



Transport properties of geomaterials

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Many properties of real or reconstructed materials can be obtained by solving the relevant local equations such as the Stokes equations for low Reynolds number flow and then averaging over the sample to get the macroscopic properties such as permeability. Over the years our team has addressed a large number of transport properties and media and it has tried to rationalize the results obtained by a few correlations.

This talk is focused on two groups of properties. The first one is concerned with diffusion (either stationary or not) and permeability. The second one addresses electrokinetic phenomena. The data are relative to unconsolidated materials such as packings of particles of complex shapes and to consolidated materials such as reconstructed media (either by the standard correlation function or by grain reconstruction) or media obtained by microtomography.

1. Permeability and macroscopic diffusion

These properties were thoroughly investigated for a large number of different porous media. Let E be the local electrical field inside a porous medium submitted to a macroscopic field. A key quantity which can be used to unify the permeability K and the formation factor F (i.e. the inverse of the macroscopic dimensionless conductivity) is the Johnson length Λ which is proportional to the ratio of the integral of E^2 over the pore volume divided by its integral over the surface of the pores.

It was shown that Λ is inversely proportional to the specific surface. Moreover, it was verified numerically that Λ is equal to the square root of $8KF$.

This approach was extended to the apparent diffusion coefficient which can be measured by NMR, and it was shown that it could be renormalized in such a way to obtain a universal curve as a function of a universal time based on Λ for all the media. This is also valid when two phases are present in the pore space.

2. Electroosmotic phenomena

Electroosmotic phenomena, and more generally coupled transports, are generated at the local scale by the flow of an electrolyte close to charged solid surfaces while far from the walls, the solution can be considered as neutral. These phenomena may become very important when the characteristic length scales of the media are submicronic.

The problem is most complex on the pore scale. The medium filled by an electrolyte is submitted to macroscopic gradients of pressure, of electrical potential and of concentration. They induce fluxes of mass, current and solute. Close to equilibrium, the macroscopic coefficients which relate the fluxes and the forces, can be obtained by solving three coupled partial differential equations. Numerical results can be rationalised again by means of Λ . More precisely, when made dimensionless, the coupling coefficients only depend on the ratio of Λ with the Debye-Hückel length κ^{-1} , whatever the porous medium.

Systematic experimental checks of these properties were performed on various sorts of finely divided materials, including clays. The data were in agreement with the previous numerical predictions.

These properties can be extended to high values of the zeta potential. A universal curve is found for the electroosmotic coefficient which is valid for any porous medium and any value of zeta.

These results are practically very important since good estimations of the coupling coefficients can be derived from the knowledge of F , K , κ and ζ which are much easier to measure than the coupling coefficients themselves.