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Role of the pore-size distribution function on water flow in unsaturated soil

Qian ZHAI, Harianto Rahardjo, Alfrendo SATYANAGA, PRIONO, Guoliang Dai

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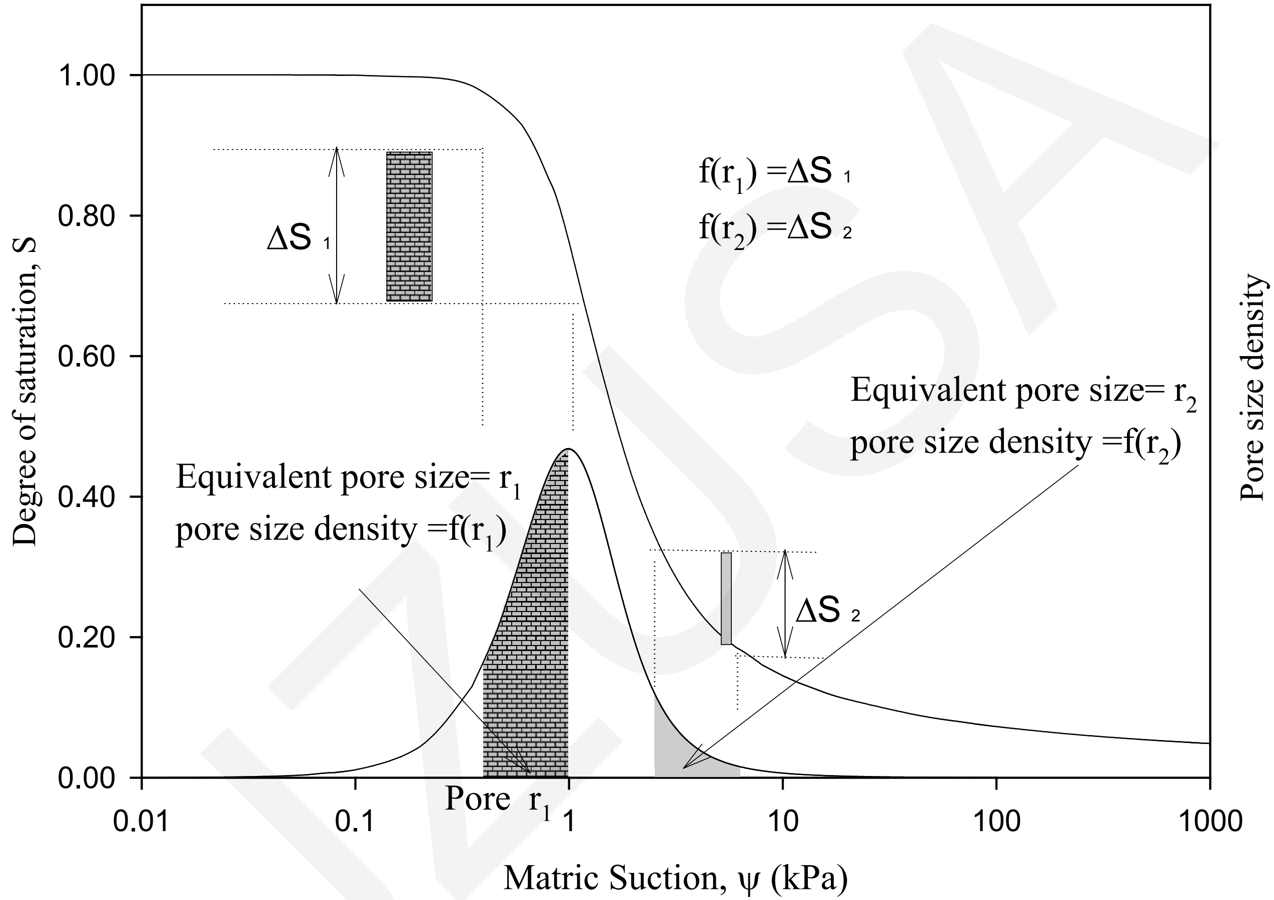
Southeast University, China

