Explaining Pore-Scale Phenomena of water Infiltration into Sand

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Background and Motivation

Column or fingered in homogeneous sand carry rapidly water and its constituents (including colloids) to groundwater bypassing most of the soil matrix. The process that these fingers form has not been examined experimentally. In this part of the project, we present how the discontinuous pressure at the finger front results in the wetting front moving one pore at a time, causing high pore velocities with increased dynamic contact angles according to the Hoffman-Jiang equation.

Hoffman-Jiang Equation

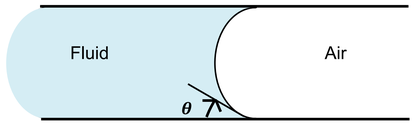

Fig 1. Contact angle of an advancing liquid-air interface.

$$\theta_d = \theta_s + \left(1 - \frac{\theta_s}{\pi}\right)\arccos\left[1 - 2\tanh\left(4.96\,\mathrm{Ca}^{.702}\right)\right]$$

where θ_d - dynamic contact angle; θ_s – static contact angle

Material and Methods

In a series of flow cell infiltration experiments, a high-speed camera (500 fps) was used to capture the waterfront movement as water infiltrated four different kinds of porous media (unwashed sand, acid-washed sand, unwashed glass beads, acid-washed glass beads). The porous materials were packed in a 0.6 x 0.2 x 2 cm transparent channel and flushed with red-colored deionized water at 10 µl/min. Frame-by-frame image analysis was used to determine the position and velocity of the wetting front, and the advancing front contact angle.

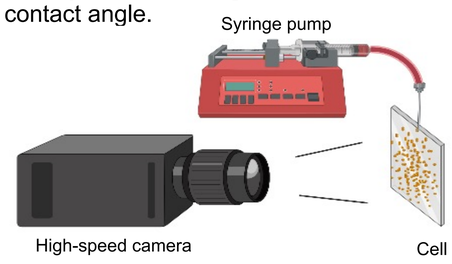

Fig 2. Schematic of experiment procedure.

Measured dynamic contact angle

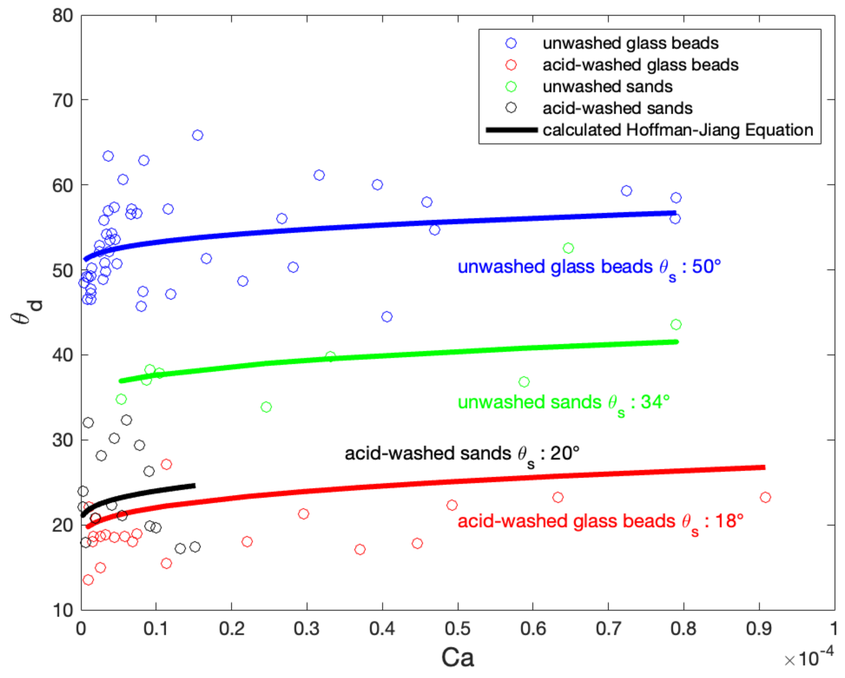

Fig 4. Measured dynamic contact angle (points) with the calculated Hoffman-Jiang equation (lines).

Results

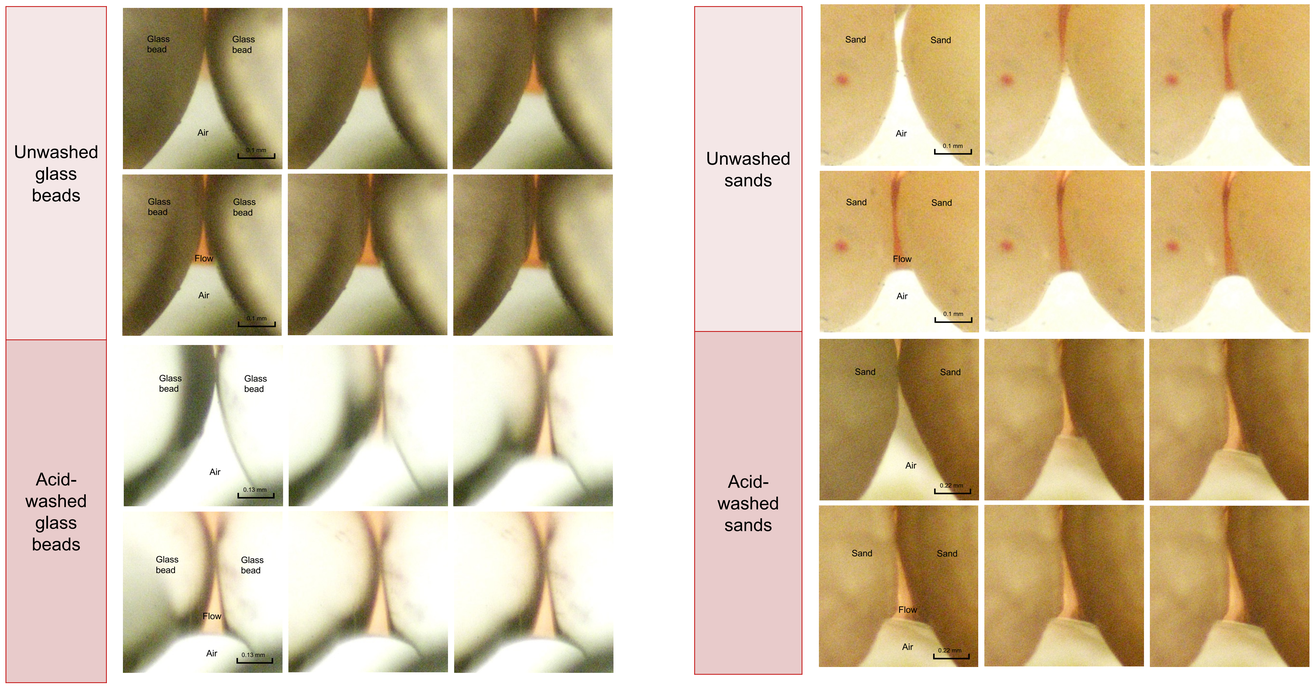

Fig 3. Movement of water in pores during infiltration into glass beads and sands

Conclusion and Future Work

The results show that the changes in contact angle between the wetting front and particle surface are consistent with the Hoffman theory and the Hoffman Jiang equation. It strengthens the claims that changes in contact angle during infiltration should be considered when studying water infiltration and colloid transport in porous media.

More experiments will be conducted to have more data points. Colloid particles will also be added to the solution to simulate the transport of colloid-sized contaminants in sandy soil.

References

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