FLOW MECHANISM AND SUCTION DISTRIBUTION IN HETEREGENOUS RESIDUAL SOIL SLOPE UNDER RAINFALL INFILTRATION

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DEDICATION

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ABSTRACT

An imperative factor in rainfall induced slope failure is infiltration rate. Water that infiltrates into residual soil is predominantly controlled by two factors, i.e. rainfall intensity and saturated permeability of soil, which varies with depth as a result of weathering processes. Variation in permeability may either prevent or allow water to seep into deeper soil layers. Therefore, this study aimed to investigate the behaviour of suction distribution in a two-layered residual soil system consisting of Grade V and Grade VI residual soils with various saturated permeability functions using a laboratory physical slope model, in-situ or field work, and numerical modeling. The laboratory physical slope model was developed for the purpose of facilitating infiltration tests with three different permeability functions for each of the Grade V and Grade VI soils. A total of 42 infiltration tests were performed. The two-layered slope was then numerically simulated using SEEP/W GeoStudio software, which served to verify field data and determine the best modelling scheme that later be applied to signify the suction distribution behaviour of the residual soil slope model. Burrow holes present in the Grade VI soil layer caused the loss of the capillary barrier effect, which in turn allowed more rainfall to infiltrate into the soil layers. It was also found that when the ratio of permeability function between Grade V and Grade VI soils was high, an increase in the breakthrough time with corresponding decrease in the breakthrough matric suction occurred. From the seepage analysis, the numerical model incorporating burrow holes in Grade VI residual layer coupled with the effect of two sets of relict joints in Grade V yielded significant improvement in heterogeneous residual soil slope modelling. The findings of this study were then validated with previous findings using Prediction Accuracy (PA) analysis. It was established that burrow holes and two sets of relic joints conclusively improved the modelling of heterogeneous residual soil slope particularly at depths of 1.0 m and 1.5 m.

ABSTRAK

Faktor penting dalam kegagalan cerun disebabkan oleh hujan ialah kadar penyusupan. Air yang menyusup ke tanah sisa kebanyakannya dikawal oleh dua faktor, iaitu intensiti hujan dan kebolehtelapan tepu tanah, yang bervariasi dengan kedalaman akibat proses luluhawa. Variasi kebolehtelapan ini samada mencegah atau membenarkan air untuk menyusup masuk ke dalam lapisan yang lebih dalam. Oleh itu, objektif kajian ini adalah untuk mengenal pasti taburan sedutan bagi dua lapisan sistem tanah iaitu Gred V dan Gred VI dengan ciri-ciri fungsi kebolehtelapan tepu yang berlainan melalui fizikal model cerun makmal, data di tapak dan juga pemodelan berangka. Satu model fizikal cerun telah dibangunkan dalam makmal untuk ujian penyusupan dimana tiga kebolehtelapan yang berbeza bagi setiap lapisan Gred V dan Gred VI. Sebanyak empat puluh dua (42) ujian penyusupan telah dilakukan. Cerun dengan dua lapisan tanah itu kemudiannya disimulasi secara berangka menggunakan perisian SEEP/W GeoStudio, yang berfungsi untuk mengesahkan data lapangan dan menentukan skema pemodelan terbaik yang kemudiannya digunakan untuk mengesahkan taburan matrik yang terdapat di dalam cerun tanah baki. Kehadiran lubang jara pada Gred VI menyebabkan berlakunya kehilangan penghalang kapilari dan ini ini membenarkan lebih banyak air menyusup masuk ke dalam lapisan tanah. Keputusan juga mendapati bahawa apabila nisbah fungsi kebolehtelapan di antara Gred V dan Gred VI terlalu tinggi, akan meningkatkan masa keadaan bulus dan mengurang sedutan matrik pada keadaan bulus. Daripada analisis resipan, pembangunan pemodelan berangka dengan mengambil kira kehadiran lubang jara di lapisan Gred VI tanah berbaki bersama-sama dengan kesan dua set ketakselanjaran relikta di lapisan Gred V menunjukkan penambahbaikan yang ketara di dalam pemodelan cerun keheterogenan tanah berbaki. Kajian ini kemudiannya disahkan dengan dapatan kajian lepas dengan menggunakan kaedah Ketepatan Ramalan (PA). Didapati lubang jara dan dua set ketakselanjaran rekta secara menyeluruh telah menambaik pemodelan berangka cerun keheterogenan tanah berbaki terutama pada kedalaman 1.0 m dan 1.5 m.

