SLOPE STABILITY ANALYSIS OF CRITICAL SLOPE ALONG NORTH SOUTH HIGHWAY (SOUTHERN REGION) USING LIMIT EQUILIBRIUM METHOD

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DEDICATION

To
The Almighty Allah
that granted me with
patient and strength
to complete this project.

To
Beloved Mother and Father

To
My beloved wife and all my kids,
your love and support are much appreciated

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ABSTRACT

The occurrence of slope failure is always hard to be predicted. Hence, slope stability analysis must be often carried out in order to ensure the slope is safe and also minimise the probability of slope failure. The slope stability analysis is a prediction on what conditions that can make the slope fail. In this study, the Limit Equilibrium approach is used to determine the degree of stability in terms of Factor of Safety (FOS). Malaysia climatic condition that governed by wet and dry periods will give an effect to the FOS of the slope in terms of shrinkage and creep that accelerate the development of tension cracks on the slope surface. The Proposed Slope Stabilization Works at KM 16.10 (Northbound) Machap - Skudai Expressway has been chosen as a case study. This slope is considered as critical slope because it has been experience a failure in 2004. Tension cracks and high intensity rainfall has been specified as a factor that accelerate the probability of slope failure. The results obtained using SLOPE/W shown that, the slope analyzed is still intact with the minimum FOS is 1.258 even though with the presence of the two factors. Based on that the slope analyzed is confirmed to be safe and the slope has been constructed based on an adequate design.

ABSTRAK

Kejadian cerun runtuh adalah sesuatu yang sukar untuk dijangka. Sehubungan dengan itu kajian kestabilan cerun perlu dilakukan dengan kerap bagi memastikan cerun adalah selamat dan ianya juga dapat meminimakan kebarangkalian cerun runtuh. Kajian kestabilan cerun adalah proses membuat jangkaan tentang keadaan-keadaan yang boleh menyebabkan sesuatu cerun tersebut runtuh. Dalam kajian ini, kaedah Had Kesaksamaan (Limit Equilibrium Method) digunakan bagi mendapatkan faktor keselamatan bagi cerun yang dikaji. Keadaan cuaca di Malaysia yang terdiri dari keadaan kering dan lembab boleh mempengaruhi faktor keselamatan cerun dimana ianya menyebabkan pengembangan dan pengecutan tanah serta mempercepatkan kewujudan rekahan di permukaan cerun. Cadangan kerja-kerja pengukuhan cerun di KM 16.10 arah utara lebuhraya Skudai – Machap telah dipilih sebagai cerun kajian di dalam projek ini. Cerun ini di kategorikan sebagai cerun kritikal kerana ianya pernah mengalami kejadian runtuh pada thaun 2004. Rekahan permukaan dan kadar hujan yang tinggi telah digunakan sebagai faktor yang boleh mempercepatkan kebarangkalian cerun untuk runtuh. Hasil kajian melalui perisian SLOPE/W mendapati cerun tersebut tetap stabil walaupun dengan kehadiran kedua-dua faktor tersebut dengan faktor keselamatan minimum yang diperolehi adalah 1.258. Sehubungan dengan itu, cerun tersebut dipastikan selamat serta telah dibina mengikut rekabentuk yang mencukupi.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

Basic parameters and dimension used in stability analysis

α = alpha

β = beta

γ = gamma

δ = delta

ε = epsilon

ζ = zeta

η = eta

θ = theta

ι = iota

κ = kappa

λ = lambda

μ = mu

ν = nu

π = pi

ρ = rho

σ = sigma

τ = tau

φ = phi

ω omega

A area
A activity
B breadth or width
B parameter for peak state power law envelope
B pore pressure parameter
C compliance
C cover (above tunnel)
Cc slope of the normal compression line
Cs slope of a swelling and recompression line
D depth
Dr relative density
E work done by external loads
E Young's modulus (E_ for effective stress; Eu for undrained loading)
F force
Fa axial force
Fn normal force
Fs shear force
Fs factor of safety
G shear modulus (G_ for effective stress; Gu for undrained loading)
Gp, Hp parameters for peak strength in triaxial tests
Go shear modulus at very small strain
Gs specific gravity of soil grains
H height or thickness
H maximum drainage path
H horizontal load (on a foundation)
Hc critical height (of a slope)
Il liquidity index
IP plasticity index
Iσ influence coefficient for stress
Iρ influence coefficient for settlement
J stiffness modulus coupling shear and volumetric parameters
K_ bulk modulus
K0 coefficient of earth pressure at rest
Ka coefficient of active earth pressure
Kp coefficient of passive earth pressure
L length
Lf load factor
M_ one dimensional modulus
N normal force
Nc,Nγ ,Nq bearing capacity factors
Nd number of equipotential drops (in a flownet)
Nf number of flow channels (in a flownet)
Ns stability number (for undrained slopes)
P length of tunnel heading
P potential
P force on retaining wall
Pa force due to active pressure

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Slope stability analysis is often carried out in order to ensure that the slope analyzed is safe and also minimise the probability of slope failure. Slope along the highway which have been experiencing deep excavations are very susceptible to slope failure and thus landslide. The highway engineers must therefore give serious considerations before any construction or development is executed to ensure the designed slopes remain stable (Hamdan et al., 2006).

