EFFECT OF SLOPE ANGLE AND SOIL PROPERTIES ON DEFORMATION AND STABILITY OF CUT SLOPES

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EFFECT OF SLOPE ANGLE AND SOIL PROPERTIES ON DEFORMATION AND STABILITY OF CUT SLOPES

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

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I declare that this thesis entitled "*Effect of Slope Angle and Soil Properties on Deformation and Stability of Cut Slopes*" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently in candidature of any other degree.

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To My Beloved Mother and Father …

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ABSTRACT

The rapid development of an area has led to the cutting of natural slopes to form man made slopes which will induce deformation and reduction in the stability of the slope itself. The first part of the project focuses on the parametric study on the influence of soil parameters and slope angle on the deformation and stability of a slope. A total of 48 analyses were carried out on six types of soil with four slope configurations. The analysis was carried out in two parts, which are, deformation and stability analysis using finite element method and Strength Reduction Technique (SRT) as well as stability analysis using Limit Equilibrium Method (LEM). The outcome of this study is presented in the form of charts for preliminary design of excavated slopes. The application of the charts is demonstrated through a case study of a cut slope. The chart predicts that the slope will have deformation of 15 mm and the factor of safety of 1.12 while finite element analysis shows that the deformation of the case cut slope is 8.93mm. Meanwhile, the factor of safety by SRT and LEM are 1.29 and 1.33 respectively. Hence, the slope is in satisfactory condition. The results obtained from the charts show some differences due to the assumptions and limitation used in the parametric study. However, the differences are in the safe side, thus, in the absence of more sophisticated tools, the chart can be used as preliminary estimation of slope deformation and stability.

ABSTRAK

Pembangunan yang pesat di sesuatu kawasan telah menyebabkan pemotongan cerun semulajadi untuk membentuk cerun potongan yang akan membawa kepada deformasi and pengurangan kestabilan sesuatu cerun itu. Bahagian pertama dalam projek ini tertumpu kepada kajian parametrik pada pengaruh parameter tanah dan sudut cerun terhadap deformasi dan kestabilan cerun. Sejumlah 48 analisis dilakukan pada enam jenis tanah dengan empat konfigurasi cerun. Analisis dilakukan dalam dua bahagian, iaitu, deformasi dan analisis kestabilan menggunakan kaedah FE dan SRT serta analisis kestabilan menggunakan kaedah keseimbangan batas. Keputusan kajian tersebut dibentangkan dalam bentuk grafik untuk reka bentuk awal cerun potongan. Aplikasi grafik ditunjukkan melalui kajian kes cerun potongan. Graf meramalkan bahawa cerun potongan tersebut akan mempunyai deformasi sebanyak 15mm dan faktor keselamatan 1.12 sedangkan analisis finite element menunjukkan bahawa deformasi cerun potongan adalah sebanyak 8.93mm. Sementara itu, faktor keselamatan oleh SRT dan LEM adalah 1.29 dan 1.33 masing-masing. Oleh itu, cerun berada dalam keadaan stabil. Keputusan yang diperolehi daripada graf menunjukkan sedikit perbezaan kerana andaian dan keterbatasan yang digunakan dalam kajian parametrik. Namun, perbezaan berada di belah yang selamat, dengan demikian, dengan ketiadan alat-alat yang canggih, graf tersebut boleh digunakan sebagai anggaran awal deformasi dan kestabilan cerun.

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c	-	cohesion
c’	-	effective cohesion
E	-	Young’s Modulus
F	-	failure function
FS	-	factor of safety
s	-	available shear strength
TD	-	total displacement
β	-	slope angle
γ_{dry}	-	dry unit weight
γ_{wet}	-	wet unit weight
ε	-	strain
ν	-	Poisson’s ratio
σ	-	stress
σ_n	-	normal stress
τ	-	equilibrium shear stress
τf	-	shear strength at failure
ø	-	angle of internal friction
ø’	-	effective angle of internal friction

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CHAPTER 1

INTRODUCTION

1.1 Background

Many countries have experienced natural disasters such as landslide, slope failures and soils collapse due to the lack of planning in dealing with sloping ground. Demand for engineered cut and fill slopes on construction projects has only increased the need to understand analytical methods, investigative tools, and stabilization methods to solve slope stability problems since man-made slope has disrupted the delicate balance of natural soil slopes. Existing natural soil slopes have been cut to form man-made slope in the name of rapid infrastructure development in the past fifty years has caused an imbalance in natural formations. Disturbance to soil particles due to construction has led to soil instability and deformation of slope faces. The movement or instability of natural slopes or man-made slopes has become a common civil engineering problem for many construction works and sometimes has major socio-economic impacts on the society (Lee, 2003).

