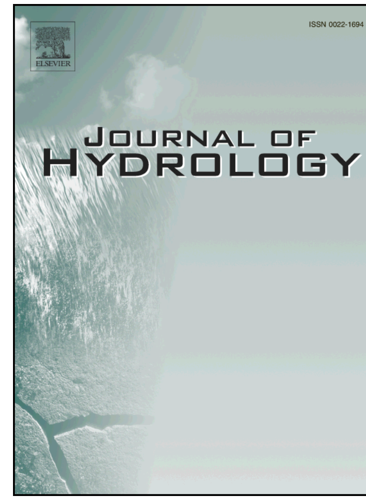
Accepted Manuscript



Water flow across the interface of contrasting materials: Pressure discontinuity and its implications

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PII: S0022-1694(18)30716-9
DOI: https://doi.org/10.1016/j.jhydrol.2018.09.029
Reference: HYDROL 23126

To appear in: *Journal of Hydrology*

Received Date: 12 May 2018
Revised Date: 6 August 2018
Accepted Date: 10 September 2018

Please cite this article as: Li, Z., Wang, D., Zhang, X., Crawford, J.W., Water flow across the interface of contrasting materials: Pressure discontinuity and its implications, *Journal of Hydrology* (2018), doi: https://doi.org/10.1016/j.jhydrol.2018.09.029

Water flow across the interface of contrasting materials: Pressure discontinuity and its implications

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Abstract

Water flow along or across the interfaces of contrasting materials is ubiquitous in hydrology and how to solve them in macroscopic models derived from volumetric average of the pore-scale processes remains elusive. While the change in the average velocity and pressure at water-sediment interface has been well established for channel flow over porous beds, whether a volumetric average could alert the pressure continuity when water flows across the interface of two porous materials is poorly understood despite its imperative implications in hydrological modelling. The primary purpose of this paper is to provide evidences via pore-scale simulations that volumetrically averaging the pore-scale processes indeed yields a discontinuous pressure when water flows across a material interface. We simulated two columns numerically reconstructed by filling them with stratified media: One is an idealised two-layer system and the other one is a 3D column filled by fine glass beads over coarse glass beads with their pore geometry acquired using x-ray computed tomography. The pore-scale simulation is to mimic the column experiment by driving fluid to flow through the void space under an externally imposed pressure gradient. Once fluid flow reaches steady state, its velocity and pressure in all voxels are sampled and they are then spatially averaged over each section perpendicular to the average flow direction. The results show that the average pressure drops abruptly at the material interface no matter which direction the fluid flows. Compared with the effective permeability estimated from the homogenization methods well established in the literature, the emerged discontinuous pressure at the interface reduces the combined ability of the two strata to conduct water. It is also found that under certain circumstances fluid flow is direction-dependant, moving faster when flowing in the fine-coarse direction than in the coarse-to-fine direction under the same pressure gradient. Although significant efforts are needed to incorporate these findings into practical models, we do elicit the emergence of discontinuous pressure at material interface due to volumetric average as well as its consequent implications in modelling of flow in heterogeneous and stratified media.

Key words: Homogenization; stratified media; pore-scale modelling; pressure discontinuity; upscaling.