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NUMERICAL SIMULATION OF CONSTITUTIVE RELATIONS FOR UNSATURATED FLOW IN FRACTURED POROUS MEDIA

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Summary. Modelling water flow in unsaturated fractured porous media is of interest to many research areas such as groundwater hydrology, soil science and environmental engineering. Most studies describing water movement through unsaturated porous media are based on the highly non-linear Richards' equation (continuum approach). To solve this equation constitutive relations of effective saturation versus pressure head and relative hydraulic conductivity versus pressure head are required. Direct measurements of these constitutive relations for fractured rocks are particularly difficult to obtain and experimental data are virtually non existent. In this study we determine constitutive relations using a computational procedure which is similar to the laboratory technique of measurement. Synthetic three-dimensional rock samples with random vertical and horizontal fractures are computationally constructed. Fractures are conceptualized as two-dimensional porous media whose hydraulic properties are described by the well-known van Genuchten constitutive model. The procedure used to obtain the simulated values is based on the numerical solution of the steady-state unsaturated flow equation in a 3D domain. The same values of pressure head are prescribed at the top and bottom boundaries of the rock sample and non flow conditions are imposed at side boundaries. Because the effective pressure head gradient is zero in the vertical direction, the average vertical flow should be, according to Darcy's law, the same as the hydraulic conductivity of the fractured sample for the prescribed value of pressure head. Then, for a number of different values of pressure head the effective saturation and the relative hydraulic conductivity can be computed for the synthetic rock sample. Pressure head values are chosen such that a complete set of constitutive relation can be defined from the simulation results. The unsaturated flow equation is solved using a mixed finite element method. Finally, the simulated constitutive relations are fitted using two recently proposed closed-form analytical expressions (Constitutive relations for unsaturated flow in a fracture network, H-H Liu and G Bodvarsson, Journal of Hydrology 252(2001): 116-125; A fractal constitutive model for unsaturated flow in fractured hard rocks, L Guarracino, Journal of Hydrology 324(2006): 154–162). Numerical examples show that both models can match reasonably well the simulated relations for fractured porous media.