Man-made slopes exist all over the world. In mountainous areas natural slopes are adapted for construction of roads and other infrastructure. In deltaic regions man-made slopes are created by construction of embankments and dykes. The qualities posed by nature often are not well studied during the pre-investment phase in a project in which stability problems may threaten the safety and economy of exploitation of the product during its engineering lifetime. Design of man-made

slopes should be based on evaluation of the natural physical, hydrological and rock and soil mechanical conditions. (Rupke, *et al*, 2006)

Stability of slopes is controlled by several factors including stratigraphy, groundwater levels, seepage gradients, weathering profiles, inaccurate measurement, shear strength of the soil or rock mass, geometry, modes of failures and methods of analysis. Hence, the stability of slopes depends on the internal factors such as soil strength and groundwater level as well as external factors such as external loads which induce destabilizing forces on the slope. Lee (2003) has stated that soil mass located beneath a sloping ground surface has a tendency to move downward under the influence of gravity. If the shearing resistance of soil is adequate, the slope is stable. Otherwise, slope tends to move and this cause instability conditions.

The study and analysis of slopes is essential for understanding their performance and, in particular, their stability, reliability and deformations. Thus geotechnical engineers often seek to calculate values of quantitative indicators of performance such as the factor of safety (safety factor), lateral deformation, and probability of failure and reliability index.

Limit equilibrium method are commonly adopted for the stability analyses of slope. This approach gives factor of safety as indication of the stability of the slope while adopting of probability concept results in the probability of failure and reliability index. Soil deformation may be simulated using numerical modeling which has made significant strides in the past fifty years. By using numerical modeling, engineers are now able to simulate detailed aspects of the construction process for a variety of problems including embankment loading, deep excavation, tunnels, and other static or dynamic soil-structure interaction boundary value problems.

Finite element or the finite difference methods are numerical techniques available to solve equilibrium equations governing the boundary value problem. PLAXIS, FLAC and SIGMA/W are numerical modeling tools commonly use in simulating the soil behaviour and deformation.

1.2 Problem Statement

The rapid development of an area has led to the cutting of natural slopes to form man made slopes which will induce deformation and reduction in the stability of the slope itself. In general, the factor of safety calculated based on limit equilibrium method for idealized slope geometry. In reality, the excavation activities to form a cut slope can induce deformation of the slope face. Therefore, it is very important to predict the amount and direction of soil displacement due to the deformation and calculate the slope stability based on the actual geometry. In this project, the deformation and stability analysis of a slope cut according to area development were conducted by taking into account the factor of safety obtained by Simplified Bishop method in limit equilibrium analysis. Therefore, the trends of the deformations and factor of safety are studied for changes in degree of slope angles for different types of soil.

1.3 Objectives of Study

The objectives of this study are:

a) to determine the effect of slope angle on the deformation and slope stability by parametric study
b) to develop charts that correlates the slope angle, soil properties and factor of safety as well as maximum deformations for preliminary assessment of slope stability
c) to validate the application of the charts by using case study of cut slope

1.4 Scope of Study

The study is focused on deformation and stability analysis of cut slopes of various slope angle mainly for two types of soil which is cohesive soil and

cohesionless soil. For cohesive soil, it is grouped into three types which is soft clay, medium clay and stiff clay and meanwhile, cohesionless soil also grouped into three types which is loose sand, medium sand and dense sand. The study is also focused on the Finite Element and Limit Equilibrium Method analysis of a man-made cut slope for the road widening construction project at Damansara Perdana, Petaling Jaya. Both analyses are made using Strength Reduction Technique and Simplified Bishop Method since the analysis is considered for a long term analysis.

1.5 Importance of Study

The importance of the study is the evaluation of the effects of various degree of slope angle on slope deformation and stability for different types of soil; and long term stability and deformation analysis of a man-made cut slope. Furthermore, it is important to understand the role of deformation of cutting slope in predicting the failure. A practicing geotechnical engineer may save time, quality and cost in dealing with slope problem if the deformation of the slope face can be predicted and adopted for analysis during the design stage.