Factors Affecting Magnitude of Clay Settlement

J. Michael Duncan
University Distinguished Professor, Department of Civil Engineering,
Virginia Polytechnic Institute and State University, Blacksburg, VA, USA

Jean-Pierre Rajot
Assistant General Manager, Ecole Nationale des Travaux Publics de l'Etat, Lyon, France

Vincent J. Perrone
Geotechnical Engineering Consultant, Perrone Consulting, Inc.

ABSTRACT

The compressibility of clay depends on the duration of loading and the rate of loading, as well as load magnitude. These facts are ignored in conventional settlement analyses, in which primary consolidation and secondary compression are considered to be separate and distinct phenomena. This paper describes a theory for the time-dependent compressibility of clay that is capable of modeling both primary consolidation and secondary compression in a single, consistent analysis. Numerical analyses performed using this theory can model primary consolidation, secondary compression, "time lines," and the effect of strain rate on the magnitude of the preconsolidation pressure. The theory provides a consistent method for using all of the information obtained from laboratory consolidation tests to estimate the rate and magnitude of field settlements.

1 INTRODUCTION

The compressibility of clay increases as rates of loading decrease, and secondary compression continues after all excess pore pressures have dissipated. It is unclear how these important effects should be included in predictions of settlements of thick clay deposits. Two extreme hypotheses (Jamiolkowski et al., 1985) result in greatly different settlements, and offer little guidance for important problems.

A theory of clay compression described in this paper is capable of modeling various aspects of the behavior of clays, including secondary compression, time lines, ageing, and variation of preconsolidation pressure with rate of strain. The new theory results in calculated settlements between those predicted by the extreme hypotheses, and appears to offer an improved method of predicting the settlement of thick deposits of clay.

2 MECHANISM OF CLAY COMPRESSION

The magnitude of settlement due to increased load on a deposit of clay is affected by the magnitude of the increase in stress, the stress history and age of the deposit, and the duration of the load. Compression continues after load application for two reasons: (1) compression can only proceed as fast as water is able to flow out of the voids in the clay, which causes hydraulic impedance, and (2) the compressibility of the soil skeleton itself is affected by time. It is readily apparent that the compressibility of clay varies with time of loading because compression continues to after the load on the soil skeleton becomes constant, in the process called secondary compression.

Terzaghi's theory of consolidation provides clear insight into hydraulic impedance. The model of clay compressibility used in that theory is simple time-independent, linear compressibility, as shown in Figure 1(a). With that simple model of clay compressibility, all time delay in compression is due to the time required for water to escape. A more complete model for the compressibility of clay is shown in Figure 1(b). It involves a complex spring (nonlinear compressibility), a complex slider allowing for irrecoverable strains during compression, and a complex spring and dashpot capable of modeling secondary compression under constant load. With this model of clay compressibility, time delay in compression is due to both hydraulic impedance and the rheologic behavior of the soil skeleton.

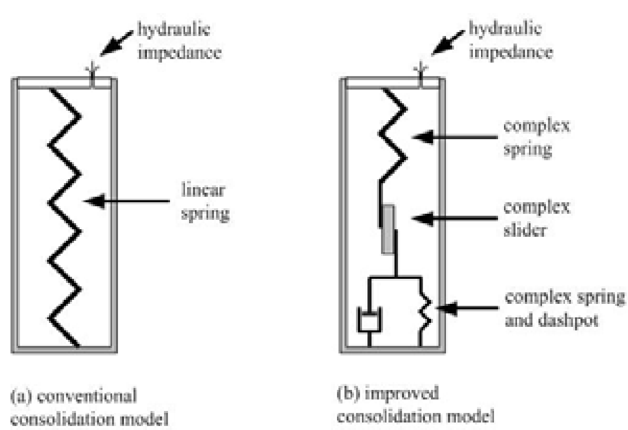

Figure 1. Consolidation mechanisms.