

A New Method For Predicting Three Dimensional (3-D) Settlement Using Groundwater Flow Analysis

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Abstract

To estimate the degree of consolidation settlement, the soil mass conservation principle was used in the analysis. The specific storage coefficient was treated as a function of effective stress and void ratio. With this method, the behaviour of consolidation from over-consolidation to normal-consolidation state is easy to analyze. To evaluate its validity, results from the new method were compared with those from laboratory tests and Terzaghi's one-dimensional analysis. From these comparisons, the proposed method has been proved to be very accurate and reliable for estimating ground settlement arising from the double-step landfill phenomenon such as Kansai Airport landfill. The results in all these show that the method has a wide application and the behaviour of three-dimensional ground consolidation can easily be analyzed.

Key words: seepage, consolidation, numerical analysis.

1 INTRODUCTION

There have been various researches about soft ground consolidation due to the existence of landfill. A lot of evaluation has been done on comparing the numerical prediction value to the measured value. The most common method used is the Terzaghi's one-dimensional consolidation theory. In the case of a three-dimensional field, the Biot's theory of consolidation which couples the equilibrium of total stress, continuity of soil mass and strain of soil formation has been useful (Biot, 1941).

In accordance with the effective stress equation and appropriate stress-strain relationship, there is a direct relationship between the excessive pore water pressure and volume change. It has now become common using Biot's equation to form constitutive equations to explain the complex behaviour of soil consolidation based on the analysis of laboratory data developed. However, applying these methods in a practical field and in more complex geological formations to estimate the consolidation behaviour in a wider area still has a lot of difficulties. The reason is that when the coupling methods are applied there are some limitations of computer memory and central processing unit (CPU) time.

To solve these limitations, a new method has been developed to estimate the 3-D behaviour of consolidation from over-consolidation to normal-consolidation states. The method is based on just 3-D groundwater flow numerical analysis with specific storage coefficient treated as a function of effective stress and void ratio.

2 NUMERICAL METHOD OF CONSOLIDATION SETTLEMENT

2.1 Method of calculation for consolidation settlement.

To simplify the problem, only the vertical phenomenon was treated for the calculation of the consolidation settlement hence the lateral deformation was not treated at all. If an assumption is made that soil particle and pore water are incompressible, then the change in volume of a cell is equal to the mass of water drained. If the water drained from each surface at any time dt is $q_i(t)$, the total drainage volume ($Q(t)$) from an element is given by Eq. (1).

$$Q(t) = \sum_l^i q_i(t) \quad (1)$$

The vertical settlement in each element equals the amount of water drained by the horizontal area (A_{xy}) as shown in Eq. (2).

$$\Delta L(t)_{elem} = Q(t) / A_{xy} \quad (2)$$

The surface settlement $\Delta\rho(t)$ is estimated from the sum of each element vertical deformation as shown in Eq. (3)

$$\Delta\rho(t) = \sum \Delta L(t)_{elem} \quad (3)$$

By using these equations, it will also be easier to estimate the consolidation by considering the individual layers settlement.

2.2 The method of calculating the variable coefficient of specific storage

The governing equation of 3-D groundwater flow is shown in Eq. (4)