Mathematical Modeling of the Hydraulic Gradients of Stratified Soils in a Steady State Upward Seepage Condition

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ABSTRACT

As of this writing, studies about upward seepage normally analyze soils as a homogenous block. This kind of assumption, however, leaves much to be desired since soils in its natural state are stratified. For this reason, the research explores the possibility of analyzing soils as a stratified block, particularly through the observation of the behavior of hydraulic gradient through each stratum of significantly different soil physical properties, as the entire soil block becomes subjected to steady-state upward seepage pressure.

Twelve disturbed soils samples representative of the soil textures in the United States Department of Agriculture soil texture triangle was subjected to steady-state upward seepage test to determine the relationship between their hydraulic gradients, and the combined effect of effective stresses and permeabilities. Using Microsoft Excel 2013 Analysis Toolpak, multiple linear regression was performed on homogeneous, two-strata, and three-strata setups of the disturbed samples to model their corresponding equations, which were then compared to the yielded values of hydraulic gradients of real-world undisturbed stratified soil samples collected from identified locations.

In all setups, the effective stresses and permeabilities all greatly influenced the behavior of the hydraulic gradient. The two-stratum model turned to be at least 92% accurate whereas the three-stratum model turned to be at least 78% accurate, thus implying inverse proportional relationship between degree of stratification and model accuracy. The use of the two-stratum mathematical model is deemed to be advisable for use in analysis of real-world scenarios involving stratified soils.

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A	Area of soil cylinder
e	Void ratio
e_{ave}	Average void ratio
EV	Experimental value
f	Seepage pressure
FS	Factor of safety
γ	Moist unit weight of soil
γ_d	Dry unit weight of soil
γ_{sat}	Saturated unit weight of soil
γ_w	Unit weight of water
γ'	Buoyant unit weight of soil
G_s	Soil specific gravity
$G_{s\ ave}$	Average soil specific gravity
h	Height of stratum
i	Hydraulic gradient
i_{ave}	Average hydraulic gradient
i_c	Critical hydraulic gradient
i_{EV}	Experimental hydraulic gradient
i_{TV}	Theoretical hydraulic gradient
k	Permeability
k_{ave}	Average permeability
k_c	Bottle calibration constant
k_t	Permeability of top stratum
k_m	Permeability of middle stratum
k_b	Permeability of bottom stratum
L	Total length of soil
σ'	Effective stress
σ'_t	Effective stress at top stratum
σ'_m	Effective stress at middle stratum
σ'_b	Effective stress at bottom stratum
P_{error}	Percent error
Q	Rate of discharge
r^2	Coefficient of correlation
s	Degree of saturation
t	Time
V_w	Volume of discharged water
y	Piezometric head
Δy	Difference in piezometric heads