

Probability and Risk of Slope Failure

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Abstract: This paper aims to demystify the use of risk assessment as a decision management tool and present a methodology that places quantitative risk assessment within reach of every geotechnical engineer, even for routine engineering assignments. In particular, we propose using quantification of expert judgment (i.e., subjective probabilities) as a practical alternative for determining probability of slope failure. The writers present a semiempirical relationship between factor of safety and annual probability of failure that permits estimation of slope failure probabilities with relatively modest effort. The case study for a tailings dam shows that risk assessment based on quantification of expert judgment provides a framework to arrive at rational management and engineering decisions related to dam safety and other geotechnical problems. Using the semiempirical relationship presented here, practicing engineers can use this helpful tool by applying their current skills.

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Introduction

This paper presents a risk assessment methodology the writers use in the practice of geotechnical engineering. This methodology has evolved over the last 30 years in response to client's needs for quantified risk assessments at affordable costs. Owners and operators of industrial facilities understand the concept of risk. Risk concepts and risk management form part of many management programs. These owners and operators expect engineers to provide probability and risk data to help them make informed business decisions. Although geotechnical engineers have applied probability and risk concepts for several decades, too frequently the numbers proved difficult to support or dependable numbers required prohibitively costly investigations, evaluations, or modeling.

When considering slope stability problems in geotechnical engineering, an early step consists of correctly determining the level of safety of a slope. Numerous references exist to help engineers with this task (Lambe and Silva 2003; Duncan and Wright 2005; Cornforth 2005). A correct determination of level of safety should properly handle the three geotechnical fundamentals that control slope stability: geometry, pore pressures, and strength. Lambe and Silva (1992) have shown that nearly all the methods commonly used to integrate these fundamentals into determination of a safety factor provide similar answers when

done correctly. The engineer should focus his effort on obtaining a representative geometry (surface and subsurface) and correctly defining pore pressures and strength.

This paper moves beyond the determination of safety factor to:

1. More fully understand the significance of level of safety;
2. Describe a practical method of risk-based decision making for situations involving slope failures; and
3. Illustrate that geotechnical engineers have all the necessary skills to perform these risk-based analyses through an example.

The engineering literature (Morgenstern 1995; Vick 1994; and others) identifies three commonly accepted ways of estimating event probabilities:

1. Based on frequency of observations (historical data);
2. Derived from probability theory (mathematical modeling); and
3. Quantification of expert judgment (subjective probabilities).

The main objective of this paper is focused on demonstrating that quantification of expert judgment provides the engineer with a practical method to determine probabilities for risk analyses. We combine historical and subjective probabilities to obtain a correlation between safety factor and failure probability suitable for use in engineering practice.

Probability of Failure

When involved with a potentially unstable slope, engineers want to know whether or not the slope will fail. Since there are many uncertainties that affect this determination, the engineer has to settle for estimating the probability of whether the slope will fail. One can estimate the probability of a failure (or of any other event occurring) using one of the three methods listed in the previous section. All three methods have wide acceptance within the profession. Benjamin and Cornell (1970) state: "The sources of these probabilities may include observed frequencies, deductions from mathematical models, and in addition, measures of an engineer's subjective degree of belief regarding the possible states

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