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Modelling of unsaturated water flow in double porosity media. An integrated approach.

J. Lewandowska

Laboratoire Sols, Solides, Structures – Risques (3S-R), UMR 5521 CNRS, UJF, INPG, Grenoble, France,
(Jolanta.Lewandowska@hmg.inpg.fr)

"Multi-scale, multi-components, multi-phases" are the key words that characterize the double porosity media, like fissured rocks or aggregated soils, subject to geo-environmental conditions. In relation to this context we present an integrated upscaling approach to the modelling of unsaturated water flow in double porosity media. This approach combines three issues: theoretical, numerical and experimental. In the theoretical part, the macroscopic model is derived by using the asymptotic homogenization method. It is assumed that the microstructure of the medium is composed of two porous domains of contrasted hydraulic parameters (macro- and micro-porosity), so that the water capillary pressure reaches equilibrium much faster in the highly than in the weakly conducting domain. Consequently, large local-scale pressure gradients arise, which significantly influence the macroscopic behaviour of the medium (local non-equilibrium). In this case, the macroscopic model consists of two coupled non-linear equations that have to be solved simultaneously. The homogenization model offers a complete description of the problem, including the definition of the effective parameters (in a general case anisotropic) and the domain of validity of the model. By the latter term we understand the set of underlying assumptions on the microstructure of the medium, the considered spatial and time scales, and the relations between the local hydraulic parameters and the forces driving the flow. All these assumptions are explicitly introduced via the estimation of the dimensionless parameters and the formulation of the appropriate boundary and interface conditions at the microscopic scale. For practical applications the model was generalized to take into account all possible situations (and the appropriate models) that can occurs during a flow process (local equilibrium/local non-equilibrium). The numerical implementation of double-porosity model requires a particular strategy, allowing for the two-scale computations. This kind of models is still under development because of growing interest of taking into account the microstructure of the medium (and its possible evolution). The double porosity generalized model was implemented in the code DPOR-2D for the macroscopically two-dimensional case (axi-symmetric conditions), coupled with the microscopically one dimensional case (spherical flow). The general idea of the numerical model is to associate with each macroscopic "point" a period representing the microstructure. The experimental validation of the double-porosity models requires a priori knowledge of the microstructure of the medium and the local hydraulic parameters. It is possible in case of artificially created media in laboratory conditions (physical models). We present a series of unsaturated flow experiments on a physical model of a double porosity medium. The model is a three dimensional periodic structure, composed of sintered clay spheres embedded in Hostun sand HN38. The experimental procedure followed the logic "from micro towards macro". The experiments were carried out under different flow conditions: infiltration or drainage, and in different macroscopic geometrical conditions: one or two-dimensional axi-symmetrical case. In all cases good agreement between the measurements and the numerical simulations was obtained, confirming the capacity of the model to reproduce the main features of the flow process.