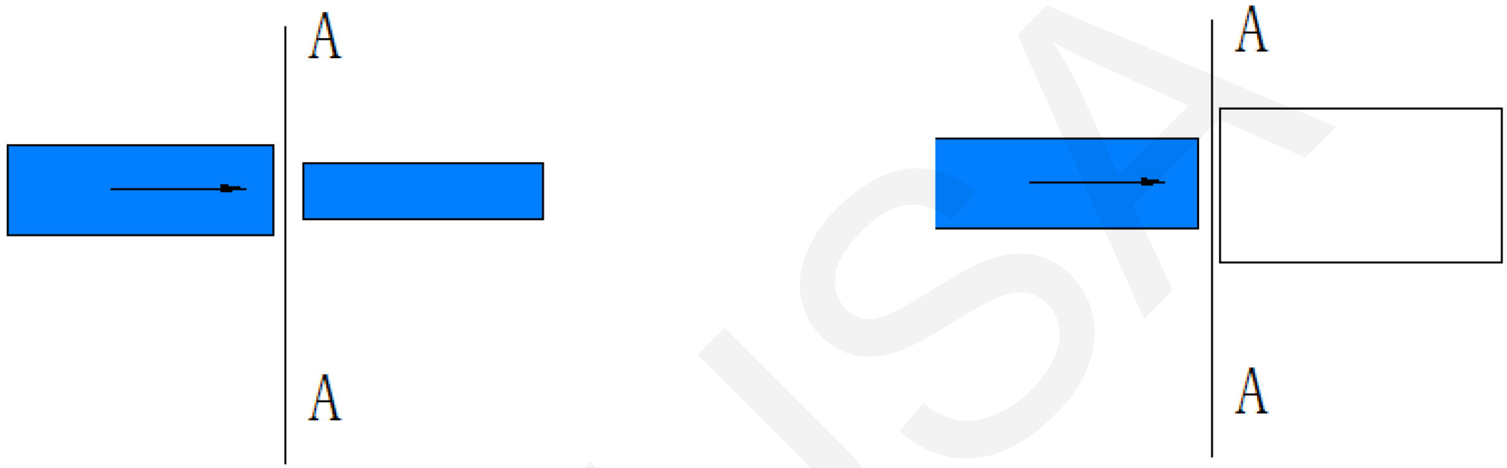
Water flow in soil is mainly governed by the geometrical pore-space. Void ratio, e, or porosity, n, only represents the overall volume of pores in soil. Effective particle size, d_{10}, is used as an approximation of pores in soil, which cannot represents the true geometrical pore-space in soil. Void ratio or effective particle size only can partly reflect the geometrical pore-space in soil and only the pore-size distribution function can represent the true geometrical pore-space in soil.

