Hysteresis and Percolation in Continuum Modelling of Water Transport in Cementitious Materials

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Abstract

In order to obtain a model capable of predicting water transport in a material with possibly complicated geometry subjected to arbitrary humidity conditions, it is necessary to develop an appropriate coarse-graining of the material. Of particular importance is the dependence of permeability on local water content, which can be very strong in hardened cement paste and other mesoporous materials.

Here we outline a suitable coarse-grained model and demonstrate its ability to explain experimental results. The model includes both diffusion of water vapour, which dominates at low humidity, and flow of confined liquid water in mesopores, which dominates at high humidity. The reliance of both transport mechanisms on percolation of one of the phases present leads to a non-monotonic dependence of permeability on humidity, with a minimum at a material-dependent intermediate humidity.

Additionally, the model accounts for the hysteresis in the dependence of water content on local humidity. A quasi-equilibrium model relates the sorption-desorption isotherm to pore size and connectivity, which are used as inputs in the dynamical model.

The model is applicable to a wide variety of scientific and engineering problems in the field of cementitious materials. For example, an uneven distribution of water within a concrete structure can lead to incompatible dimension changes and hence cracking. A better understanding of transport will lead to the ability to quantify and minimize such a risk.