CAPILLARY FORCES ON SEDIMENT PARTICLES: EXPERIMENTAL MEASUREMENTS AND THEORETICAL ESTIMATES

Abstract

by Nirmalya Chatterjee, Ph.D.
Washington State University
August 2013

Chair: Markus Flury

At the Hanford Site, radioactive wastes have been disposed into the subsurface. These radionuclides move with infiltrating water both in solution and via adsorption on mobile colloidal soil particles. Extensive research has been directed to understand the mechanism of colloid transport: at field-scale in lysimeters, at laboratory scale in columns and by indirect field measurements. This dissertation investigates experimental and theoretical methods to determine capillary forces on millimeter-scale particles in the subsurface. The specific objectives of this dissertation were:

1. *Measure capillary forces on irregularly shaped sediment particles and compare with theoretical estimates.*

   Capillary forces due to a moving air-water interface were measured experimentally on three PTFE particles of standard shape (sphere, circular disc, square tent) and seven natural sediment particles (basalt, granite, hematite, magnetite, mica, milky quartz, quartz) using a tensiometer. Theoretical calculations were done to estimate maximum capillary forces, assuming the particles to be spherical, cylindrical, and ellipsoidal. The ellipsoidal model was found to give the best approximation of the capillary forces.

2. *Measure capillary forces on model particles of standard shapes and compare specific features of the force-position curves with theoretically reconstructed curves.*

   Capillary forces due to a moving air-water interface were measured experimentally on nine model polyacrylate particles. Particles were divided

into three categories (rounded, fixed, and tapered) based on cross-section. The theoretical reconstruction of the force-position curves indicated that the pinning, snap-in and snap-off of the air-water interface on sharp edges and variation of cross-section along z-axis dictated the shape of the force-position curve.

3. *Develop a numerical model to predict capillary forces on subsurface particles.*

   Surface roughness features of basalt and quartz sediment particles were reconstructed at triangle resolutions of 3%, 5% and 10% of the particle's root-mean-square radius using scanning electron microscopy. Force-position curves were measured experimentally and calculated theoretically for comparison to determine an optimum mesh resolution. The results provided a lower size-limit of roughness features which can affect capillary forces on mm-scale particles interacting with a moving air-water interface.