Reliability Analysis On The Stability Of Slope

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A project report submitted in partial fulfillment of the requirement for the award of the degree of Master of Engineering (Civil Engineering – Geotechnics)

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MARCH 2005

ADKNOWLEDGEMENTS

I would like to express my heartfelt gratitude to my supervisor, Dr. Nurly Gofar for her valuable advice and great encouragement as well as for her excellent guidance and assistance for this research. I am also indebted for the amount of time and effort she has spent reading and correcting my thesis.

A special thanks to my friends, who have given tremendous support throughout my engineering degrees. Lastly, I am very thankful to my family members for their support and encouragement.

ABSTRACT

Slope stability is one of the geotechnical subject most dominated by uncertainty. The current practice in slope stability analysis is based on the limit equilibrium and not directly addresses uncertainty. The objective of this study is to integrate probabilistic approach as a rational means to incorporate uncertainty in the slope stability analysis. The study was made through a hypothetical problem which includes a sensitivity analysis, and two real cases. The methodology is based on Monte Carlo simulation integrated in commercially available computer program SLOPE/W. The output of the analysis is presented as the probability of failure as a measure of the likelihood of the slope failure. Results of this study have verified that the probability of failure is a better measure of slope stability as compared to the factor of safety because it provides a range of value rather than a single value.

ABSTRAK

Kestabilan cerun merupakan salah satu subjek geoteknik yang dibelenggui oleh ketidakpastian. Penggunaan umum masa kini dalam taksiran kestabilan cerun adalah berdasarkan had keseimbangan dan ia tidak dapat menangani unsur-unsur ketidakpastian. Objektif kajian ini adalah untuk mengintegrasikan kaedah kebarangkalian dalam analysis cerun supaya unsur ketidakpastian dapat dinilai. Kajian ini dijalankan melalui satu masalah andaian dan dua kajian kes. Metodologi kajian ini melibatkan penggunaan Simulasi Monte Carlo yang sediada dalam perisian SLOPE/W. Hasil analisis disampaikan dalam bentuk kebarangkalian gagal yang boleh dijadikan sebagai ukuran kemungkinan gagal sesuatu cerun. Hasil kajian ini membuktikan kebarangkalian gagal merupakan kaedah yang lebih bagus berbanding dengan faktor keselamatan kerana ia membekalkan satu julat nilai dan bukannya satu nilai sahaja.

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CDF	-	Cumulative distribution function
COV	-	Coefficient of variation
c	-	Cohesion
c’	-	Effective cohesion
D	-	Line load
E, T, X	-	Shear force
FOS	-	Factor of safety
F_m	-	Moment equilibrium factor of safety
F_f	-	Force equilibrium factor of safety
k	-	Coefficient of permeability
N’	-	Normal force
PDF	-	Probability density function
P_f	-	Probability of failure
r_u	-	Pore pressure coefficient
s or SD	-	Standard deviation
S_u	-	Undrained shear strength
U	-	Water force
u	-	Pore water pressure
W	-	Weight
$\bar{x}$	-	Mean value or expected value
τ_m	-	Shear strength
ϕ	-	Angle of friction
ϕ’	-	Effective angle of friction
α	-	Angle
β	-	Reliability index
γ	-	Unit weight

CHAPTER 1

INTRODUCTION

1.0 Overview

The stability of slopes is of great importance to geotechnical engineers worldwide. In Malaysia, the collapse of Block 1 of Highland Towers in 1993, slope failure at Taman Hillview in November 2002 and the recent tragic landslide at Bukit Lanjan in 2003 had prompted our government and public to concern about the stability of slope and the risk involve in such occasion. Hence, it is importance that the current practice of slope stability analysis to be revised in order to minimize the tragedies.

Nowadays, most of the slope analysis and design are based on deterministic approaches. The shear strength, slope geometry, external load and pore water pressures are assigned as specific unvarying values and as a result, single factor of safety is then determined. However, the single deterministic safety factor of a slope is often not enough to analyze the slope stability due to uncertainty in input parameters.

Probabilistic methods were introduced in the late sixties,, most notably by Wu and Kraft (1970), to quantify the sources of geotechinical uncertainties and to study the effect of those uncertainties on the reliability of a slope. In slope problem, uncertainty arises as a result of the variability of soil parameters, systematic error,

changing environmental conditions, unexpected failure mechanism, simplifications and approximations adopted in geotechnical model and human error. The impact of uncertainty on the performance predictions in geotechnical practice is substantial (Morgenstern, 2000). Therefore, the implementation of statistic method is essential in the evaluation slope performance.

Reliability analysis or probabilistic methods are gradually being accepted in civil engineering because of economic and theoretical pressures (Mostyn and Li, 1993). The concept of probabilistic slope stability analysis (PSSA) had developed since 70's and wealth in literature. However, the adoption of the method in geotechnical design is slow. There are some reasons toward it. First, lack of formal training in statistics and probability theory among geotechnical engineers. Second, there is a common misconception that probabilistic analyses require significant amounts of data, time and effort and are, thus, not practical. Finally, poor definition on the limits of the acceptable probability of failure and the there is no link between a probabilistic assessment and a conventional deterministic assessment. These make the understanding of probabilistic analysis difficult.

1.2 Problem Statement

Most slope analysis and design is based on deterministic approach i.e a set of single valued design parameter are adopted and a set of single valued factor of safety (FOS) is determined. Usually the FOS is selected in view of the understanding and knowledge of the material parameters, the problem geometry, the method of analysis and the consequences of failure. This results in different FOS obtained by different designers. This inherent variability characteristic dictates that slope stability problem is a probabilistic problem rather than deterministic problem. Furthermore, the FOS approach cannot quantify the probability of failure or level of risk associated with a particular design situation.

Given the appeal of probabilistic slope stability analysis (PSSA) and the advanced state-of-practice of reliability techniques, there is a need to facilitate the adoption of PSSA concept in slope design practice among geotechnical engineer.

1.3 Objective

The objective of this research is to integrate reliability concept into slope stability analysis by developing a probabilistic model using Monte Carlo Simulation integrated in readily commercial software, SLOPE/W. The output of this study is the probability distribution of factor of safety and reliability index of a slope.

1.4 Scope

The study is focused on the use of Monte Carlo simulation integrated in SLOPE/W software package to analyze the probability of failure of a slope. The analysis is made using Bishop Method where circular failure surface is assumed. The critical slip surface is determined based on the mean value of the input parameter. Sensitivity analysis is conducted on the variability of the soil parameters and the position of groundwater table.

5.3 Recommendations

This research demonstrated the feasibility of probabilistic slope analysis. However, before this research is implemented into practice several issues need further development and refinement.

1. The main draw back in the use of reliability analysis is the scarcity of suitable data, quantitative information about how closely these data represent field conditions and determination of the correlation coefficient between the random variables representing soil parameter.

2. In SLOPE/W, the critical slip surface is first determined based on the mean value of the input parameters in deterministic analysis. Probabilistic analysis is then performed on the critical slip surface. However in reality, the critical slip surface from deterministic analysis may not be the critical slip surface for probabilistic analysis.

3. The variability of the input parameters in SLOPE/W is assumed to be normally distributed with user-specified mean values and standard deviations. This will give result that are not correctly simulated the soil conditions.

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