Flow Structure Characteristics in Transition from Steady to Turbulent Flow in Porous Media.

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The flow characteristics associated with distinct flow regimes in a porous bed, and their evolution with Reynolds number, is an area not well understood. This experimental study provides detailed velocity fields, using refractive index matching to obtain particle image velocimetry data, in a randomly packed bed of uniform diameter spheres. The bed is approximately a cube with five bead diameters on a side, with 15 mm beads. The pore Reynolds numbers range from approximately 50 to 4000, resulting in flow in the inertial, unsteady inertial and turbulent flow regimes. Two-dimensional time series velocity fields are used to analyze the unsteady flow within four identified characteristic pores. These pores were selected based on their mean flow characteristics, illustrating specific inertial flow structures. These structures include converging jets, separated wakes, impinging flows and flow channeling. Velocity data are analyzed using Large Eddy Simulation methods to filter the velocity fields, as well as small scale vortex detection methods, including swirl strength distributions, to visualize the large and small scale events. The data are also analyzed statistically to determine turbulent kinetic energy, Reynolds stresses, and pore flow length scales and time scales and how they vary with increasing pore Reynolds number. The data indicates that the pore-based scales asymptotically reach uniform values with increasing Reynolds number, and the turbulence characteristics becomes more homogeneous and isotropic. Swirl strength monotonically increases with Reynolds number and vortex stretching is shown to scale with swirl strength. These conditions in general help to justify an estimation of the Lagrangian time scale, using the method suggested by Corrsin. The result is used to estimate turbulent dispersion in a porous bed.