Rapid Drawdown Analysis using the Finite Element Method

Daniel R. VandenBerge, J. Michael Duncan, and Thomas L. Brandon

ABSTRACT

Rapid drawdown (RDD) occurs when the water level adjacent to a slope or embankment is lowered quickly after a long period of being elevated either at the normal operating level for a dam or in the case of levees, during a prolonged flood. The current state of practice for RDD analysis is a multi-stage undrained strength method based on limit equilibrium.

The primary objective of this research was to develop a new method for rapid drawdown based on the finite element method. The new method estimates undrained strengths based on effective consolidation stresses from finite element analysis and the results of isotropically consolidated undrained triaxial compression (ICU-TC) tests. The field strengths appropriate for use with this rapid drawdown method were found to be on average 70% of the strength measured in ICU-TC tests based on back analysis of rapid drawdown failures. For rapid drawdown, anisotropic consolidation, plane strain deformation, and principal stress rotation were shown to produce field undrained strengths in the range of 60 to 80% of the strengths measured in isotropically consolidated undrained (ICU) triaxial compression. The current limit equilibrium method for rapid drawdown was shown to produce a similar reduction in ICU-TC strength.

This study also investigated other issues related to RDD. Effective stress analysis of RDD, especially using uncoupled transient seepage analysis, was shown to be inappropriate because important aspects of soil behavior are ignored. Consolidated-undrained strength tests on compacted clay specimens highlighted the importance of relative compaction on undrained strength. Anisotropic consolidation was shown to produce lower undrained strengths in triaxial compression than isotropic consolidation, especially at higher consolidation stresses. The behavior of compacted specimens under principal stress rotation was investigated using triaxial and direct simple shear tests. Finally probabilistic methods were applied to RDD to assess the probability that the factor of safety is less than one, assuming RDD occurs.