Pore-size distribution function and soil-water characteristic curve



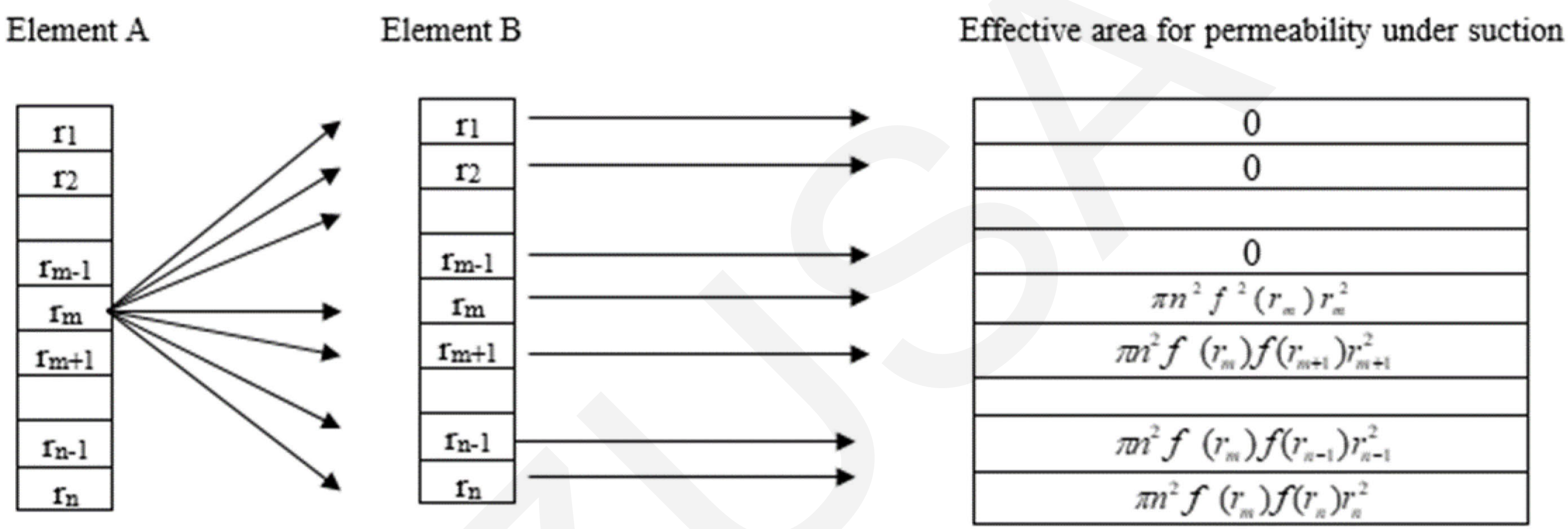
If there is no soil volume change, the soil-water characteristic curve (SWCC) in the form of degree of saturation (S-SWCC) can be considered as the integration of pore-size distribution function (PSD) .

Water flow in pores



If the pores on the both sides of section A are wet, then the water can flow through section A. If the water in the big pore on the one side of section A is drained out due to the applied suction, then the water cannot flow through section A because the water flow is blocked by air-water interface.

Effective area allows water flow through the section



Divide the pores in soil into several groups, each group can be represented by a tube with a particular radius, r, and its statistical distribution, f(r). Consider these tubes with different radii are randomly connected on one section, then the effective area which allows water flow through the section can be calculated and illustrated in the table.

Equation for relative coefficient of permeability

$$k_r = \frac{\left(S(\psi_m) - S(\psi_{m+1})\right)^2 \psi_m^{-2} + \sum_{i=m+1}^{N} \left[\left(S(\psi_m) - S(\psi_i)\right)^2 - \left(S(\psi_m) - S(\psi_{i-1})\right)^2 \right] \psi_i^{-2}}{\sum_{i=1}^{N} \left[\left[1 - S\left(\psi_i\right)\right]^2 - \left[1 - S\left(\psi_{i-1}\right)\right]^2 \right] \psi_i^{-2}}$$

Where, ψ_m is the suction in soil. ψ_i is the section corresponding to the pore radius, *r,* using the capillary law, *r* is pore radius in capillary model, and S(ψ_i) is degree of saturation of soil corresponding the suction of ψ_i.

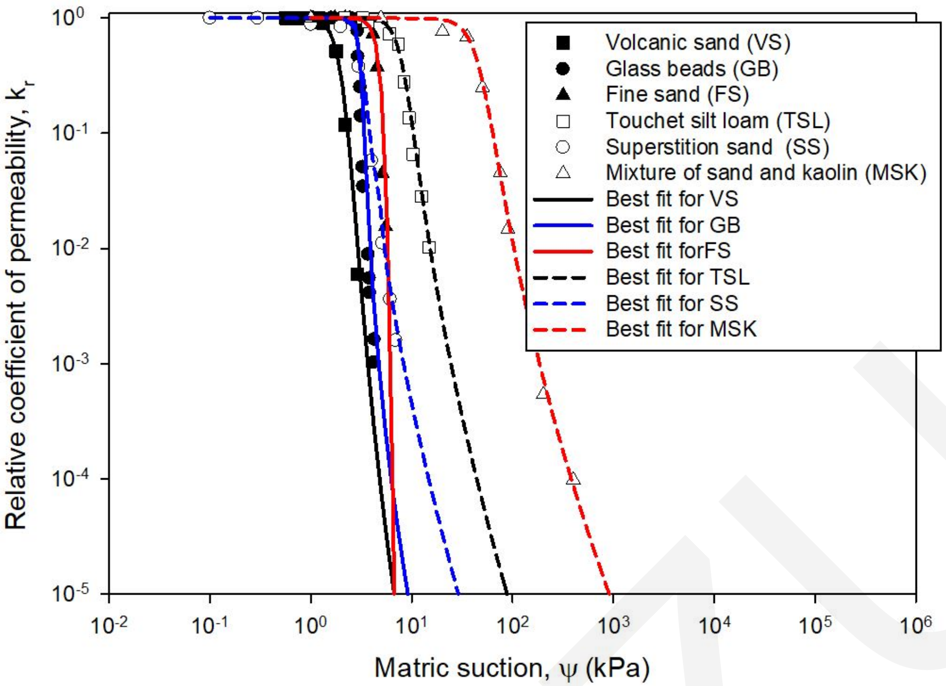
Indirect method to estimate PSD from measured permeability data

