SOIL MOISTURE VARIATION DUE TO GRASS WATER UPTAKE IN SHALLOW SLOPE

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I would like to dedicate my thesis to my beloved husband Mohd Muzri Bin Mohamad and to my lovely daughter Siti Amni Nasuha Binti Mohd Muzri.

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ABSTRACT

Shallow landslide is the slope failure phenomenon that frequently occurs in tropical rainforest region such as Malaysia. While fine root distribution for grass with depth is consistent and easily defined, the fine root network plays an important role as geosynthetic mesh by providing apparent enhanced cohesion that increases the strength of the soil. This study is aimed to evaluate the effects of grass on shallow slope stability in terms of soil moisture variation and to develop 1D soil moisture suction due to grass water uptake. The numerical simulation modelling was applied based on the literature review results to obtain the most appropriate condition to replicate the grass water uptake within the soil slope. The transpiration was solely based on six types of grass which have significantly altered the matric suction or moisture variation distribution on an unsaturated soil slope. The types of grass were Axonopus Compressus, Pennisetum Purpureum, Andropogon Gayanus, Brachiaria Humidicola, Melinis Minutiflora and Digitaria Eriantha. The assessment of slope stability due to the influence of six type of grasses induced suction was provided in this research. The length of grass roots are different for all grasses, ranging from 0.3048 m up to 4.000 m. Results of safety factor demonstrated that shallow slope stability is sensitive to pressure head. The factors of safety for all grasses are ranging from 2.8800 until 3.1860. A value which is greater than 1 represents the stability of the slope. This research delivers a strongly belief that Axonopus Compressus grass absorb water way faster from others with factor of safety of 3.0670 and is beneficial in maintaining stability of unsaturated soil.

ABSTRAK

Tanah runtuh cetek adalah fenomena kegagalan cerun yang sering berlaku masalah geoteknikal di kawasan hutan hujan tropika seperti Malaysia. Bagi rumput di mana pengagihan akar bergantung pada kedalaman adalah konsisten dan mudah ditakrifkan, rangkaian akar memainkan peranan yang penting sebagai jaringan geosintetik dengan menyediakan panduan jelas yang dipertingkatkan untuk meningkatkan kekuatan tanah. Kajian ini adalah untuk menilai kesan rumput pada kestabilan cerun cetek dari segi perubahan kelembapan tanah dan membangunkan 1D untuk sedutan kelembapan tanah mengenai pengambilan air dari rumput yang terlibat. Pemodelan simulasi berangka telah digunakan berdasarkan keputusan kajian literatur untuk mendapatkan keadaan yang paling sesuai untuk mendapatkan kadar pengambilan air rumput di cerun tanah. Transpirasi adalah berdasarkan kepada enam jenis rumput di mana ia telah mengubah dengan ketara matrik pengedaran sedutan atau kelembapan perubahan pada cerun untuk tanah tak tepu. Kajian ini dapat disimpulkan bahawa enam rumput seperti Axonopus compressus, Pennisetum purpureum, Andropogon Gayanus, Brachiaria Humidicola, Melinis Minutiflora dan Digitaria Eriantha telah digunakan. Penilaian kestabilan cerun disebabkan oleh pengaruh dari enam jenis rumput yang disebabkan sedutan terdapat dalam kajian ini. Panjang akar rumput adalah berbeza untuk semua rumput, dari 0.3048 m sehingga 4m digunakan. Keputusan faktor keselamatan menunjukkan bahawa kestabilan cerun cetek adalah sensitif kepada turus tekanan. Faktor-faktor keselamatan untuk semua rumput adalah dalam julat 2.8800 hingga 3.1860. Nilai lebih besar dari 1 mewakili kestabilan cerun. Kajian ini menyatakan bahawa rumput Axonopus Compressus menyerap air lebih cepat daripada enam jenis rumput yang lain dengan faktor keselamatan 3.0670 dan bermanfaat dalam mengekalkan kestabilan tanah tidak tepu.

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LIST OF SYMBOLS

$C(\psi)$	Specific moisture capacity (cm^{-1})
K_s	Saturated hydraulic conductivity (cm/s)
σ_3	Pressure cell
u_a-u_w	Different suctions
q_u	Undrained compressive strength
N	Total normal force on the base of the slice (kN)
$S_{max}, S(\psi), S(\psi, z), S(\psi, z, r)$	Sink term ($cm^3/cm^3/s$)
T, T_j	Potential Transpiration rate (cm/s)
t	Time (s)
V, V_w	Volume of water (cm^3)
W	Total weight of a slice (kN)
α, l, m, n	Soil specific parameter
(ω)	Moisture content
(u_a)	Air pressure
(u_w)	Water phase pressure
G_s	Specific gravity of soil solids
e	Void ratio
θ	Volumetric moisture content (%)
$\theta 1, \theta 2$	Contact angle of an interface
θ_r	Residual water content (%)
θ_s	Saturated water content (%)
ψ	Capillary potential (cm)
ϕ	Total potential for moisture flow
λ	Water flux at the boundary (cm/s)
P	Pressure Head

ϕ^b	Angle indicating the rate of increase in shear strength relative to matric suction (degrees)

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Shallow landslide or shallow slope failure is the slope failure phenomenon that occurred frequently in tropical rainforest region such as Malaysia. It is a common geotechnical problem faced by slope engineers. Shallow slope failure usually occurred within 2 m of the ground surface and normally taken to be translational, rotational failures or a combination of both (Coppin and Richards, 1990). There are many factors that induce the landslides in residual soil slopes and rainfall has been considered to be the cause of majority landslides that occur in regions experiencing high seasonal rainfalls (Brand, 1984).

