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Prediction of low velocity distribution from pore structure in simple porous media

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The macroscopic properties of fluid flow and transport through porous media are a direct consequence of the underlying pore structure. However, precise relations that characterize flow and transport from the statistics of pore-scale disorder have remained elusive. Here, we investigate the relationship between pore structure and the resulting fluid flow and asymptotic transport behavior in 2D geometries of non overlapping circular posts. We derive an analytical relationship between the pore throat size distribution $f(\lambda) \sim \lambda^{(-\beta)}$ and the distribution of the low fluid velocities $f(u) \sim u^{(-\beta/2)}$, based on a conceptual model of porelets (the flow established within each pore throat, here a Hagen-Poiseuille). Our model allows us to make predictions—within a Continuous Time Random Walk (CTRW) framework—for the asymptotic statistics of spreading of fluid particles along their own trajectories. These predictions are confirmed by high fidelity simulations of Stokes flow and advective transport. The proposed framework can be extended to other configurations which can be represented as a collection of known flow distributions.