COUPLING EFFECT OF SCTION VARIATION ON RIVERBANK STABILITY

MAZIAR FOROUTAN

UNIVERSITI TEKNOLOGI MALAYSIA

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MAZIAR FOROUTAN

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In the name of God the most beneficent and merciful

To my beloved family

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ABSTRACT

Failure of riverbank slope is a common problem in tropical country like Malaysia. Problems are often encountered when calculating the real factor safety of riverbank slope due to varying rainfall intensity and fluctuating of surface water table applied on the slope. In this study, the coupling effect of rainfall infiltration and tidal cycle on riverbank stability was investigated by measuring suction development in the riverbank slope. The coupling effect of suction variation on riverbank stability becomes more complicated as the up going tide of water on the riverbank saturates the soil mass resulting in negative effect to the Factor Safety, and on the contrary, the weight of surface water applied on the face of riverbank contributes to positive Factor of Safety. Furthermore, the riverbank slope failure induced by rainfall, involves infiltration through unsaturated zone above ground water table. Therefore, to achieve stability analysis in term of rainfall effect, the slope should be considered as an integral system of saturated- unsaturated soils. The critical factor of safety on the riverbank slope was calculated by integrating simulated pore water distribution in the slope by using SEEP/W into SLOPE/W software. From monitoring factor of safety it was found that the coupling effect of extraordinary rainfall, which makes the soil over-saturated and ponds on the slope, and tidal effect induces failure on the riverbank slope.

ABSTRAK

Kegagalan cerun tebing sungai adalah masalah biasa di negara tropika seperti Malaysia. Masalah sering dihadapi apabila mengira faktor keselamatan sebenar cerun tebing sungai disebabkan oleh perbezaan keamatan hujan dan naik turun paras air. Untuk mencapai kestabilan analisis dari segi kesan hujan, cerun boleh dianggap sebagai satu sistem keseluruhan tanah tepu-tak tepu. Kesan gandingan perubahan sedutan terhadap kestabilan tebing sungai menjadi lebih rumit apabila air pasang menaik di tebing sungai menjadi tepu dan melemahkan tanah cerun tetapi berat air permukaan yang dikenakan ke atas muka tebing sungai menyumbangkan kesan positif. Dalam disertasi ini, kesan gandingan penyusupan air hujan dan kitaran pasang surut terhadap kestabilan tebing sungai telah disiasat dengan mengukur perubahan sedutan dalam cerun tebing sungai.Faktor keselamatan kritikal di cerun tebing sungai itu dikira dengan mengintegrasikan pengagihan liang air dalam cerun yang disimulasi dengan perisian SEEP/W ke dalam SLOPE/W.Ia didapati bahawa kitaran pasang surut yang menyebabkan paras air naik tidak menyebabkan kegagalan cerun tebing sungai, kerana berat air menahan kegagalan jisim dan mengimbangi pengurangan dalam nilai-nilai sedutan.Kesan gandingan hujan dan pasang surut air juga didapati bukan sebab kegagalan. Fenomena yang menyebabkan kegagalan cerun tebing sungai ialah takungan dan limpahan air di permukaan cerun yang berlaku akibat hujan yang luar biasa atau kitaran pasang surut yang luar biasa.

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LIST OF ABBREVIATIONS

LEM	-	Limit Equilibrium Method
FOS	-	Factor of Safety
SWCC	-	Soil-Water Characteristic Curve
AEV	-	Air Entry Value

LIST OF SYMBOLS

c'	-	Effective cohesion
k	-	Hydraulic conductivity
i	-	Hydraulic gradient
u	-	Pore pressure
u_a	-	Pore-air pressure
u_w	-	Pore-water pressure
$(u_a - u_w)$	-	Matric suction
v	-	Darcian velocity
V	-	Volume of typical slice
W	-	Total weight of soil
x	-	Perpendicular distance of the line of the slice weight from the centre of rotation
α	-	Inclination of slip surface at the middle of slice
β	-	Slice base length
ϕ'	-	Effective friction angle
ϕ^b	-	Unsaturated friction angle
$\emptyset'_{min_f}$	-	Minimum effective friction angle at failure
γ	-	Unit weight
γ_d	-	Unit weight of dry soil
γ_w	-	Unit weight of water = 9.81kN/m^3
θ	-	Volumetric water content
θ_{wet}	-	Wetted volumetric water content
θ_{field}	-	Field volumetric water content
θ_r	-	Residual volumetric water content

σ	-	Total normal stress
$(\sigma - u_a)$	-	Net stress
$(\sigma_a - u_w)_r$	-	Residual suction
μ	-	Coefficient of friction
τ	-	Average shear stress developed along the potential failure surface

CHAPTER 1

INTRODUCTION

1.1 Background of the study

One of the basic calculations in geotechnical engineering field is analysis of slope stability in various conditions. The method of reaching stability analysis in slope is the most important part of this field. Whereas, this method involves the identification of the critical slip surface and the associated minimum factor of safety.

