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Effect of Viscosity on the Process of Consolidation with Vertical Drains

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ABSTRACT

In order to examine the effects of clay skeleton's viscosity on the process of consolidation with vertical drains, a constitutive equation which considers the viscosity as well as the quasi-yielding due to viscosity is used in the present study. The results obtained by this analysis are compared with the commonly used solution by Barron-Terzaghi and with a non-viscous linear model. A parametric study is performed with regard to the effect of viscosity (C_α), drain spacing, extent and variation of permeability in smear zone.

KEY WORDS: Consolidation, elasto-viscoplastic, void ratio rate, vertical drain, soft soil, smear zone, permeability.

INTRODUCTION

The installation of vertical drains in a soft clay layer shortens the drainage path, rapidly dissipates the pore pressure developed from construction loads and thereby increase shear strength. This consolidation process with vertical drains is usually calculated by the use of Barron's method, which is based on the assumption of equal strain and constant horizontal coefficient of consolidation. Several solutions obtained by different followers are also available for the consolidation of a unit cell considering the effect of well resistance and smear (Yoshikuni and Nakanodo, 1974, Hansbo,1981, Onoue, 1988a,1988b, Hird. et. al. 1992 etc.). On the other hand, Berry and Wilkinson (1969) critically examined the effect of C_k (slope of e-log$k$) and C_c (slope of e-logσ'), ignoring the effect of viscosity and self weight, with small strain theory and showed that the value of coefficient of horizontal consolidation, C_h, is constant, if $C_c/C_k = 1$. Based on the research thus developed on vertical drain, Hansbo (1997) proposed "the compression characteristics of the soil may have to be chosen in a conservative way with regard to the ...... secondary consolidation taking place during primary consolidation period ..." and " the discharge capacity of modern drain type...is high enough for well resistance to be neglected..."

In this study, the following three models in which vertical as well as lateral flow of water is taken into account; (I) a model combining Barron's solution and Terzaghi's one with constant C_h and C_v without viscosity (II) a linear model with variable of C_k and C_c without viscosity and (III) an elasto-viscoplastic model with quasi-preconsolidation pressure in order to take into account of viscosity during primary consolidation.

At first, numerical algorithm used to solve the problem with this model (model-III) in finite difference technique is presented. Then, the results obtained from these three models are compared to find out the effects of viscosity on the overall process of consolidation with vertical drain. The effect of smear zone is further precisely examined in terms of its lateral extents and the variation of its permeability.

EQUIVALENT CLAY CYLINDER WITH VERTICAL DRAIN

Analytical examination of consolidation with vertical drains is invariably made by the use of a unit cell (a cylinder of soil mass around a drain) as shown in Fig. 1. This unit cell has an equivalent soil mass of radius r_e centered with another cylindrical drain of radius r_w. A pervious upper surface settles vertically downward under a constant effective stress uniformly applied. The drainage of the soil mass takes place both in vertical and horizontal direction, in which horizontal one is predominant.

ASSUMPTIONS

The following assumptions and boundary conditions are used in this study:

1) The flow of pore water takes place in vertical as well as horizontal direction, however, the soil compression due to pore water movement is only in the vertical direction i.e. the deformation of the soil elements is considered to be one dimensional.
2) Permeability in the drain well and the drainage layers above and beneath the cylindrical soil mass is infinite.

$u = 0$ at $t = t$; $z = z$ and $r = r_w$

$u = 0$ at $t = t$; $z = 0$ and $r = r$

$u = 0$ at $t = t$; $z = H$ and $r = r$