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LIST OF ABBREVIATIONS

AEV	–	Air-Entry Value
IDF	–	Intensity Duration Frequency
PA	–	Prediction Accuracy
SWCC	–	Soil Water Characteristics Curve

LIST OF SYMBOLS

α – Coefficient of Hydraulic Conductivity Function

θr – Residual Water Content

ϕ – Inclination Angle

γ_w – Unit Weight of Water

h_a – Air-Entry Head of Fine Soil Layer

h_w – Air-Entry Head of Coarse Soil Layer

k_{sat} – Coefficient of Permeability

$P_{(t)}$ – total input (rainfall intensity, irrigation)

Q – Storage Capacity

q – Infiltration Rate

${}^{R}I_{t}$ – The average Rainfall Intensity (mm/hr) for ARI and duration

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Rainfall-induced slope failures are common problems in many tropical areas covered by residual soil. Basically the soil profile in the area is from granitic formation and the existing of rainfall that decreased the matric suction caused a shallow rotational failure (Jamaludin & Hussein, 2006). Slope stability in residual soil and rainfall infiltration has a close relationship between each other. Experience has shown that many slopes failure occurred during or shortly after rainfall (Gavin and Xue, 2007). In general, many factors could govern the slope stability. Rainfall induced slope failure are normally governed by two factors, which are, rainfall intensity and coefficient of saturated permeability, k_{sat} (Chao *et al.*, 2013).

The tropical residual soil mantle derived from igneous rocks mainly consists of materials dominantly decomposed to Grades IV and V according to the six-fold weathering classification system of International Society for Rock Mechanics (ISRM) (1981) of saprolitic soils, and true or matured residual soil (Grade VI) of laterites (Bland & Rolls, 1998; Taylor & Eggleton, 2001; Aydin, 2006). The weathering process involved in the formation of residual soil introduces variation in material scale and also in field scale. In material scale, the weathering process cause the igneous rock to decompose to Grade IV (lateritic layer) and V (saprolitic layer). Therefore, it produced variations in grain size, porosity, mineralogy, lithologic texture, rock mechanical properties, structure and diagenetic processes. In field scale, the variation in residual soil because of discontinuities in soil mass such as relict joints, bedding planes, foliations, faults and shears happen in saprolitic layer. While in lateritic layer, insect population such as burrow holes govern the properties of soil such as density and hydraulic properties of soil (Bastardie, Capowiez, De Dreuzy, & Cluzeau, 2003). The permeability of lateritic layer can be as high as to 0.01 m/s within 1 m depth with the existence of burrow holes (Keith, 1992). Meanwhile, the permeability of saprolitic soil varies with depth, and the variation is within two orders of magnitude (Agus, Leong, & Rahardjo, 2005; Harianto Rahardjo, Satyanaga, Leong, Ng, & Pang, 2012).

Residual soil is commonly found in an unsaturated state because of the location of ground water table is well below the soil layer and possesses high matric suction, especially during dry seasons. However, the different in permeability in the soil layers, results in variation in suction distribution in the residual soil. This permeability value is a dominant factor that contributes to the changes of suction distribution in residual soil. At relatively dry conditions or high matric suctions, the fine-grained soil has a high coefficient of permeability, while the coarse-grained layer has an extremely low coefficient of permeability. When the infiltrating water starts to infiltrate from the surface, the coefficient of permeability of the fine grained layer increases gradually, while that of the coarse grained layer remains extremely low. As the infiltrating water accumulates and reaches the fine-coarse interface, the matric suction of the coarse-grained layer begins to decrease significantly. Once the matric suction of the coarse grained layer reaches its water-entry‟ value, (ψw), the coefficient of permeability of the coarse-grained layer increases rapidly and may exceed the coefficient of permeability of the fine-grained layer (Ross, 1990).

Many studies such as Kassim *et al*., (2012), Kim and Lee, (2013), Lee, *et al*. (2011) and Trandafir *et al*. (2008) concluded that matric suction plays an important role in slope stability especially in residual soil. The slope failure happens due to total or partial loss of matric suction during rainfall infiltration and causes the shear strength of soil to decrease. At initial condition, when the matric suction is high, there is a greater initial factor of safety and hence the slope is stable. However, during rainfall, the matric suction decreases which eventually decreases the factor of safety of the slope. Previous studies have already demonstrated that matric suction contributes to the shear strength of soil. The rainfall intensity and duration affect the suction distribution in soil with an intermediate saturated permeability such as sandy silt, which is common type of residual soil (Gofar and Lee, 2008). Suction distribution in coarse-grained soil is greatly influenced by short and intense rainfall.

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b) Proceeding Paper

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