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S Majid Hassanizadeh

Utrecht University, The Netherlands

Grain-scale modeling of highly swelling granular materials

Swelling is an important process in many natural materials (e.g., swelling clays) and industrial products such as in fuel cells, paper and Absorbent Gelling Material (AGM) particles in hygienic products. AGM particles are capable of swelling, because of their hydrophilic polymers that allow AGM to absorb large amounts of fluid, namely, 30 to 1000 times their initial weight. To gain insight in the swelling behavior of a bed of AGM particles, we have developed a grain-scale model and we have tested the model by comparing it to experiments. The grain-scale model is based on the Discrete Element Method (DEM) and the Pore Finite Volume (PFV) method, which we have extended to include the swelling of individual AGM particles. Using this model, we can simulate the behavior of individual particles inside a water-saturated bed of swelling AGM particles while taking into account the hydro-mechanical effect arising from the presence of pore water. The model requires physical input parameters, which were obtained from literature for the particle stiffness and the friction angle, while the particle size distribution and the diffusion coefficient were measured in experiments. We have simulated and studied experimentally a bed of dry AGM particles inside a glass beaker to which we add plenty of water for the AGM particles to swell in. Simulations reveal that the numerical model is in accordance with the experimental data. We have also verified the model with Terzaghi's analytical solution for a small swelling event. Finally, the model is extended to the swelling of a layer under unsaturated conditions.

Biography

S Majid Hassanizadeh is Professor of Hydrogeology at Utrecht University and Senior Advisor with Soil and Groundwater Department of Deltares. He is on Editorial Boards of many journals (Transport in Porous Media, Journal of Porous Media and Journal of Fluids) and has organized many conferences, workshops and short courses. He is Elected Fellow of American Geophysical Union (2002) and Fellow of American Association for Advancement of Science (2007). He has been selected as Distinguished Darcy Lecturer by US National Groundwater Association (2012). He is the recipient of Honorary Degree of Doctor-Ingenieur from Stuttgart University (2008), von Humboldt Prize (2010), Don and Betty Kirkham Soil Physics Award (2011), Advance Research Grant from European Research Council (2013), and Royal Medal of Honor Knight in the Order of Netherlands Lion (2015).

s.m.hassanizadeh@uu.nl

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