Available analytical methods include limit equilibrium methods, limit analysis methods, rigid element methods, and finite element methods. The most popular methods used for slope stability analysis is based on the limit equilibrium theorem. These methods make use of the limit equilibrium theory to derive the factor of safety against sliding for the slope. The factor of safety is defined as the ratio between resisting and disturbing forces involved in the slope stability problem. Therefore, when the factor of safety is below unity, e.g. 0.8, it's assumed that the failure happens. So, it's very important to know about the parameters that cause loss of factor of safety in slope. Furthermore, sometimes ignoring some parameters in purpose of simplifying calculation will cause inaccuracy in obtaining factor of safety. For example when effect of negative pore water pressure (suction), is not considered in slope stability, maybe the relative FOS is below unity, for the standing slopes. Besides, selecting the proper shear strength model which reflects the actual behavior of the soil is another important aspect to achieve correct analysis of stability of the slope. Although there are many different shear strength models for defining soil behavior, none of them reflect the exact behavior of the soil, but some are closer to reality. Furthermore, it is proved that using inappropriate shear strength model will cause over estimation or sometimes under estimation in slope stability calculation.

Therefore, more research should be done on studying of the factors like rainfall, suction, etc, to understand the real mechanism of slope failure which is very important so that the same mechanism with the right soil properties can be coupled in the slope stability analysis to achieve a reliable stability factor.

1.2 Problem Description

There are many functioning elements that ignoring each of them will cause inaccuracy in calculating the factor safety of riverbank slope. One of the most challenging factors in tropic conditions is rainfall effect that may induce shallow failure due to lowering shear strength at infiltrated areas. Moreover, there is another challenging aspect that is fluctuation of water table in the river due to tidal cycle and rainfall. In the flood season that there is high volume of rainfall, the water in the river will go up on the riverbank, and in the season that there is less rainfall the lowering of water table could be seen in the river, this also could be occurred during a day because of tidal effect. Furthermore, this phenomenon would cause variation of suction in both cases. Therefore, when the water will go up on the riverbank it will decrease shear strength of soil to the lowest value because it will eliminate suction on the riverbank. On the other hand, the water on the riverbank, will act in the opposite way to the sliding mass of soil on the slip failure that will help to keep stability of slope. In addition, when the water goes down slope will face inverse situation, it means that the suction will increase shear strength that will keep the factor of safety, but there is lack of the effect of weight of water.

Another aspect of difficulties in slope analysis is rainfall effect. Furthermore, when this problem is combined with suction variation, it is necessary to investigate which one causes the loss of factor safety. Firstly people believed that evaluation of suction could be ignored because the weight of the water could be a make up for lack of shear strength caused by saturation, but in this case another problem may arise is the rainfall intensity may causes shallow failure on the slope. This shallow failure is because of infiltration of the rainfall on the riverbank that creates unsaturated-saturated zone, so that the saturated area would face reducing shear strength and loss of factor safety. In this case, the depth of the failure is up to the depth of infiltration of rainfall. Shallow mode of rainfall induced landslide is complex soil mechanics behaviors. Hence it needs a more realistic state-of-the art theoretical concept for the shallow rainfall infiltration induced failure.

All in all is that, a kind of integrated analysis based on real data which will be accompanied by precise result should be done. Since, this result could be used to predict the time that any failure is near to happen or do remedial works to prevent failure from happening or reducing damages of failure, also achieving to factors that govern the stability of slope among many different factors.

1.3 Objectives and Scope of the Study

The aim of this study is to investigate the coupling effect of rainfall infiltration and surface water pressure on riverbank stability by observing suction variation in the riverbank slope. This study is undertaken in order to achieve the following objectives:

i. To measure suction distribution on riverbank slope under different surface water level due to tidal cycle and rainfall.
ii. To determine the factor safety of riverbank slope at different surface water table on the riverbank slope.

iii. To determine the factor of safety of the riverbank slope under different levels of rainfall intensity coupling with fluctuation of surface water table due to tidal cycle.

iv. To determine the factor of safety of the riverbank slope under different levels of rainfall intensity coupling with fluctuation of surface water table due to tidal cycle which resulted in ponding on the riverbank.

In order to measure suction on the site, tensiometers were installed on the riverbank slope located at Paya Mengkuang, Gelang Patah, Johor which is about 45 km from UTM. The measurement was done based on the suction development due to rainfall and tidal cycle. Consequently, the pore water pressure distribution was simulated and analyzed with SEEP/W, and factor safety of riverbank slope was calculated with SLOPE/W by an integrated analysis between these two softwares. In this study tidal cycle were applied by defining different surface water table along the riverbank slope. Then, low, medium and high rainfall intensity was applied to analyze riverbank stability against coupling effect of rainfall and tidal cycle which can induce failure. Furthermore, this coupling effect was evaluated in case of ponding and non-ponding on slope.

1.4 Significance of the Study

Slope failure involves a very complicated mechanism that could be effected by different parameters. Therefore, studying and evaluating these various parameters can be useful to find out the dominant factors which will cause loss of factor of safety.

In this study the coupling effect of suction due to fluctuation of water level and rainfall effect is evaluated. Moreover, by getting details of analysis result, the periods of time which are more susceptible to failure could be known. Since, the results which are achieved from this study are based on real and exact in-situ suction measurement by tensiometer and could be used for interpretation of same cases with similar soil type and similar rainfall condition.

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