

Tuesday 3/14/2017

3–4:30 p.m.

Thermal & Hydraulic Conduction 2

Chairs: Ingrid Tomac, University of California, San Diego; John McCartney, University of California, San Diego

Infiltration Characteristics of Chemically Treated Water-repellent Kaolin

Youngmin Choi, Sanghyeong Lim, and Woojin Lee, Korea University; Changho Lee, Chonnam National University; Tae Sup Yun, Yonsei University

Degree of water repellency significantly influences the infiltration behavior of water-repellent soils. In this study, the chemically treated water-repellent kaolin clays with different concentrations (CO) of an organosilane solution are examined to explore the effect of water repellency on its infiltration characteristics. Experimental results show that the soil-water contact angle tends to increase with increasing CO until CO = 5%, and then shows an almost constant value with increasing CO. The water infiltration time (WIT) results show that water infiltration resistance is significantly improved by organosilane treatment (CO ≥ 5%) under low hydrostatic pressure (WP). However, as the hydrostatic pressure increases, WIT is converged (CO = 5%) or exacerbated (CO = 10% and 20%) to the WIT of untreated clay. The different behaviors of infiltration are discussed in terms of wetting patterns. The findings can be used to improve a conventional hydraulic barrier system.

Comparison of Averaging Methods for Interface Conductivities in One-dimensional Unsaturated Flow in Layered Unsaturated Soils

Ruowen Liu, Bruno Welfert, and Sandra Houston, Arizona State University

Numerical simulations of water flow through unsaturated soils have been well studied but very few studies have addressed water movement across soil interfaces by imposing continuity of both flux and pressure head. Imposing continuity of both head and flux leads, at a local discrete level, to a nonlinear interface equation which may exhibit multiple solutions if the spatial discretization is not fine enough, for example during infiltration with sharp fronts or in the presence of very dissimilar soil layers. The non-uniqueness of solutions of the interface equation can lead to numerical errors and/or numerical oscillations. We use a staggered finite difference approach with cell-centered hydraulic conductivities estimated by averaging nodal conductivities. We evaluate the impact of several averaging schemes (arithmetic, harmonic, geometric and log-mean) on the occurrence of multiple solutions and associated numerical issues. The resulting numerical schemes are compared in terms of their propensity to trigger multiple roots at soil interfaces. Our results show that the choice of averaging scheme does affect the occurrence of multiple solutions and long term behavior of the numerical solution. In particular, our simulations confirm that the averaging schemes associated with larger interface conductivities (log-mean and arithmetic mean) are less likely to suffer from non-uniqueness issues of the interface problem.

A Review on Coupled Heat and Water Vapor Transport in Unsaturated Soils

Arsha Lekshmi K.R. and D.N. Arnepalli, Indian Institute of Technology, Madras

Coupled heat and water transport has found to be relevant in unsaturated soils because of increasing interest in disposal of radioactive wastes, geothermal energy, hydrology and agricultural problems. In an

unsaturated soil, heat can be either latent or sensible or both and water may take the form of either liquid or vapour or both. The impact of thermal gradient on water vapour movement in terms of both vapour and liquid flow is essential and it requires accurate experimental quantification and representation for modeling of coupled heat and water vapour flow. Although it is possible to calculate the total water vapour flux, it is difficult to distinguish experimentally between liquid and vapour fluxes in unsaturated soils. This paper focuses on providing a critical review on heat and water vapour transport in unsaturated soils.

A Fast-convergence Solution for Modeling Transient Flow in Variably Saturated Soils Using Isogeometric Analysis

Shahriar Shahrokhbadi, Farshid Vahedifard, and Manav Bhatia, Mississippi State University

In this study we developed a numerical model based on Isogeometric Analysis (IGA) to simulate variably saturated flows. A head-based formulation and mass-lumping technique are used to determine the wetting front progress in unsaturated soils. This study shows that the IGA-based method is able to use higher order Non-Uniform Rational Basis Functions (NURBS), extensively used in Computer Aided Design (CAD), to model highly nonlinear problems. Unlike Lagrange shape functions, NURBS have non-negative amplitude even for high order approximations. It is shown that higher order NURBS are able to predict wetting front in highly nonlinear problems. To demonstrate this capability, a highly non-linear transient unsaturated seepage problem is simulated in both IGA and Finite Element Analysis (FEA). The results show that the IGA model performs properly over a wide range of unsaturated flow problems while higher order FEA model diverges especially in problems with high level of nonlinearity.

Water and Gas Flows in Hydrate-bearing Sediments

Yue Xu and Sheng Dai, Georgia Institute of Technology; Yongkoo Seol, National Energy Technology Laboratory; Jaewon Jang, Arizona State University

Gas hydrate plays a critical role in new energy resource, global carbon budget, and submarine instability. Enhanced understanding on how gas hydrates influencing these issues largely depends on in-depth understanding of multiphase flow in hydrate-bearing sediments particularly during hydrate formation and dissociation processes. However, appropriate selection of flow parameter values for hydrate simulators is not available. Published parameter values show large discrepancies among hydrate simulators as well as between numerical and experimental studies. Based on experimental results of single-phase flow in hydrate-bearing sediments, recommended flow parameters for hydrate-bearing sediments are $\lambda = 1$, $S_{rw} = 0.1$, and $S_{rg} = 0.55$ for the Brooks and Corey model and $m = 0.7$, $S_{rw} = 0.1$, and $S_{rg} = 0.5$ for the van Genuchten model. In general, current hydrate simulators underestimate residual gas saturation S_{rg} , which will lead to overestimated rate of gas production from hydrate deposits. These results are also relevant to multiphase flow in porous media undergoing diagenesis, bio-clogging, or mineral precipitation and dissolution.

Experimental Evaluation of Thermal Conductivity of Silica Sands with Varying Porosity and Particle Size

Jongwon Jung and Mohammad Jafari, Louisiana State University; Jaehun Ahn, Pusan National University

The physical properties of granular materials, such as hydraulic, strength, and thermal properties, are dependent on the density (or porosity) and particle size distribution of materials. Among others, the understanding in thermal properties of granular materials is still in immature stage. In this study, the thermal conductivity, one of important thermal properties, of Silica sands with varying porosity and

particle size are experimentally investigated using the transient method. Based on experimental results, the thermal conductivity of granular materials was presented as the function of porosity and proportion of finer particles. It was found that the thermal conductivity tends to become lower under higher porosity and lower proportion of finer particles, and vice versa. Further study on the thermal conductivity of granular materials regarding their packing condition and particle size distributions should be required more in mechanical or generalized terms.