Water vapor transfer though unsaturated soils due to temperature variations and its effect on soil shear strength

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Keywords: Unsaturated Soils; Shear Strength; Water Vapor Transfer

Climate condition variations have direct effect on the air pressure and temperature; consequently, this is reflected on the water vapor transport from inside the soil voids to the atmosphere or vice versa. The variation of the water content due to this process has a direct effect on the degree of saturation (S).

The main potential for transport mechanism for water vapor in unsaturated soil is the chemical potential of water vapor, expressed in terms of vapor density or concentration. Fick's first law can express and describe the vapor flux q_v (in kg/m^2.sec) (e.g., De Vries, 1958); (Lu & Likos, 2004) (Fredlund & Rahardjo, 1993). As follows:

$$q_v = -D_v \nabla \rho_v \quad (1)$$

Where D_v (m^2 / s) is the diffusion coefficient for water vapor transport in unsaturated soil and ρ_v (kg/m^3) is the vapor density or absolute relative humidity of the pore water vapor.

The driving potential can be represented by the gradient of the water vapor density as in Eq. 2. (Lu & Likos, 2004)

$$\nabla \rho_v = \frac{\omega_w u_{v,sat}}{RT} \nabla RH + \frac{\omega_w RH}{R} \nabla \frac{u_{v,sat}}{T} \quad (2)$$

Vapor transport can change the degree of saturation inside the soil, consequently the shear strength of the soil, as the third term of Eq. 3 represents the contribution of the matric suction to the shear strength and this term can be greatly affected by the degree of saturation. (Vanapalli, Fredlund, Pufahl, & Clifton, 1996)

$$\tau_f = c' + (\sigma_n - u_a)_f tan\phi' + (u_a - u_w)_f \frac{S - S_r}{1 - S_r} tan\phi' \quad (3)$$

Figure 1 shows the variations of temperature in an alluvial soil deposit at different depths as an example. This shows that the top surface of the soil is affected by temperature variations more than deeper deposits. Consequently, most of the shallow foundations which are constructed at shallow depths are affected by this variation of temperature.

A model was made using the Geo-slope software to simulate the seasonal variations of temperature showing the water vapor transport through the soil and consequently the variation of the degree of saturation.

The shear strength is then subsequently calculated using Eq. 3. Results show the effect of the variation of the vapor transport on the shear strength of the soil.

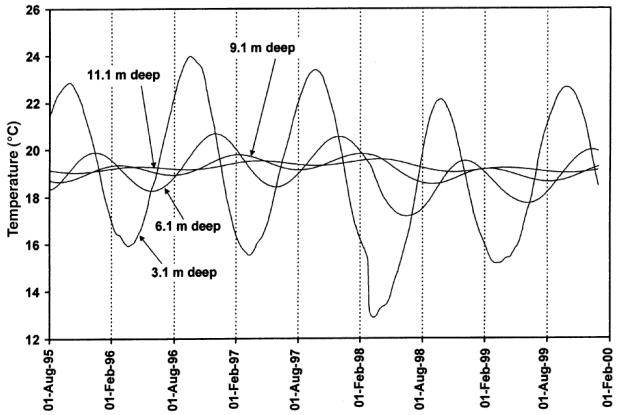

Fig. 1. Seasonal temperature variation in alluvium soil deposit at different depths—Yucca Mountain, Nevada (Lu and LeCain, 2003).

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Professor Abdul-Kareem was born in Baghdad in 1959. He earned his Bachelor degree in Civil Engineering from the University of Basrah in 1980. He later assumed a position as *Chairman* and *Director* of the *Department of Computer Applications* at the *Mayorship of Baghdad*. In 2002, he earned a *Doctorate* degree in *Geotechnical Engineering* from the *University of Baghdad*. His thesis focused on *Solutions to Some Problems of Partially Saturated Soils Using the Finite Element Method.* In 2002, he earned a second Bachelor's degree in Software and Computer Engineering from the University of Technology in Baghdad.

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***Professor Abdul-Kareem Ismet Zainel* was a most pleasant person, humble and warm. He passed away on Wednesday July 17, 2018. He will be much missed, but never forgotten by his family, colleagues and former and current students at the university. May his soul rest in peace and in heaven.**

Omar al-Farouk Salem al-Damluji, President,
Iraqi Geotechnical Society,
August 30, 2018.