Consolidation Analysis of Sri Lankan Peaty Clay using Elasto-viscoplastic Theory

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Abstract

The consolidation of peat is complex due to the resultant large strain associated with the highly compressible nature of natural peat deposits and to the rapid changes in soil properties during the consolidation process. In addition, the consolidation process is further complicated by the occurrence of secondary compression which significantly contributes to the overall settlement of peaty soil. Therefore, it is necessary to take these properties into account in order to obtain better predictions from peat consolidation analyses. In the present study, the consolidation behavior of peaty clay found in Sri Lanka is extensively studied using a model based on the elasto-viscoplastic theory. The model can describe the prominent creep behavior of peaty soil as a continuous process. In addition, the model can accommodate the effect of structural degradation on the consolidation process. The analysis takes into account all the main features involved in the peat consolidation process, namely, finite strain, variable permeability, and the effect of secondary compression. Also, it considers the variable compressibility for stage-constructed embankments which exert high levels of pressure on the peaty subsoil.

The constitutive equations used in the model and the procedure adapted to account for the above-mentioned features of the analysis are described. The constitutive model is based on Perzyna's type viscoplastic theory and the Cambridge elasto-plastic theory combined with empirical evidence. In the finite element formulations, which are based on the finite deformation theory, an updated Lagrangian method is adopted. A description of the material parameters used in the model and the procedures applied to evaluate them, with standard laboratory and field tests, are explained. In addition, a performance of the model incorporating the original and the modified Cam-clay theory is evaluated by simulating triaxial test results. A comparison shows that with the present definition of the parameters, the original model yields more representative results than the model based on the modified Cam-clay theory.

Initially, the capability of the constitutive model to capture the consolidation behavior is verified using the consolidation model test data on peaty clay found in Sri Lanka. It is confirmed that the constitutive model is able to predict the observed creep characteristics and the effect of sample thickness on settlement predictions for the material under consideration.

The performance of the model in predicting the consolidation behavior under field conditions is studied using field data on instrumented earth fill constructed on peaty clay. One-dimensional compression is assumed for the peaty clay due to the large plane area of the fill. Separate analyses are carried out by the model considering the infinitesimal strain theory, the finite strain theory, and the finite strain theory together with the effect of structural degradation in order to explore how these features describe the observed field

behavior. Analyses reveal that it is necessary to consider finite deformation together with the effect of structural degradation in order to successfully simulate the resultant large strain and the stagnated pore water pressure observed in the field.

The construction of road embankments over peat deposits is quite problematic, and thus, it is often done after first improving the properties of the peaty soil through the utilization of appropriate ground-improvement techniques. Understanding the field response of peaty clay during this improvement process is naturally of great importance. A constitutive model is applied to predict the field performance of embankments constructed on peaty clay using different ground-improvement techniques. The back analysis of embankments constructed with the preloading method indicates that the model can be successfully applied to predict both the deformation and the stability of structures constructed on peaty clays. The stability of the embankment during and after construction is verified by investigating the stress-strain characteristics of the subsoil.

The model applications used to predict the consolidation behavior of embankments constructed by the preloading method, combined with other ground-improvement techniques, are then discussed. Embankments constructed with prefabricated vertical drains (PVDs) and sand compaction piles (SCPs) are considered, and finite element analyses are carried out in all cases by converting the actual three-dimensional conditions that exist around the drains into simplified two-dimensional plane strain conditions. The field behavior when PVDs are installed in the peaty clay is simulated using the equivalent vertical permeability for the PVD-improved subsoil. In the case of SCPs, a conversion scheme is used to transform the axisymmetric nature of sand columns into equivalent plane strain conditions. A comparison of the predicted results with the field observations shows a reasonable agreement. An analysis of the PVD-improved foundation indicates that the installation of PVDs not only accelerates the rate of consolidation, but influences the deformation pattern of the subsoil due to embankment loading. The analysis also shows that the use of PVDs can significantly increase embankment stability. The model prediction for the SCP-improved foundation reveals that the stiffness and the area replacement ratio used in the conversion scheme play vital roles in predicting the behavior of SCP-improved soft grounds. The observed improvements in the bearing capacity of the subsoil and in the stability of the embankment, brought about by the installation of SCPs, can be simulated by the model.

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