BACK ANALYSIS OF SLOPE FAILURE INDUCED BY RAINFALL INFILTRATION

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Special dedication to my

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ABSTRACT

The slope stability issues concerning rainfall induced slope failures constitute a major threat to both lives and property worldwide particularly in the tropical climate of Malaysia which is characterized by very intense and long duration rainfall. The aim of this study is to investigate landslide occurrence due to rainfall infiltration through numerical simulation. The objectives are to determine the soil properties of the failed slope, to study the hydrological data of the slope and lastly to analyse the rainfall-induced slope failure by observing the factor of safety (FOS) at failure. The study focuses on the failure mechanisms of a landslide that occurred at Phase 8, Taman Sri Gombak, Batu Caves on 25th May 2011 by utilizing well established SEEP/W and SLOPE/W developed by Geoslope. The findings of the back analysis suggests that with the factor of safety 0.992, the slope begins to exhibit failure on 23rd May due to the increase level of ground water table that eliminates the apparent strength contributed by matric suction in the unsaturated soil system. All in all, it is proven that beside the contributing factors such as soil strength properties, soil mass and geometry, the factor of safety can be altered by the fluctuating pore water pressure induced by rainfall infiltration which in return greatly influences stability of slopes.

ABSTRAK

Kebelakangan ini, isu-isu berkaitan ketidakstabilan cerun yang berlaku akibat limpahan hujan yang kerap berlaku mendapat perhatian ramai. Fenomena ini disumbang oleh iklim hujan tropika di Negara Malaysia yang panas dan lembap sepanjang tahun. Kesan dari kegagalan cerun menyebabkan berlaku kehilangan nyawa, kerosakan harta benda dan menganggu proses pembangunan negara. Tujuan kajian ialah untuk menyiasat kesan penyusupan air hujan terhadap kegagalan cerun menerusi kaedah simulasi numerik. Objektif kajian ini meliputi menentukan sifat kekuatan tanah, mengkaji data hydrologi dan akhirnya menganalisa faktor keselamatan ketika berlakunya kegagalan. Kajian ini tertumpu pada kegagalan cerun yang berlaku pada 25hb Mei 2011 di Fasa 8, Taman Sri Gombak, Batu Caves. Analisis dijalankan menggunakan kaedah keseimbangan had yang menggunakan simulasi komputer model SLOPE/W berdasarkan taburan tekanan air liang yang dianalisis oleh perisian SEEP/W. Jangkaan keputusan yang akan deperolehi adalah nilai faktor keselamatan cerun (FOS) pada tempoh 14 hari analisis dijalankan. Nilai FOS yang terendah iaitu 0.992 dicatat pada 23 Mei 2011 di mana penyusupan air hujan yang berterusan didapati mengurangkan sedutan matrik tanah dan seterusnya melemahkan kekuatan ricih tanah yang mengakibatkan berlakunya tanah runtuh.

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T	-	shear strength
c’	-	effective cohesion for saturated soils
$\emptyset'$	-	effective friction angle for saturated soils
$\emptyset_b$	-	friction angle in unsaturated soils
u_a	-	pore air pressure
u_w	-	pore water pressure
v_w	-	flow rate of water;
k_w	-	coefficient of permeability
h_w	-	hydraulic head
ρ_w	-	density of water
g	-	acceleration due to gravity
h	-	hydraulic head
y	-	elevation head
ρ_w	-	density of water
g	-	gravitational acceleration
τ	-	average shear stress
s	-	average shear strength of soil
FOS	-	factor of safety

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CHAPTER 1

INTRODUCTION

1.1 Introduction

There are many slope failures caused by long period of heavy and intense rainfall, especially in tropical regions where the hot and humid weather coupled with high annual rainfalls have resulted slope instability that leads to landslides. Rapid infiltration of rainfall and the increasing of pore pressure can be considered the main trigger of landslide (Wieczorek, 1987). Rainfall induced landslides are among the most dangerous natural hazards acting on hillslopes, leading to structural damage and casualties. These shallow landslides are triggered by heavy rainfall, very often falling on already wet soils.

Research in the area of slope stability has brought about the realization that most slope failures are caused by the infiltration of rainwater into the slope (Gasmo et.al, 2000). Hence, back analyses of landslides are vital and useful for understanding the failure mechanisms of rainfall induced slope instability. According to Sharihan and Stark (1998), the location of the case study, soil composition, soil's shear strength properties, slope geometry, location of the slip surface and pore pressure conditions are among the particulars that should be defined prior to any justification.

Furthermore, the increasing rate of urbanisation has increased hillside developments for engineered and fill slopes in many regions in the tropics. The analyses of the stability of these slopes involve unsaturated soils because the water table is usually deep. Climatic changes directly affect the unsaturated soil zone. It is important to note that rainfall-induced slope failure involves infiltration through the unsaturated zone above the ground water table. Therefore, a slope area is be considered as an integral system of unsaturated-saturated soils in the stability analyses.

1.2 Problem Statement

High rainfall conditions in tropical areas give rise to many slope instability problems. The factor of safety of residual slopes with a high ground water level depends on, among other factors, the magnitude of the negative pore water above the ground water table which contributes to additional shear strength of the soil. With precipitation, the pore pressure becomes less negative or even positive. As a result, the shear strength of the soils decrease and this may trigger landslides. Thus, there is a pressing need to study and investigate the stability of slopes due to rainfall infiltration.

1.3 Objectives of Study

The aim of this study is to investigate landslide occurrence due to rainfall infiltration through numerical simulation. In order to achieve the stated aim, the following objectives are outlined;

i to determine the soil properties of the failed slope
ii to study the hydrological data of the slope
iii to analyse the rainfall-induced slope failure by observing the factor of safety (FOS) at failure

1.4 Scope of Study

Back analysis was conducted on a soil slope that failed on 25th May 2011 at Phase 8, Taman Sri Gombak, Batu Caves to study its failure mechanisms. The scope of the study focuses on the landslide which occurred adjacent to the TNB Substation of Sri Townvilla extending to downslope toe which near to residential area of Kg. Sg. Cincin. Laboratory analyses were carried out to classify and to determine the strength parameters of the soil. Furthermore, these laboratory tests were supplemented by appropriate field tests to take into consideration the mass behavior of the actual ground condition. Rainfall Infiltration is analysed using the concept of numerical modeling of SEEP/W programme. Whereas, limit-equilibrium based SLOPE/W is utilized for slope stability analysis purpose.

Figure 1.1: Aerial view of site location showing landslide area

1.5 Significance of Study

Rainfall-induced slope failure involves a very complicated mechanism that governed by a number of parameters and uncertainties. It is evidenced that beside the contributing factors such as soil strength properties, soil mass and geometry, the factor of safety can be altered by the fluctuating pore water pressure or suction which in return greatly influenced by triggering factor of rainfall infiltration. Therefore, the study is crucial to evaluate the effect and governing factors of rainfall infiltration in causing slope failure.

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