Embankments Stability Analysis Based on Limit Equilibrium and Finite Element Methods

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Abstract
In the assessment of slopes, factor of safety values still remain the primary indexes for determining how close or far slopes are from failure. Traditional limit-equilibrium techniques are the most commonly-used analysis methods. Recently, however, the significant computing and memory resources typically available to the geotechnical engineer, combined with low costs, have made the Finite Element Method (FEM) a powerful, viable alternative. The Shear Strength Reduction (SSR) technique enables the FEM to calculate factors of safety for slopes. The method enjoys several advantages including the ability to predict stresses and deformations of support elements, such as piles, anchors and geotextiles, at failure. Despite the SSR finite element technique's many benefits, it has not received widespread adoption among geotechnical engineers for routine slope stability analysis. This could be probably due to the very limited experience engineers have had with the tool for slope stability analysis, and limited published information on the quality/accuracy of its results.

Keywords: Slope Stability, Limit Equilibrium, Shear Strength Reduction, Finite Element Method, FS.

1. Introduction

In spite of all experience obtained over the last decades, designing an embankment on a soft soil still raises several concerns related to the weak geotechnical properties of the soft soil: (1) its low shear strength significantly limits the embankment height that is possible to undertake with adequate safety for short term stability and (2) its high deformability and low permeability determine large settlements that develop slowly as pore water flows and excess pore pressure dissipates. Geotechnical engineers commonly perform slope stability analyses to determine the factor of safety against shear failure near the edge of an embankment. Ordinarily, limit equilibrium methods are used to find the critical failure surface that shears through the embankment.

In the assessment of slopes, engineers primarily use factor of safety values to determine how close or far slopes are from failure. Conventional limit-equilibrium techniques are the most commonly-used analysis methods. Recently, however, the significant computing and memory resources available to the geotechnical engineer, combined with low costs, have made the Finite Element Method (FEM) a powerful, viable alternative. The Shear Strength Reduction (SSR) technique [Dawson et al, 1999; Griffith and Lane, 1999; Hammah et al, 2004; Han et al., 2005;Won et al.;, 2005; Cheng et al., 2007; Han et al., 2008; Sun et al., 2008; Srivastava and Sivakumar Babu, 2009] enables the FEM to calculate factors of safety for slopes. The method enjoys several advantages including the ability to predict stresses and deformations of support elements, such as piles, anchors and geotextiles, at failure. As well the technique makes it possible to visualize the development of failure mechanisms. Advances in program interfaces and competitive computational times help account for the method's attractiveness.

Despite the SSR finite element technique's many benefits, it has not received widespread adoption among geotechnical engineers for routine slope stability analysis. In the authors' opinion this is primarily due to the very limited experience engineers have had with the tool for slope stability analysis, and the limited published information on the quality/accuracy of its results. To improve confidence in the SSR technique, this paper will compare the method's performance to those of well-established limit-equilibrium methods on a broad range of slope cases. These cases have all been reported in literature, and have been used to verify the results of some slope stability programs (Rock science 2003).