TREE WATER UPTAKE ON SUCTION DISTRIBUTION IN UNSATURATED TROPICAL RESIDUAL SOIL SLOPE

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ABSTRACT

This study provides an investigation of active root tree zone located at the toe of a slope. This section and its vicinity generated matric suction due to tree water uptake on tropical residual soil slope. The research employed several approaches i.e field monitoring, laboratory experimental and numerical modelling. A field monitoring was carried out to collect matric suction data at the slope with two conditions; in absence of a tree and with a tree located at the toe of a slope. The unsaturated shear strength behaviour of soil under different stress level is investigated, using uncomplicated testing procedure subject to actual matric suction encountered during field monitoring. The numerical simulation modelling was applied based on the laboratory results to obtain the most appropriate condition to replicate the tree water uptake within the soil slope. A decrease in matric suction occured after a long duration of intense rainfall. This condition was function as an initial condition before the water uptake driven by active root tree generated to the maximum matric suction (low moisture content). The pattern of matric suction profiles revealed that majority of matric suction changes was greater at the proximity of tree trunk below 4 m and at a shallow depth of 0.5 m. Transpiration on single mature tree has significantly altered the matric suction or moisture variation distribution on an unsaturated soil slope. This study also illustrated the nonlinear relationship between the apparent shear strength and suction influencing the stability of the slope. The assessment of slope stability due to the influence of a tree induced suction was provided in this research. The factor of safety against slope failure has improved up to 63 % on slope with tree at toe compared to a slope without tree. Lastly, the numerical simulation modelling of matric suction induced by a tree has been verified through comparison to actual field monitoring results recorded during the dry period. Generally, an acceptable aggrement between simulation and field monitoring results has been achieved. This research delivers a strong belief that a preserved mature tree can improve soil properties in slopes designs.

ABSTRAK

Kajian ini merangkumi penyiasatan di zon aktif akar pokok yang terletak di kaki cerun. Di bahagian ini dan kawasan sekitarnya menjanakan sedutan matrik disebabkan pengambilan air daripada pokok di tanah tropika sisa pada sekitar cerun. Penyelidikan ini mengambil beberapa pendekatan iaitu pemantauan di lapangan, ujikaji-ujikaji makmal dan pemodelan berangka. Pemantauan di lapangan yang dijalankan bagi mengumpul data sedutan matrik di cerun dilakukan dalam dua keadaan; tanpa kewujudan pokok dan dengan kewujudan pokok yang terletak di kaki cerun. Sifat kekuatan ricih tanah tak tepu diuji dibawah tahap tekanan yang berbeza dengan menggunakan kaedah yang tidak rumit bergantung kepada nilai sebenar sedutan matrik yang direkodkan semasa pemantauan di lapangan. Simulasi berangka dijalankan berdasarkan keputusan makmal untuk mendapatkan nilai yang paling sesuai bagi menunjukkan pengambilan air daripada pokok di cerun tanah dengan corak sedutan matrik di lapangan. Penurunan sedutan matrik berlaku selepas hujan lebat yang panjang. Situasi ini berfungsi sebagai keadaan awalan sebelum pengambilan air didorong oleh akar pokok yang aktif menjana sedutan matrik kepada nilai yang paling tinggi (kandungan kelembapan yang rendah). Corak profil sedutan matrik mendedahkan bahawa kebanyakan perubahan sedutan matrik adalah lebih besar berdekatan batang pokok berdekatan (4 m) dan pada kedalaman yang cetek (0.5 m). Transpirasi hanya daripada sebatang pokok matang dapat memberikan sumbangan yang amat ketara dalam mengubah sedutan matrik atau kelembapan pada cerun tanah tak tepu. Terdapat hubungan tak linear di antara kekuatan ricih dan sedutan yang mempengaruhi kestabilan cerun. Penilaian kestabilan cerun disebabkan pengaruh sedutan oleh pokok juga terdapat dalam kajian ini. Faktor keselamatan terhadap kegagalan cerun telah bertambah sehingga 63 % pada cerun dengan pokok di kaki berbanding dengan cerun tanpa pokok. Terakhir sekali, simulasi pemodelan berangka sedutan matrik yang dijanakan oleh pokok dan disahkan secara langsung dengan keputusan pemantauan sebenar yang dicatatkan semasa tempoh keadaan kering. Secara amnya, keputusan simulasi dan pemantauan di lapangan menunjukkan hubungan yang munasabah. Kajian ini memberikan keyakinan yang kuat terhadap pemeliharaan pokok matang yang boleh memperbaiki sifat-sifat tanah dalam merekabentuk cerun..

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LIST OF SYMBOLS

A_{ev}	-	Air entry value
c'	-	Effective cohesion
e	-	Void ratio
g	-	Gravity = 9.81 m/s^2
G_s	-	Specific gravity
I	-	Rainfall intensity
k	-	Water coefficient of permeability
k_{sat}	-	Saturated permeability
$K(\psi)$	-	Hydraulic conductivity of wetted zone
L_f	-	Wetting front depth
L_r	-	Redistribution depth
m_w	-	Slope of soil water characteristic curve (SWCC)
n	-	Porosity
q	-	Rainfall unit flux
t	-	Time
u_a	-	Pore-air pressure
u_w	-	Pore-water pressure
$(u_a - u_w)$	-	Matric suction
W	-	Total weight of soil
W_{ev}	-	Water entry value

β	-	Slope inclination angle
χ	-	Parameter related to the soil degree of saturation
ϕ'	-	Effective friction angle
ϕ^b	-	Angle indicating unsaturated
γ_d	-	Unit weight of dry soil
γ_w	-	Unit weight of water = 9.81 kN/m^3
π	-	Osmotic suction
θ	-	Volumetric water content
θ_i	-	Initial volumetric water content
θ_r	-	Residual volumetric water content
θ_s	-	Volumetric water content at saturation of absorption curve
ρ_b	-	Bulk density
ρ_d	-	Dry density
ρ_w	-	Density of water
σ	-	Total normal stress
σ'	-	Effective normal stress
τ_f	-	Shear stress at failure
ψ	-	Suction
ψ_{min}	-	Minimum Suction value
ψ_T	-	Total suction
$C(\psi)$	-	Specific moisture capacity (cm^{-1})
r_r	-	Maximum rooting radial (cm)
S_m	-	Shear force mobilized on the base of each slice (kN)
$S(\psi, z, r)$	-	Sink term (cm^3/cm^3/s)
T, T_j	-	Potential Transpiartion rate

z_r	-	Maximum rooting depth (m)
$\alpha(\psi)$	-	Pressure head dependent reduction factor
N	-	Total force on the base of the slice (kN)
O	-	The centre of slip rotation
Θ	-	Normalized volumetric water content
χ	-	Parameter related to the soil degree of saturation
C_{app}	-	Apparent shear strength
q_u	-	Undrained compressive strength
W_s	-	Weight of solid soils in the specimen
W_T	-	Target weight of the specimen
W_w	-	Weight of water in the specimen
$(\Delta\sigma_d)_f$	-	Deviator stress at failure
ε	-	Axial strain
ω	-	Moisture content
ω_0	-	Initial moisture content
ω_T	-	Target moisture content of the specimen

LIST OF APPENDICES