Measurement of the permeability of cement paste by GARField magnetic resonance profiling

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Abstract

Intrinsic permeability is less often measured in cement paste than in other porous media, partly because it is very low and difficult to measure reliably. Reported values range from circa 10^{-17} to 10^{-22} m^2 [1-5]. Although the intrinsic permeability should be independent of permeating fluid, the larger values tend to be associated with gas permeation, the smaller values with liquid water. Zalzale *et al.* [6] have sought to explain this in terms of the effective permeability of partially saturated materials using Lattice Boltzmann modeling.

In this work we measure the effective permeability using GARField nuclear magnetic resonance (NMR) profiling. In essence, the experiment is a spatially resolved version of the cup-test[7] applied to a small paste sample. The water concentration profile is equilibrated over an extended period within a relative humidity (RH) gradient. The water concentration profile is measured using GARField. The water flux is measured gravimetrically from the change in mass of the salt solution reservoirs maintaining the RH gradient. Small samples enable relatively quick equilibration (2-4 months for 1 cm size samples). GARField enables all the water within the sample to be visualised, including the bound water, so enabling quantitative measurement. Further advantages are that NMR is non-invasive and non-destructive so that time course measurements can be made and that ^1H NMR directly probes the water that is the fluid of interest.

The data is interpreted in terms of effective permeability as a function of relative humidity from the profile spatial gradient. The results show that the effective intrinsic permeability to water transport has a broad minimum of the order of 10^{-22} to 10^{-21} m^2 at intermediate relative humidities in the range 40-70% RH rising very steeply in liquid saturated material (high humidity) and dried, gas filled material (low humidity). This is consistent with the results of Zalzale *et al*. In addition, the data is interpreted in terms of the model of coupled liquid and vapour transport due to Baroghel-Bouny *et al.*[8] yielding the relative permeability of the liquid and gas as a function of relative humidity.

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