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High Resolution Dual Modality (Neutron and X-ray) Imaging of Partially Saturated Sand and Direct Numerical Simulation Technique Application of Flow through Porous Media

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High spatial resolution dual modality (neutron and X-ray) tomography was performed on partially water-saturated silica sand specimens with two different grain shape morphologies (round and angular) at Helmholtz-Zentrum-Berlin. Partially saturated sand specimens were placed in custom developed granular material compaction molds. Partially saturated silica sand is a three phase material consisting of solid phase (Silica: SiO2), gas phase (air), and liquid phase (water). Due to different attenuation characteristics of neutrons and X-rays to these three phases of interest, neutron and X-ray images provided unique but complementary information. While the water phase contrast is well identified using high resolution (˜13.7 μm/voxel) cold neutron images without using a contrast agent, the detailed structure of silica phase is much clearly shown in higher resolution (˜11.2 μm/voxel) X-ray images due to low attenuation of air/water phases to X-rays. Such dual modality image characteristics make the detailed spatial analysis of the three phases with high confidence by utilizing both contrasts. Image registration technique was further applied to align the neutron and X-ray data to the same location, and the three phases were quantified more precisely. Direct numerical simulation based on the actual pore geometry of a dry sand specimen obtained from X-ray tomography. Capillary pressure –saturation curves and the water distribution at different capillary pressures were obtained from the simulations. The data presented in this research is of critical importance to many disciplines that involve multi-phase flow visualization and analysis, granular mechanics that considers quantitative 3-D distribution of voids (gas and liquid phases) and solids, geotechnical and petroleum engineering, and contaminant transport through vadose zone. The dual modality imaging was presented as an effective tool to study partially saturated porous medium at micro scale. The technique has potential to be applied to experiments involving in-situ fluid flow and solid deformation, and the experimental results can be directly compared with image based simulation results.

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