Reliability Assessment of Vertical Cut by Limit Equilibrium and Finite Element Models

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Abstract

Uncertainty in soil parameters comes from its inhomogeneity, including factors that reduce certainty in geotechnical analysis is considered. Accordingly, compared with a deterministic analysis, probabilistic analysis capabilities inherent variability and uncertainty in input parameters in geotechnical engineering has gained a special place. In this research, the reliability of a vertical cut in cohesion soil is assessed by limit equilibrium and finite element methods. In limit equilibrium approaches an analytical method is used and in finite element method PLAXIS 2D is utilized. The selected stochastic parameters are height, cohesion, unit weight and elastic modulus, which are modeled using a truncated normal probability distribution function. The angle of slope relative to vertical is regarded as constant parameter. Finaly to evaluate the model response to changes in input parameters, a sensitivity analysis was carried out. Comparison of the results indicates the probability density functions of two methods are close to each other.

Keywords: Reliability, Jointly distributed random variables, Monte Carlo simulation, Finite element, slope stability.

1. Introduction

Traditional methods of stability analysis of slopes, such as limit equilibrium method [1–4], are restricted by the use of single valued parameters to describe the slope characteristics. Consequently traditional analysis methods yield single valued estimates of the slope's stability. However, the inherent variability of the characteristics which affect slope stability dictates that slope stability problem is of a probabilistic nature rather than being deterministic. In other words, stability of a slope is a random process that is dependent on the distributions of the controlling parameters.

In general, two main observations can be made concerning the existing body of work on this subject. The first common approach accounts for the uncertainty in the geometrical properties of the failure network in the slope, and the second one considers uncertainties in the slope performance. Uncertainty in the geometrical characterization of failure within the soil mass has led to the development of stochastic failure network models which are widely discussed and well documented in the literature [5, 6]. In the second approach which is frequently used in slope stability analyses, the aim is to find the probability of slope failure given uncertain input parameters in the stability analysis model. In this category, the output of slope stability analysis is a probability distribution of either factor of safety for a fixed slope height, or a probability distribution of critical height for a fixed level of factor of safety.

Many probabilistic techniques have been devised for analysis of stability of slopes with uncertain input parameters. These methods can be grouped into five categories: analytical methods, approximate methods, Monte Carlo simulation, response surface method and stochastic finite element method.

In analytical methods, the probability density functions of input variables are expressed mathematically. They are then integrated analytically into the adopted slope stability analysis model to derive a mathematical expression of the density function of the factor of safety. The Jointly Distributed Random Variables (JDRV) method lies in this category [7,8]. A recent research has been made to apply analytical method to slope stability analysis by JDRV method [9].

Most of approximate methods are modified versions of three methods namely, Point Estimate Method [10,11], First Order Second Moment reliability method (FOSM) [12] and First Order Reliability Method (FORM) [13]. All these approaches require knowledge of the mean and variance of all input variables as well as the performance function that