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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Neutron and X-ray Total Macroscopic Cross Section Comparison

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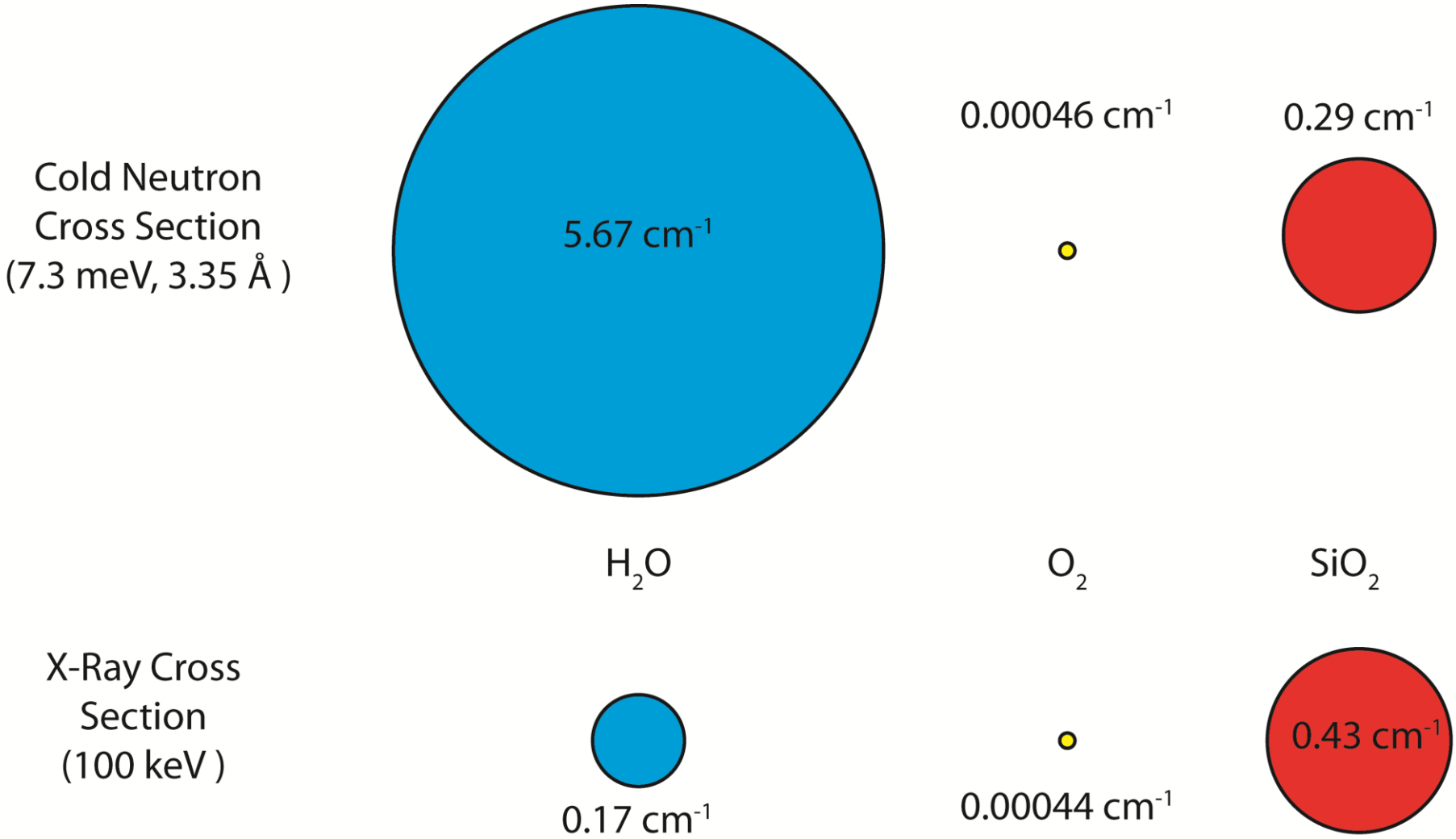

