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Comparison of Coupled and Uncoupled Consolidation Equations Using Finite Element Method in Plane-Strain Condition

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Abstract

In the current paper, the consolidation settlement of a strip footing over a finite layer of saturated soil has been studied using the finite element method. In Biot's coupled consolidation equations, the soil deformation and excess pore pressure are determined simultaneously in every time step which refers to the hydro-mechanical coupling. By considering a constant total stress throughout the time and by assuming that volume strain is a function of isotropic effective stress, uncoupled consolidation equations can be obtained using coupled consolidation equations. In these uncoupled equations, excess pore pressure and deformation are determined separately. In this approach, the excess pore pressure can be identified in the first stage. Using the calculated excess pore pressure, the soil deformation is determined through effective stress-strain analyses. A computer code was developed based on coupled and uncoupled equations that are capable of performing consolidation analyses. To verify the accuracy of these analyses, the obtained results have been compared with the precise solution of Terzaghi's one-dimensional consolidation theory. The capability of these two approaches in estimation of pore water pressure and settlement and to show Mandel-Crayer's effect in soil consolidation is discussed. Then, the necessity of utilizing coupled analyses for evaluating soil consolidation analysis was investigated by comparing the coupled and uncoupled analyses results.

Keywords: Coupled Consolidation Analysis; Uncoupled Consolidation Analysis; Finite Element Method; Strip Footing; Excess Pore Pressure.

1. Introduction

Consolidation of a saturated porous medium is a critical problem in geotechnical engineering. Due to the time-dependent nature of consolidation, the settlement of structures placed upon compressible soils is regarded as a significant design consideration. In practice, the consolidation theories can be used to evaluate the amount and rate of consolidation settlements. In most cases, the results of laboratory Oedometer consolidation test, based on one-dimensional consolidation theory, are used to determine the compressibility indexes and consolidation coefficient of consolidating soils. This theory was presented by Terzaghi in 1925 by using simple assumptions [1]. The major statements in this theory include:

(i) Incompressibility of solid particles and pore fluid,

(ii) One-dimensional seepage

(iii) Validity of Darcy's law to model the fluid flow through the porous medium.

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