$$k_r = \frac{\left(S(\psi_m) - S(\psi_{m+1})\right)^2 \psi_m^{-2} + \sum_{i=m+1}^{N} \left[\left(S(\psi_m) - S(\psi_i)\right)^2 - \left(S(\psi_m) - S(\psi_{i-1})\right)^2 \right] \psi_i^{-2}}{\sum_{i=1}^{N} \left[\left[1 - S\left(\psi_i\right)\right]^2 - \left[1 - S\left(\psi_{i-1}\right)\right]^2 \right] \psi_i^{-2}}$$

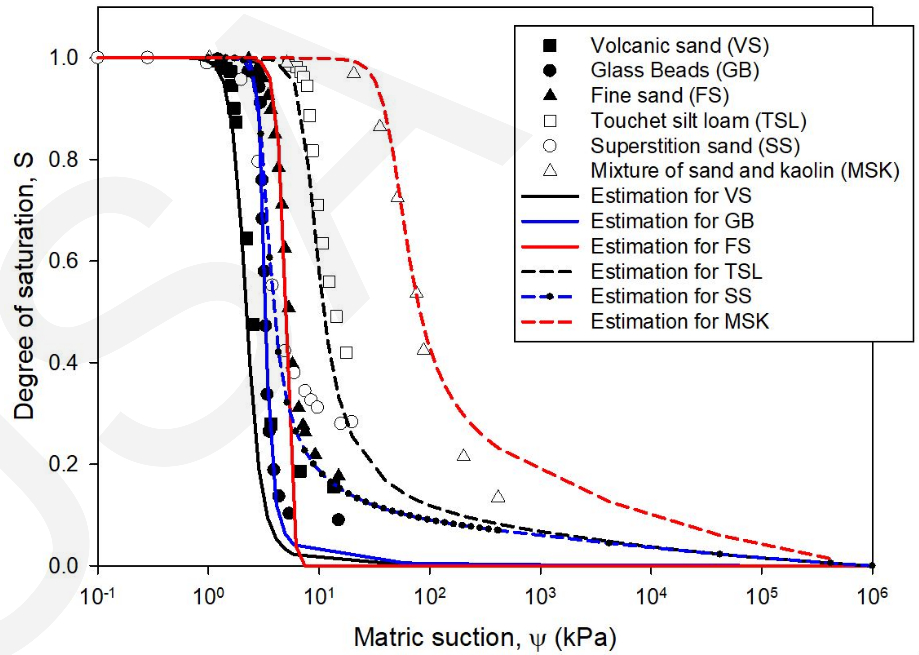
Derived equation can be used to estimate the relative permeability function from S-SWCC (or PSD). If use this equation to best-fit the measured data of permeability, then the S-SWCC (or PSD) can be estimated directly.

The equation derived is based on the assumption that soil volume change during SWCC or permeability measurement can be ignored.

Indirect method to estimate PSD from measured permeability data



Measured data of permeability and best-fit curve using proposed equation



Estimated S-SWCC from proposed equation and measured data of S-SWCC.

The estimated results from proposed equation show good agreement with measured data of S-SWCC for different types of soil. Proposed equation provides an indirect method to estimate PSD from measured data of permeability.