Malaysia climatic condition is governed by wet and dry periods. Shrinkage or creep of soil during dry periods after prolonged wet-and-dry cycles lead to the development of tension cracks on the surface of a sloping land (Nurly et al., 2006). The high intensity of rainfall and the absence of tension cracks will bring severe risk to the critical slope. Infiltration of rainwater into soil will increase the moisture content of soil, alter the structure of soils and thus reduce or eliminate frictional and cohesive strength (Reddi. 2003).

The slope stability analysis is a prediction on what conditions that can make the slope fail. Among The predictions are (1) Correlations between slope failure and pattern of rainfall, (2) analytical method, usually in the form as limit equilibrium method. Slope stability analysis is usually based on the limit equilibrium approach. The degree of stability is quantified in terms of factor of safety which is most commonly defined as the ratio between average shear resistance and the average shear stress along the critical slip surface (H.A Faisal., 2000).

A critical slope exists when a combination of soil and slope factors create a high potential for slope failure and subsequent erosion. Over-steepened freshly graded or disturbed slopes are considered critical when resistance to surface erosion is low and sheer and strength resistance tolerances are exceeded.

1.3 Problem Statement

In ten (10) years back, there are few incidents about slope failure in highway. A good examples of slope failure in highway, one which happen in 1996 at km 303.80(south bound) near Gua Tempurung, Perak and Bukit Lanjan at km 21.80(east bound) in November 2003(Ahmad.,2008). Most of the incidents happen during the high intensity rainfall period. Based on the study done to investigate the cause of this failure, it is revel that the lack of slope maintenance is the main factor that caused the failure. Besides that, high intensity rainfall also can cause slope failure to be happen and the existence of tension crack make the things worst.

The used of well graded sand ($Cu > 6$ and $1 < Cc < 3$) (Nurly, 2007) as a drainage layer between soil and rock fill need to be investigate. It may be in good performance when it is installed during the construction time, but after been installed for a few years, the drainage layer may be exposed to the performance reduction factor such as clogging and also damaged.

1.3.1 Case Study

A major cut slope failure at KM 16.1 NB occurred on 17th January 2001. The deep-seated failure affected the first berm to the eighth berm, measuring about 50m in width. Soil investigation works and topographical survey were carried out immediately after the failure.

Based on the desk study and site reconnaissance, the slope failure was probably triggered by an increase in pore water pressure within the slope. This resulted in the reduction of the available effective shear strength of the soil. Failure occurred at a point when the shear stress within the soil mass exceeded the available effective shear strength of the soil. The increase in pore water pressure within the slope can be attributed by the nature of high groundwater table at the site and prolonged precipitation.

The pore water pressure has a vital influence over the stability of the slope. As such, the key requirement for the design of the rehabilitation scheme is to focus on the drainage system to address the groundwater and surface runoff problem. The proposed slope rehabilitation works involves excavation and removal of all unsuitable materials from the failure scars and reinstate back the slopes with the combination of earth fill, rock fill and geogrid reinforced wall; and construction of gravel trenches, interceptor and cascade drains, and sumps at several strategic locations to address the high groundwater and surface runoff.

1.4 Aims and Objectives

North South Highway (Plus Highway) was opened to public in 1988. Since that, the highway has been operated for almost twenty two (22) years. Along the period also all items in the highway has been exposed to performance reduction factor such as wear and tear effect, weathering, rainfall and some time disaster. All this items need to be reviewed in terms of safety and serviceability. This study will review the most important item in highway which is slope.

The objectives of this study are to (1) to determine the post construction factor of safety (FOS) on one critical slope along Plus Highway; and (2) to ensure the design adequacy of these slope.

1.5 Scope and Limitations of The Project

The scope of this study will focus on one case study which is the proposed slope stabilization works at km 16.10 (Northbound) Machap – Skudai Expressway, Section 4. This study will focus on:-

(i) The effect of intensity rainfall (with drainage layer in good performance) to the proposed slope. The effect of intensity rainfall (with drainage layer in good performance) and the existence of tension crack to the proposed slope.

(ii) The effect of intensity rainfall (with drainage layer in bad performance or been clogged) to the proposed slope for a twelve consecutive months (October, 2009 until September, 2010).

(iii) The effect of intensity rainfall (with drainage layer in bad performance or been clogged) and the existence of tension crack to the proposed slope also for a twelve consecutive months (October, 2009 until September, 2010).

1.6 Significant of Research

Slope failures are not easily forecasted. There are many factors involved and until now many problems solutions such as rehabilitation works are only implemented after the slope collapse. It is necessary to have a systematic method to predict slope failure. This study will ensure that the critical slope along PLUS Highway are safe and the public can have confidence in using this highway.

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