The Primary Compression Ratio of Normally Consolidated Clays

Takahiro Yoshidomi
Ohba Co., Ltd., Chiyoda, Tokyo, Japan

Pisith Hong
Course of Architecture and Civil Engineering, Graduate School of Engineering, Tokai University, Hiratsuka, Kanagawa, Japan

Koichi Iinuma
Ohba Co., Ltd., Chiyoda, Tokyo, Japan

Motohiro Sugiyama
Department of Civil Engineering, Tokai University, Hiratsuka, Kanagawa, Japan

ABSTRACT

The purpose of this paper is to investigate the influence of the primary compression ratio on the consolidation time curve for normally consolidated clays exhibiting large secondary compression. Results of one-dimensional consolidation test are used to demonstrate that the calculated consolidation time curves are controlled by an assumption for the primary compression ratio. The significance of secondary compression during primary consolidation and the limitation of a secondary compression model are discussed.

KEY WORDS: one-dimensional consolidation; primary consolidation; secondary compression; coefficient of compressibility; primary compression ratio; finite difference analysis.

INTRODUCTION

The studies on one-dimensional consolidation analysis taking account of secondary compression are extensive. One of the earliest theories on secondary compression was formulated by Lo (1961) who suggested that one-dimensional compression is divided into primary and secondary components and secondary compression occurs during the primary consolidation stage as well as subsequently. However, in the conventional consolidation test, it is impossible to measure separately the secondary compression involved in the total compression during primary consolidation. Consequently, secondary compression behaviors during primary consolidation are not fully understood by the experimental evidence.

Some of the latest studies on secondary compression are based on the principle for evaluating settlement computation proposed by Bjerrum (1967). A series of parallel lines on e-log(p) diagram is used to represent a unique relationship between void ratio, pressure and time. In this widely used diagram, it has been postulated that the instant line for the e-log(p) relation can be approximated by the conventional compression index defined by the sum of the primary and secondary compression. Bjerrum’s concept is expressed mathematically by Garlanger (1972) and Nash (2001). In their analysis the traditional compression index is adopted commonly to calculate the instant compression component, the so-called “primary compression”. However, if secondary compression is significant during the primary consolidation stage, these predictions may be led to the overestimation of the settlement. The settlement under sustained loading continues almost indefinitely but the primary consolidation component finally ought to reach the ultimate settlement. Additional secondary compression will occur more than one day if the specimen is left under a given load. Secondary compression also may occur during the primary consolidation period although it is notable after primary consolidation is completed. The compression index or the coefficient of volume compressibility calculated by the total compression at an elapsed time of one day may include the effect of secondary compression. The compressibility defined by the primary compression cannot be conveniently determined, thereby, their experimental verifications are hindered. However, evaluating the compression index and the coefficient of volume compressibility, it is essential to consider the only primary compression. Secondary compression should be removed from the measured total compression. This paper is concerned with the evaluation for the ratio of the primary compression to the measured total compression. A simple secondary compression model is developed and solved for one-dimensional consolidation. A technique is suggested for obtaining the basic parameters of primary and secondary compressibility and the applicability of the procedure is discussed.

CONSOLIDATION EQUATION AND SECONDARY COMPRESSION MODEL

The well-known equation that governs the process of one-dimensional consolidation is expressed as follows (Terzaghi (1943)).

\[
\frac{\partial \varepsilon_v}{\partial t} = -\frac{k}{\gamma_w} \frac{\partial^2 u}{\partial y^2}
\]  

(1)

where \(\varepsilon_v\) is the time rate of the volumetric strain, \(k\) is the permeability, \(\gamma_w\) is the unit weight of water, \(u\) is the excess pore water pressure, \(t\) is the elapsed time and \(y\) is the vertical coordinate. The relationship between the effective stress and the volumetric strain