Experimental Study of Time-Dependent Behavior of Clays Subjected to Loading and Unloading with Constant Rate of Strain

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ABSTRACT

Improving soft ground by the preloading method is economical because additional operations are not needed. In this method, the ground characteristics during loading, unloading, and post-loading are studied. In general, settlement during post-loading should be small because the post-loading pressure is less than the loading pressure. However, there have been several examples of settlement occurring during post-loading. In this study, the loading history was simulated by a constant rate of strain (CRS) test to determine the secondary consolidation behavior during the post-loading process. The results of this study were as follows: (1) the loading history is simulated by the CRS test, (2) secondary compression index depends on the over-consolidation ratio, (3) the coefficient of secondary consolidation changes with time, and (4) when post-loading is induced, the coefficient of secondary consolidation is smaller than when there is no previous loading history.

KEYWORDS: constant rate of strain test; constant loading test; incremental loading test; secondary consolidation; over-consolidation ratio; clay; loading history

INTRODUCTION

In general, standard consolidation tests are used to predict the consolidation behavior of structures and embankment fill constructed on soft clay ground. These tests are used widely because the test methods are simple and various methodologies have been developed for interpreting the test results. However, carrying out the tests can be time-consuming because running one cycle of the run takes one day and several repetitions are required. The constant rate of strain (CRS) test proposed by Crawford (1964) significantly reduces the test duration by measuring the load through successive constant displacements. Its theoretical interpretations have been established by Wissa et al. (1971). The CRS test has been standardized and is now widely used in practice. Various construction methods are employed to enhance soft clay ground. Preloading methods are applied to reduce residual settlement in land development projects such as highway construction. This method utilizes consolidation for a sufficient duration by loading more than the structural load in advance. The overburden pressure is then removed, and the ground is over-consolidated. Since the structure is constructed on over-consolidated land, residual settlement occurs rarely. However, residual settlements have been reported in reality and cannot be ignored. To produce a solution for such problems, experimental studies should be carried out to determine the amount and duration of the banking material loading. Such experiments are usually carried out by performing a state loading operation until the pressure corresponding to the preloading status is reached; the load is then reduced to the point corresponding to the structural load and is retained for a long time. In this study, long-term consolidation was performed by running a load until the pressure corresponding to the preloading status was reached in the CRS test; the load was then released, and a constant pressure was applied to evaluate the secondary consolidation behavior in long-term consolidation. Further, the effects of loading methods were determined by comparing the results of the incremental loading (IL) test, in which increasing pressure is applied until it corresponds to the preloading status, with the secondary consolidation behavior.

ANALYSIS OF POST-LOADING SECONDARY COMPRESSION

Figure 1 shows the typical relationship between settlement and elapsed time in pre-post-loading. The removal of loading leads to a rebound, including the primary rebound up to \( t_p \) and the secondary rebound that levels off at \( t_l \). It is followed by secondary compression. Since both field and laboratory data show an initial increase in \( C_n \) with time, post-loading secondary settlement is expressed in terms of the secant secondary compression index \( C_n^s \). Interpreting laboratory data from present and previous investigations have revealed that \( C_n \) and \( t_l \) are functions of the effective over-consolidation ratio. In general, the post-loading secondary compression index \( C_n^s \) as defined in Fig. 1, is initially small and gradually increases with time. It continues to increase, level off, or level off and then decrease with time. Because \( C_n^s \) is not constant with time, the secant \( C_n^s \) is used for practical settlement analysis; it is defined from the time \( t_l \) at which post-loading secondary compression begins to any \( t \) at which post-loading secondary compression is to be evaluated (Al-Shamarani et al., 1997, Mesri et al., 1973, 1977, 1984, 1987).