A conversion procedure using plane strain cell for modeling of a test vacuum-embankment on soft peaty ground

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ABSTRACT

This paper presents a proposed conversion method from an axisymmetric unit cell to a plane strain unit cell under vacuum surcharge preloading condition. By using this method a full-scale plane strain modeling of a vacuum-embankment on soft soil can be conducted. In the proposed method, the determination of the drainage length \( l \) of the vertical drain in each soil layer is not required; besides, the plane strain unit cell of this method does not require inclusion of the plane strain smear zone. The method was validated for three cases being one homogenous clay layer, two clay layers, and a full-scale test vacuum-embankment.

KEYWORDS: Consolidation; finite element analysis; plane-strain modeling; pore water pressure; smear zone; vacuum-surcharge preloading; vertical drain.

INTRODUCTION

In recent years, one of the most advanced improvement method is to use vertical drains subjected to a combination of vacuum pressure with soil-surcharge preloading; we call this method vacuum-surcharge preloading. Consequently, the 3D and 2D simulations for this preloading technique by finite element method have been conducted in Japan to predict the deformation behavior of soft ground under this preloading technique, and a similar movement can be seen all over the world.

Nevertheless, the 3D simulation method for a full-scale subsoil improved by vertical drains under conventional surcharge or vacuum-surcharge preloading is usually impractical, because the number of cubic elements that is needed to create a converging result is usually too large (Hird et al. 1992; Hird et al. 1995; Chai et al. 1995; Indraratna et al. 1997). This leads to a very long computation time. By this fact, for the full-scale subsoil problem, the 2D simulation method, in which the deformation of subsoil is assumed to be under plane-strain condition, is usually to be preferred.

However, in reality, the performance of a vertical drain is under axisymmetric condition (see Fig.1). Therefore, a conversion procedure from an axisymmetric unit cell to an equivalent plane strain unit cell is needed. Hird et al. (1992, 1995), Chai et al. (1995), Indraratna and Redana (1997, 2000) proposed conversion procedures for the axisymmetric unit cell under conventional surcharge preloading, and only Indraratna et al. (2005) proposed a conversion procedure under vacuum-surcharge preloading condition.

In Indraratna et al. (2005) method, it is deemed that the plane strain smear zone in plane strain unit cell is needed, and the determination of drainage length \( l \) of the vertical drain is required. However, in practice, inclusion of smear zone in plane strain modeling significantly increases the number of elements and the input material parameters for the smear zone.

In addition, the drainage length \( l \) of the drain is defined to be the length from the bottom to the top of the drain within one homogenous soil layer, in which the bottom and the top of the drain are defined to be undrained and drained, respectively. Unfortunately, the subsoil usually has many soil layers; therefore, in our experience, the drainage condition of the drain at the adjoining boundary of each soil layer is not totally drained or undrained, especially in the case when the drain having high well resistance.

For these reasons, this research proposes an alternative conversion procedure from an axisymmetric unit cell to a plane strain cell under vacuum-surcharge preloading; in this procedure, the determination of the drainage length \( l \) of the vertical drain in each soil layer is not required, and the plane strain unit cell of this procedure does not require the inclusion of the plane strain smear zone.

THE PROPOSED CONVERSION METHOD UNDER VACUUM-SURCHARGE PRELOADING CONDITION

Analytical Models of The Axisymmetric and Plane Strain Unit Cells under Vacuum-Surcharge Preloading

In general, these two models are depicted in Fig. 2. In these figures, \( \sigma_1 \) denotes the surcharge; \( p_0 \) is the vacuum pressure applied to the top of the drain as well as the drain wall; \( k_1 \) is the maintaining factor of vacuum pressure \( (0 \leq k_1 \leq 1) \); \( z \) is depth; \( l \) is the drainage length as well