Slope can be generally classified as natural slope and man-made slope. Natural slope consist of residual soil slope and rock slope. Meanwhile, man-made slope normally are cut-back slope and filled slope with well compacted filled material. Surface protection including of vegetation and surface concreting should be conducted on man-made slope with proper surface drainage such as surface channels, catch pits and sand traps. This is to protect slope surface from rainfall-induced erosion. Subsurface stabilization which includes soil nailing and ground anchors with subsurface drainage such as weep hole are required depending on the design to keep the slope stable in position.

Normally, vegetation have two main functions in stabilizing slope stability, (i) via mechanical reinforcement, and (ii) via hydrological mechanism which causing the increased evapotranspiration and hence increase suctions or soil moisture extraction (MacNeil et al., 2001, Coppin and Richards, 1990, Greenwood et al., 2004). The stabilizing effects depend on the type of vegetation with different root distribution including dense cover of sod, grasses, herbs, shrubs and trees (Gray and Sotir, 1996, Coppin and Richards, 1990). This study focuses on the effect of soil moisture variation due to water uptake.

1.2 Problem Statement

Earthworks are a necessary part of many civil engineering projects such as road construction, riverbanks, mining operations, landfills and grass involving engineering slope. Stability of engineered landscape slope should be well analysed and evaluated continuously and professionally during construction and post construction for safety purposes. There are many shallow slope failures or landslides induced by heavy rainfall which cause soil erosion and rapid increase of water table. Shallow slope failures mostly occurred during intense increase of soil moisture and pore water pressure due to antecedent and prolonged rainfall. The increasing soil moisture or pore water pressure can be seen as the main contributing factor for decreasing soil shear strength thus leading to the weakening of the slope stability, resulting in factor of safety (FOS) reduction. Although the concrete surfacing provide adequate erosion control and hence improve stability, but it has its own disadvantages in terms of cost and aesthetic value. Vegetation cover is another option for slope surface which include trees and grass turfs.

The hydrological effect is closely related to soil moisture variation and can be directed through transpiration. This effect is found to be important as hydrological effect provides significant increase in soil strength that will definitely improve slope stability in certain conditions.

The current work is aimed at providing a framework for the simulation of moisture migration due to vegetation that will be of potential value for a range of geo engineering applications and totally about 6 types of grasses in Malaysia (tropical country). This study explores the numerical simulation capable of representing the extraction of water from the soil by the roots of grass – the so called water-uptake process.

1.3 Objective

Detailed objectives of this investigation are:

a) To develop 1D numerical simulation model soil moisture suction due to grass water uptake.

b) To analysis six types of grasses for grass water uptake due to soil moisture variation using numerical simulation.

c) To validate soil moisture variation between numerical simulation and field, laboratory test from previous study.

d) To analyse the factor of safety of slope due to grass water uptake.

1.4 Scope of Study

In this study, the related parameters of study on enhanced parameters of grass effect are determined using the methods that will be described in the methodology section. A data geometry is drawn up and will be filled into the spreadsheet and will be transferred from established Fortran Code program for stability calculation. Patterns of soil moisture transfer and migration due to the influence of tree root water-uptake on the unsaturated soil condition are presented. It focuses on the hydrological aspect on soil moisture pattern within the vicinity of the tree. The mechanical aspect of the tree roots such as tensile strength bonding between root and soils which can lead to increasing soil strength are negligible in this study. The current work would consider the effect of tropical grasses such as Axonopus Compressus, Pennisetum Purpureum, Andropogon Gayanus, Brachiaria Humidicola, Melinis Minutiflora and Digitaria Eriantha. The root growth will be excluded in this work scope and only consider on transpiration by grass. The approach to encounter soil moisture variation was based on numerical simulation computer. A series of validation were analysed with field and laboratory test with previous study for one type of grass. Apart from that, the field monitoring result brought significant result to compare with numerical simulation to analyse the soil moisture content. The comparison of these works revealed that tree moisture transfer is beneficial in maintaining stability of unsaturated soil

1.5 Significance of Study

This study is aimed to produce the results of additional hydrological parameters of grass in increasing soil strength, and hence providing the efficiency of grass in preventing shallow slope failure in terms of moisture content. Geotechnical engineers can then evaluate the suitability of grass as vegetation option on slope cover. The benefit that would be gained from this study may include the following;

a) Create database for suction due to grass water uptake

b) Numerical method for grass water uptake

c) Factor of safety for slope due to grass water uptake

1.6 Thesis Layout

An overview of related research work to the analysis of grass root water uptake in unsaturated soil is presented in Chapter 2. The review provides a commentary on the general significance of the grass and also water-uptake process. It then provides a summary of the key mechanisms involved and aims to provide some background information that can be utilised in subsequent work.

The methodology for describing the flow in a moisture variation is presented in Chapter 3. Some of the fundamental concepts used to describe moisture flow due to water uptake plant by roots are also introduced. This chapter describes the derivation of the soil moisture variation on hydrological mechanism calculation and hence increases suctions or soil moisture extraction.

Chapter 4 presents a validation of grass Andropogon Gayanus on hydrological mechanism soil moisture variation using two methods between result from laboratory test and numerical computer simulation. Data for field monitoring and laboratory test was also obtained from the previous researcher of the site which the information was determined by site survey method.

Chapter 5 presents about numerical simulation of the soil moisture variation due to grass water uptake and all parameter are included in the spreadsheet to conclude the moisture content and this particular chapter analyzes and discusses the 6 types of grasses.

Chapter 6 discusses about pressure head and parameter to be included to determine factor of safety of slope due to grass water uptake

Meanwhile, discussions in Chapter 7 focuses on objectives regarding the research and recommendations for future study.

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