Effect of roughness on solute transport through synthetic rough single fractures

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Introduction Fractures and bedding planes or faults give place to preferential flow paths for groundwater, pollution in dilution, and free product, thus become great concern [1-2]. Single fracture has been traditionally idealized as parallel plates to obtain a tractable description of fluid flow and solute transport, and the model used to describe fluid flow in such an idealized single fracture is the local cubic law (LCL), which is essentially the expression of Darcy's law for a single fracture [3-4]. Also, Fickian transport is believed to be the "right" form of governing law of transport in the subsurface where the dispersive mass flux is assumed to be proportional to the first derivative of the resident solute concentration [5-6]. However, the real fractures have rough walls with points of contact, in which the transport is found to be non-Fickian in many occasions [7-8]. The main goals here are to test different models on the solute transport through a rough single fracture under non-Darcian flow conditions and to study possible correlations between fitting parameters and fracture heterogeneities. With these objectives in mind, following tasks will be carried out in sequence.

Experimental setup Artificial horizontal single fractures were constructed in the laboratory using organic glass plates, the schematic figure was shown in Figure 1(a). Three different kinds of roughness were used for the upper wall (Figure 1(b)): a smooth parallel plate; a rough plate with rectangular rough elements and a rough plate with trapezoidal rough elements.

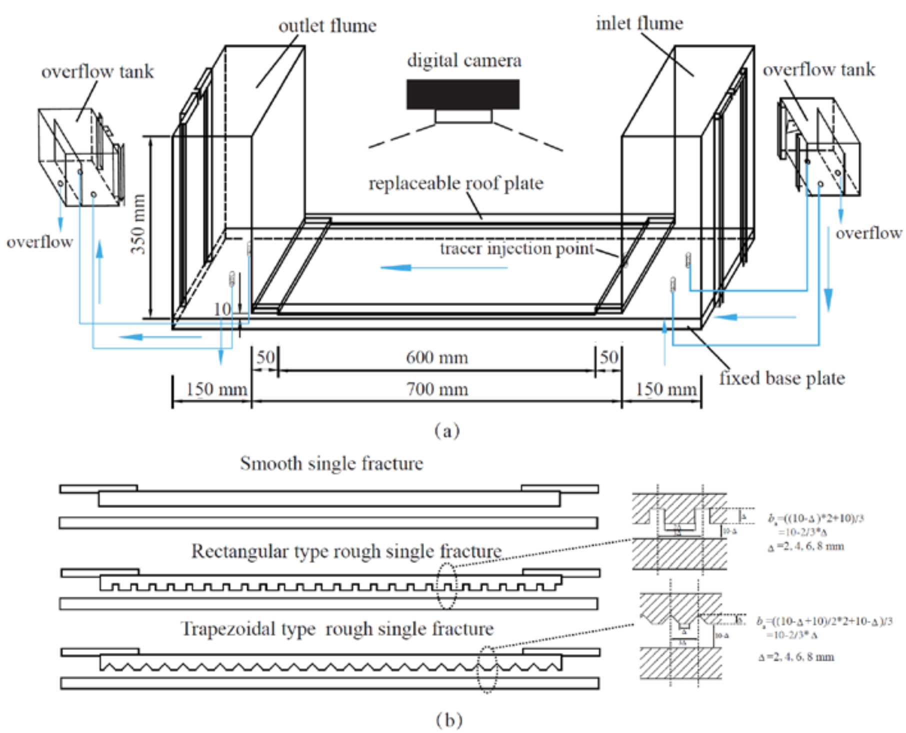
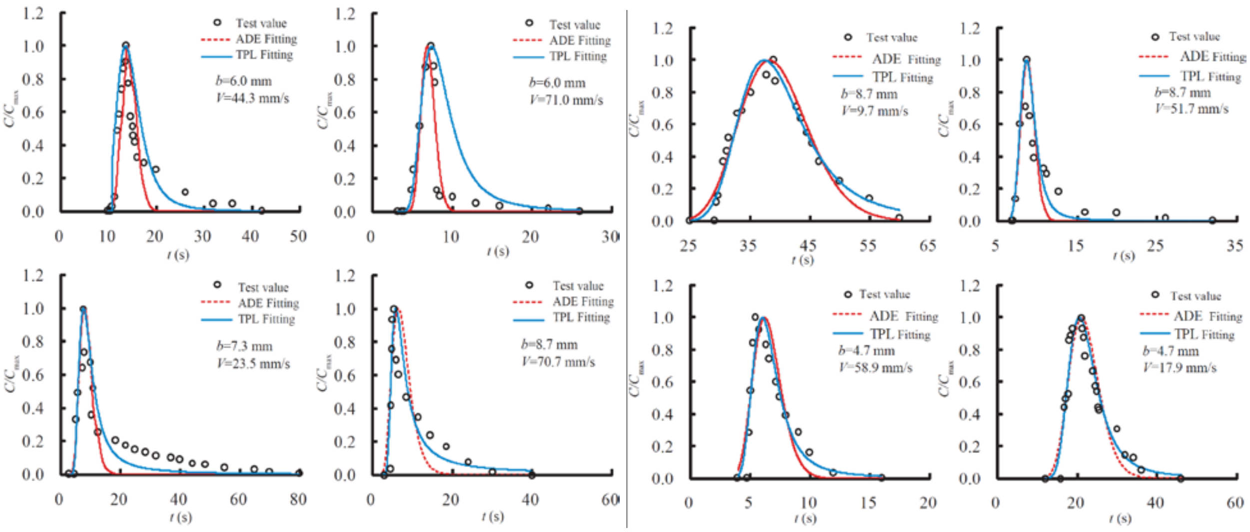


Figure 1: Schematic figure of the experimental setup

Results and Conclusions Aperture values ranging from 4.7~8.7 mm and Reynolds number (Re) values at 9.38~1743.8 were set for investigating fluid flow through synthetic horizontal single smooth and rough fractures. The Brilliant Blue FCF dye was chosen as the tracer here to visualize the transport process. Non-Darcian flow existed in both smooth and rough single fractures and the average flow velocity-hydraulic gradient (*V-J*) relationships were best described by the Forchheimer equation. The main objectives were to check the existing flow and transport models and to study possible correlations between fitting parameters and heterogeneities. The classical advection-dispersion equation (ADE) model failed to capture the long-tailing of breakthrough curves (BTCs). Instead, the continuous time random walk (CTRW) model could better explain BTCs in both smooth and rough fractures, especially in capturing the long-tailing feature (shown in Figure 2). The non-Darcian coefficient βc in the Forchheimer equation and the coefficient β in the CTRW model appeared to be most relevant for characterizing the heterogeneity of the rough single fractures.



(a) *(b)*

Figure 2: BTCs and fitting results in single fractures (a): with smooth parallel plates; (b):with rectangular rough fractures (x=555 mm)

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