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Transport Properties of Soil in the Presence of a Seismic Wave

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Transport properties of soil such as hydraulic and electric conductances are complicated functions of soil parameters, including porosity, water content, pore space distribution and hierarchy. Percolation and fractal theories are conventional techniques for describing transport properties of such media. Note that conductance is essentially a non-linear function of these parameters, especially in close proximity to a percolation critical point(s). Under some conditions this non-linearity could strongly affect the effective conductance, for example, the presence of seismic (acoustic) waves. To describe the main idea let's consider a simple model of the porous medium, containing pores of only one effective radius r_0. In this case the electric conductance is $\sigma = \sigma_0 \cdot \eta(\theta - \theta_c)$, where θ is the pore water content and θ_c is the critical value of the pore water content. Thus, σ=0 if $\theta < \theta_c$ and $\sigma = \sigma_0$ if $\theta > \theta_c$. Suppose that in the steady-state condition the water content is $\theta_0 = \theta_c - \varepsilon$, where ε is small compared to θ_c. If $\varepsilon >$0 the conductance is zero and if $\varepsilon <$0 the conductance is constant value. Let's apply a compressional seismic wave (say an S- or Rayleigh wave) to this medium with amplitude A. The seismic wave changes the volume strain e as well as the pore radius $r$of the medium so that

$e = e_0 + \Delta e(A)\sin(2\pi t/T)$ and $r = r_0 - \Delta r(A)\sin(2\pi t/T)$,

T is the period of the seismic wave and $\Delta e(A)$ is the amplitude of the volume strain change, which is a function of wave amplitude and pore geometry. Δr(A) is the amplitude of the radius change. The change in the volume strain also affects the water content (θ),

$$\theta(A,t) = \theta_0 + \Delta\theta(A)\sin(2\pi t/T),$$

where $\Delta\theta(A) = \gamma \cdot e(A)$ is the amplitude of the alternating part of water content

and γ may vary from about two to ten depending on pore geometry. If the amplitude of the seismic wave is small, that is $|\theta - \theta_c| < \varepsilon$ for any part of the wave cycle, the conductance is zero. For the given amplitude A, averaging over a complete cycle gives an effective conductance

$$\sigma_{eff} \equiv \langle \sigma \rangle = \sigma_0 \cdot \int_0^{2\pi/T} \eta(\theta_0 + \Delta\theta(A)\sin(2\pi t/T) - \theta_{0c})dt = \sigma_0(\pi - 2\arcsin(\varepsilon/_{\Delta\theta(A)}))/(2\pi)$$

Figure 1 depicts schematically the dependence σ_{eff} on water content. Note that the dynamic conditions (in this case seismic wave) effectively reduces percolation threshold.

Figure 1. Schematic representation of dependence of σ_{eff} on water content for various seismic wave amplitudes A.