling of soil profile and stress history of the clay foundation etc.) from tests is not easy task. Regarding this, Kamei (1985), Nakase et al. (1988) proposed a simplified procedure to estimate the input parameters for constitutive models. This procedure can determine all the soil parameters for constitutive model considering plasticity index (PI) only. In addition, Kamei and Sakajo (1993, 1995a, 1998), Sakajo and Kamei (1996) proposed a simplified method for determining the ground modeling estimated by liquid limit, plasticity index and natural water contents. These indices can be obtained in-situ data by standard penetration test. This is used worldwide, and using it to estimate soil parameters and stress of the clay foundation is clearly economical. Finite element analysis using this procedure (Simplified deformation analysis) has been conducted extensively, and its reliability has been demonstrated (e.g. Kamei, 1985; Nakase et al., 1988; Kamei and Sakajo, 1993, 1995a, 1995b, 1998; Sakajo and Kamei, 1996; Kamei et al., 2006).

However, a number of previous studies about comparisons between predicted and observed lateral displacements have shown considerable lack of agreement, despite the agreement between predicted and observed settlements was quite good (e.g. Poulos, 1972; Tavenas et al. 1979). Many factors have been cited for poor lateral displacements prediction, such as Poisson’s ratio, anisotropy, principal stress rotation under the toe of embankment, etc (Poulos, 1972). In addition, as a one of the main factor, difference of deformation theory is cited.

Deformation theory can be divided into two types, infinite deformation and finite deformation. Infinitesimal deformation theory has used on a number of previous studies about deformation analysis (e.g. Kamei and Sakajo, 1995a; Sakajo and Kamei, 1996). In this theory, the displacement gradients are assumed that infinitesimal and geometry of a deforming body is not altered during the deformation process. To this end, the relevant governing equations are simply stated as if the body was actually undeformed. However, infinitesimal deformation theory is inadequate when the large deformation and instability problems are concerned. In these situations, deformation analysis based on finite deformation theory should be used. In recent years, finite deformation analysis has been applied to problem that localization of