SLOPE STABILITY ANALYSIS BY USING MULTIPLE SHEAR STRENGTH MODEL

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All glory to God

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ABSTRACT

Rainfall-induced landslide is a condition where rain water infiltrates into slope causing additional load and loss of shear strength of soil mass and eventually triggers slope failure. It is difficult to determine by applying conventional slope stability method as the method normally ignores the role of matric suction in the unsaturated zone existed above groundwater level. Suction has a strong influence on shear strength behavior where most of the rainfall-induced slopes failure occurred within unsaturated zone. In this study, three different shear strength models, namely Terzaghi (1936), Fredlund & Rahardjo (1978) and Md. Noor & Anderson (2006) are used in slope stability analysis for a parametric study subjected to different rainfall infiltration depth. This parametric study was done to identify the trend of the each model. Factor of safety was calculated and further discussed. Md. Noor & Anderson shear strength model gives a more critical and reliable stability factor with water infiltration compared to Fredlund & Rahardjo model. Terzaghi model which neglected soil suction give a lowest factor of safety and deep type of failure.

ABSTRAK

Tanah runtuh yang disebabkan oleh hujan lebat berlaku apabila air menyusup ke dalam cerun dan menyebabkan penambahan beban and kehilangan kekuatan ricih tanah, akhirnya mencetuskan kegagalan cerun. Kegagalan ini susah untuk ditentukan mengunakan cara konvensional dalam analisasi kestabilan cerun kerana cara ini tidak mengabil kira peranan sedutan matrik di zon tidak tepu atas air bawah tanah. Sedutan mempunyai peranan penting atas kekuatan ricih di mana kebanyakan tanah runtuh yang disebabkan oleh hujan lebat berlaku di zon ini. Dalam kajian ini, tiga model kekuatan ricih yang berlainan, iaitu Terzaghi (1936), Fredlund & Rahardjo (1978) and Md. Noor & Anderson (2006) digunakan untuk mengkaji kestabilan cerun dalam kajian parametrik di mana tertakluk oleh penyusupan air hujan. Kajian ini dilakukan untuk mengenal pasti trend setiap model. Faktor keselamatan cerun dikira dan dibincangkan. Model Md. Noor & Anderson (2006) memberi bentuk kegagalan cerun dalam penyusupan air yang kritikal dibandingkan dengan model Fredlund & Rahardjo. Model Terzaghi yang tidak mengambil kira sedutan memberi faktor keselamatan yang paling rendah and kegagalan jenis mendalam.

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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
c_s^{max}	-	Maximum apparent shear strength
R	-	Radius of the potential slip circle
s	-	Average shear strength of the soil
u	-	Pore pressure
u_a	-	Pore-air pressure
u_w	-	Pore-water pressure
$(u_a - u_w)$	-	Matric suction
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
ϕ'_{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
$(\sigma - u_w)_t$	-	Transition effective stress
$(\sigma_a - u_w)_r$	-	Residual suction
$(\sigma_a - u_w)_u^{\sigma'=0}$	-	Ultimate suction
μ	-	Coefficient of friction
τ	-	Average shear stress developed along the potential failure surface
τ_{app}	-	Apparent shear strength
τ_{sat}	-	Shear strength in saturated
τ_t	-	Transition shear strength
ζ	-	Rate of increase in ultimate suction relative to net stress

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CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Slope stability analysis is often carried out in order to ensure a slope analyzed is safe, and also minimize the probability of slope failure. 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.

The causes of landslides are attributed to a number of factors, such as geologic features, topography, vegetation, weather, and groundwater/seepage conditions. A large number of cases show that rainfall infiltration is a principal factor impacting slope stability, since almost 90% of landslides were induced by rainfall infiltration in China (Huang *et al*., 2002).

The occurrence of shallow type of rainfall-induced slope failure is very rampant in tropical residual soils. The conventional shear strength model can not explicitly explain the behavior. Conventional slope stability method may end up with stability factor of less than unity but the slope still standing. This is the result of ignoring the existence of suction and its role in saturated zone located above groundwater table. Fredlund (1973) discover the important of the suction in slope stability and developed a model that includes this factor. Further Md. Noor (2006) modified the model to more realistic to influence of water infiltration.

Understanding the real mechanism of slope failure is very important so that the same mechanism with the right soil properties can be incorporated in the slope stability analysis and that the result is expected to produce a reliable stability factor.

1.2 Problem Description

The conventional soil shear strength, e.g. Terzaghi (1936) will not well explain some shallow mode of failure especially during raining. There are some limitations of conventional slope stability method. By the concept of effective stress, conventional slope stability method faced problem to back analyses due to shallow type of slip, which is common mode of the failure in rainfall-induced landslide.

Many researches, e.g. Fredlund (1978) show the role of the suction or negative pore pressure help to raise the apparent shear strength. This is due to the lost of the suction or the negative pore pressure in the infiltrated surface zone. A suitable shear strength behavior should allow the real understanding of landslide behavior to surface.

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. The application of linear shear strength behaviour like Terzaghi and Fredlund in stability analysis has the problem in modelling shallow (< 3.0 m deep) mode of rainfall induced failure (Md. Noor & Hadi, 2011).

1.3 Objectives and Scope of the Study

The aim of this study is to compare the result of multiple shear strength models on rainfall-induced slope stability analysis. In this study, three objectives have been identified.

i. To determine the factor of safety influence by slope parameter by using model of Terzaghi (1936), Fredlund & Rahardjo (1978), and Md. Noor & Anderson (2006)

ii. To determine the factor of safety by using model of Terzaghi (1936), Fredlund & Rahardjo (1978), and Md. Noor & Anderson (2006) within Infiltation zone.

iii. To determine the factor of safety by using shear strength model of Terzaghi (1936), Fredlund & Rahardjo (1978), and Md. Noor & Anderson (2006) surpass Infiltation zone.

1.4 Significance of the Study

Rainfall-induced slope failure involves a very complicated mechanism that governed by number of parameters. Compare of different shear strength model reveals the importance of this study to understand the dominant factors affecting the critical pattern, and the corresponding suction distribution in order to successfully evaluate the effect of rainfall induced on the stability of a slope. The result that gives better mode of failure with reasonable factor of safety will be considered the best. Others variable like soil strength properties, soil mass, geometry, suction and water infiltration are also consider in this study.

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