MODELLING THE EFFECT OF HETEROGENEITIES ON SUCTION DISTRIBUTION BEHAVIOUR IN TROPICAL RESIDUAL SOIL

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In the name of ALLAH, the most beneficent and merciful.

To my beloved family

Ir Norhashimah Hashim

Sarah Aida

Sarah Aina

Amin Fuad and

Mak

In memory of Sergeant 14606 Kassim bin Mohd Amin.

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ABSTRACT

The formation of tropical residual soils introduces heterogeneities in soil mantle. While the hydraulic conductivity of Grade VI soil is controlled only by the variation *at the material scale* i.e. grain size, void ratio, and mineralogy, the hydraulic conductivity of Grade V soil is also influenced by the presence of heterogeneity features *at the field scale*. One of the important features of heterogeneity is relict discontinuities which affects the saturated hydraulic conductivity, k_{sat}. This study focuses on the effect of the heterogeneities on the mechanism of rainfall infiltration and the resulting suction distribution within residual soil mass when subjected to different rainfall patterns. Three approaches were employed in this research i.e. field observation, laboratory experiment, and numerical modelling. Field observation was carried out at an instrumented site for a period of one year to monitor soil response, in term of suction distribution, when subjected to actual rainfall. Forty two (42) series of laboratory infiltration tests were performed on homogeneous and two-layered soils with relict discontinuities subjected to various rainfall intensities to study the effect of different rainfall patterns on suction distribution. The field response was then simulated numerically based on the mechanism found in the laboratory tests to obtain the most appropriate approach in modelling the heterogeneities within soil mass. The field observation shows rainfall patterns play an important role in the propagation of wetting front and suction variation in the soil slope. There was an upper limit of the soil suction in the residual soil slope, even during prolonged dry period which approximately identical to minimum suction, ψ_{min} corresponding to the residual water content, θ_r in the soil water characteristic curve, SWCC of the soils. The laboratory study also shows that heterogeneities cause the k_{sat} of the soil to vary from one to five orders of magnitude. The flow mechanisms in the residual soils are controlled by the ratio of rainfall intensity to saturated hydraulic conductivity of the soil, q/k_{sat}, the suction potential at the interface between two layers, and the physical flowing conduit within the heterogeneous soil mass resulting in disparate suction distribution profile. Continuum model is capable of modelling the effect of heterogeneities in Grade V material on the mechanism of rainfall infiltration and suction distribution in tropical residual soil. In this method, the relict discontinuities in Grade V soil were simulated by subdividing the layer into multiple isolated zones with an identical SWCC but with different average k_{sat}. The study indicated that the presence of thin Grade VI layer and the relict discontinuities in Grade V layer should be considered in the analysis of suction distributions in residual soil slope subjected to rainfall infiltration.

ABSTRAK

Pembentukan tanah baki tropika menghasilkan keheterogenan dalam mantel tanah. Konduktiviti hidraulik tanah Gred VI hanya dikawal oleh variasi *pada skala bahan* iaitu saiz zarah, nisbah lompang dan mineralogi manakala bagi tanah Gred V ianya juga dipengaruhi oleh kehadiran ciri-ciri keheterogenan *pada skala lapangan*. Salah satu dari ciri-ciri utama keheterogenan ialah ketakselanjaran relikta yang memberi kesan ke atas konduktiviti hidraulik tepu, k_{sat}. Kajian ini fokus kepada kesan heterogenan terhadap mekanisme penyusupan hujan dan taburan sedutan yang terhasil dalam massa tanah baki akibat kenaan pelbagai corak hujan. Penyelidikan ini menggunakan tiga pendekatan iaitu pemerhatian lapangan, ujian makmal dan pemodelan berangka. Pemerhatian lapangan dilakukan di tapak teralat bagi tempoh setahun untuk memantau tindakbalas tanah dalam sebutan taburan sedutan apabila dikenakan hujan sebenar. Empat puluh dua (42) siri ujian penyusupan makmal dijalankan ke atas tanah homogen dan tanah dua-lapisan dengan relikta takselanjar yang dikenakan pelbagai keamatan hujan untuk mengkaji kesan corak hujan yang berbeza ke atas taburan sedutan. Tindakbalas lapangan disimulasi secara berangka berdasarkan mekanisme yang diperolehi daripada ujian makmal bagi mendapatkan pendekatan paling sesuai untuk memodelkan keheterogenan dalam massa tanah. Pemerhatian di lapangan menunjukkan corak hujan memainkan peranan penting dalam perambatan garis basah hadapan dan kepelbagaian sedutan dalam cerun tanah. Terdapat had atasan bagi sedutan tanah dalam cerun tanah baki, walaupun dalam tempoh kering yang berpanjangan di mana nilainya hampir sama dengan sedutan minimum, ψ_{min} yang merujuk kepada kandungan air baki, θ_r pada lengkung ciri air tanah, SWCC bagi tanah tersebut. Kajian makmal juga menunjukkan bahawa keheterogenan menyebabkan k_{sat} tanah boleh berubah dari satu hingga lima aras magnitud. Mekanisme aliran dalam tanah baki dikawal oleh nisbah keamatan hujan kepada konduktiviti hidraulik tepu tanah, q/k_{sat}, keupayaan sedutan di antara muka dua lapisan dan fisikal pembuluh aliran dalam tanah heterogen tersebut yang menghasilkan profil taburan sedutan yang berbeza. Model selanjar berkebolehan memodelkan kesan keheterogenan dalam bahan Gred V terhadap mekanisme penyusupan hujan dan taburan sedutan dalam tanah baki tropika. Dalam kaedah ini, ketakselanjaran relikta dalam tanah Gred V disimulasikan dengan membahagikan lapisan tanah tersebut kepada berbilang zon terasing yang mempunyai SWCC yang sama tetapi berlainan purata k_{sat}. Kajian ini menunjukkan bahawa kehadiran lapisan nipis Gred VI dan ketakselanjaran relikta dalam lapisan tanah Gred V perlu dipertimbangkan untuk analisa taburan sedutan dalam cerun tanah baki di bawah kenaan penyusupan hujan.