Title
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Aperture-based approaches to modeling unsaturated flow in fractured rock only allow a single phase (liquid or gas) to occupy any given aperture segment. Thus, such models require continuity of locally saturated aperture segments in order to permit fast flow along fractures. Our alternative conceptual model of "film flow" in unsaturated fractures was recently presented, along with laboratory experiments illustrative of its general characteristics (Water Resour. Res., 1997). In this model, water film thickness builds up along fracture surfaces when matric potentials are high enough to sustain effectively saturated conditions in the underlying matrix. As matric potentials increase (approach zero) within this range, water films thicken along fracture surfaces by first filling finer scale roughness features, and progressively filling coarser roughness features. This permits general coexistence of water and air within segments of unsaturated fractures. Thus, on natural rough fracture surfaces, the continuity of wetted surface crevices permits film flow, while true thin films on local topographic maxima of fracture surfaces provide localized hydraulic resistance. The hydraulic properties necessary for characterizing steady-state film flow in unsaturated fractures of porous rock were identified as surface analogs to porous medium properties. These are the matric potential-dependent film transmissivity and the film moisture characteristic function. The transmissivity of films increases with average film thickness, and can support fast gravity-driven flow.

More recently, tests of the importance of surface roughness on film flow were conducted on ceramic and glass blocks with well-defined surface roughness features. Controlling influences of fracture surface channels and ridges were quantitatively demonstrated in these experiments. Another part of this study on film flow concerns transient processes in unsaturated fractures. The film hydraulic diffusivity has been identified and measured through steady-state and transient experiments.