Estimating filtration coefficients for straining from percolation and random walk theories

In this paper, laboratory challenge tests are carried out under unfavorable attachment conditions, so that size exclusion or straining is the only particle capture mechanism. The experimental results show that far above the percolation threshold the filtration coefficients are not proportional to the fractional flow through the pores smaller than the particles, but to the power-law functions of them. The experimental penetration depths of particles can be over thousands of pores even if the particle sizes are comparable to the average pore size. This observation cannot be explained by the traditional size exclusion theory or the model of parallel tubes with mixing chambers, where the filtration coefficients are proportional to the flux through smaller pores, and the predicted penetration depths are much lower. A special capture mechanism is proposed, which makes it possible to explain the experimentally observed power law dependencies of filtration coefficients and large penetration depths of particles. Such a capture mechanism is realized in a 2D pore network model with periodical boundaries with the random walk of particles on the percolation lattice. Geometries of infinite and finite clusters formed by pores of the sizes exceeding the particle size are analyzed with regard to the possibility for particle capture. Two power laws are proposed to describe the filtration coefficients close and far away from the percolation threshold of the lattice. They can be applied to match the filtration coefficients from the network model well while one of them is used to match the experimental results. The application of such a model may lead to more accurate inverse determination of the pore size distributions from the challenge tests.