HZB: Neutron and X-ray System

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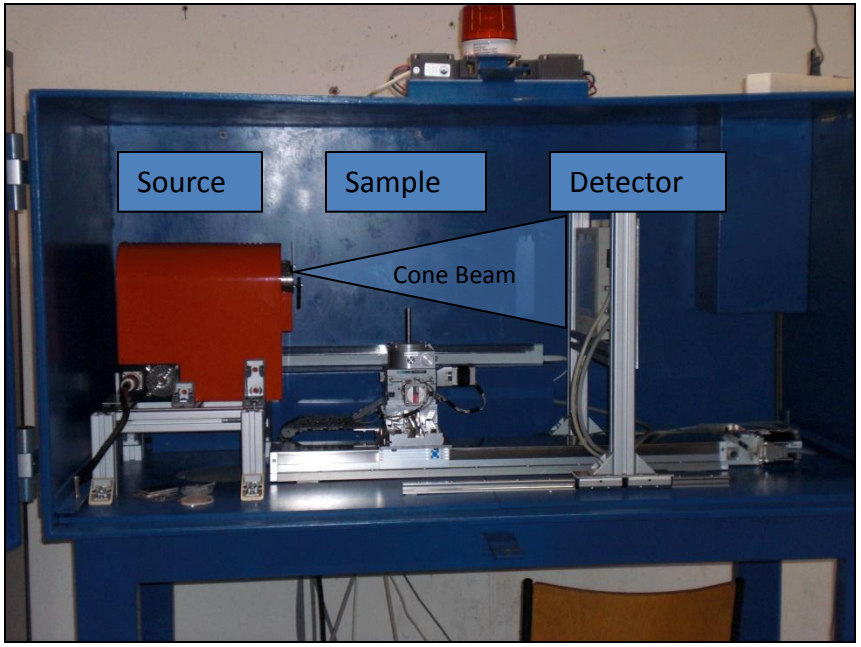
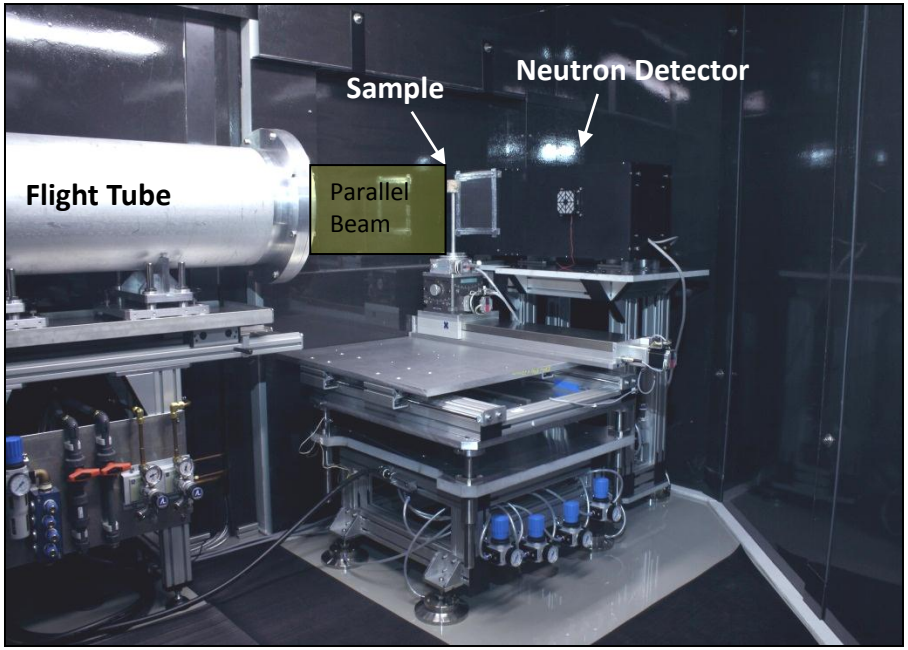


Microfocal X-Ray CT Machine

Peak Energy: 100 keV
Pixel Size: 11.25 µm
FOV: 25.9 mm × 25.9 mm (2316 × 2316)
Cone Beam Reconstruction
Focal spot size: 5 µm



High Resolution Neutron Imaging Detector Setup

Peak Energy: 7.30×10^{-6} keV, 3.35 Å (Cold Neutron)
Pixel Size: 13.7 µm
FOV: 28 mm × 28 mm (2048 × 2048)
Parallel Beam Reconstruction

Dual – Modality of X-ray and Neutron

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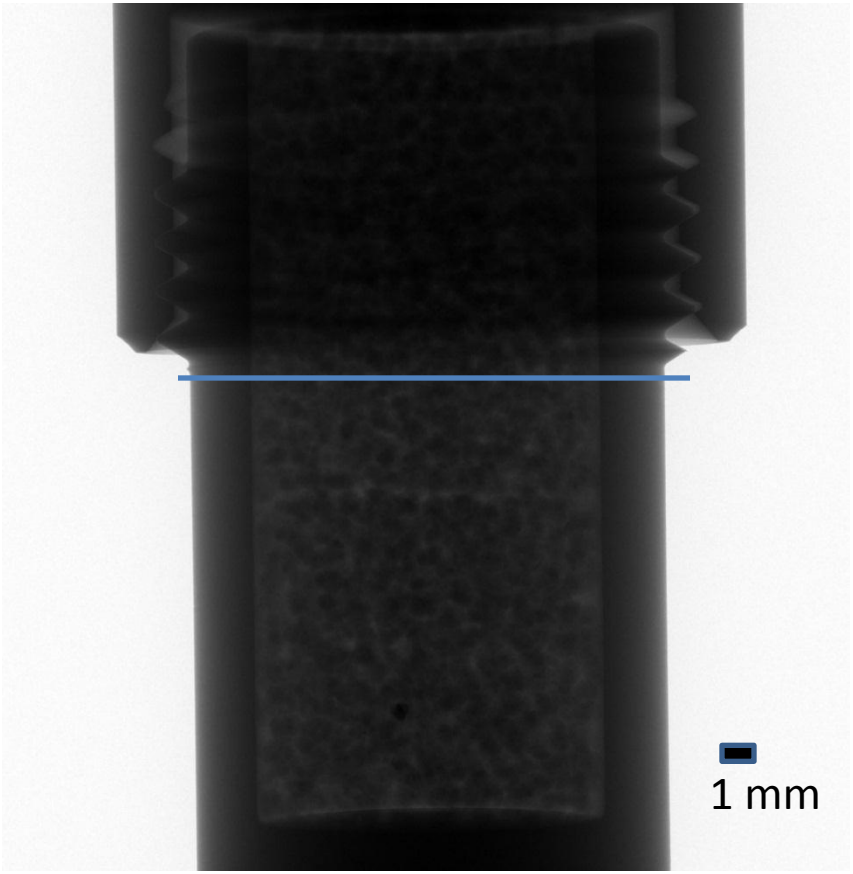

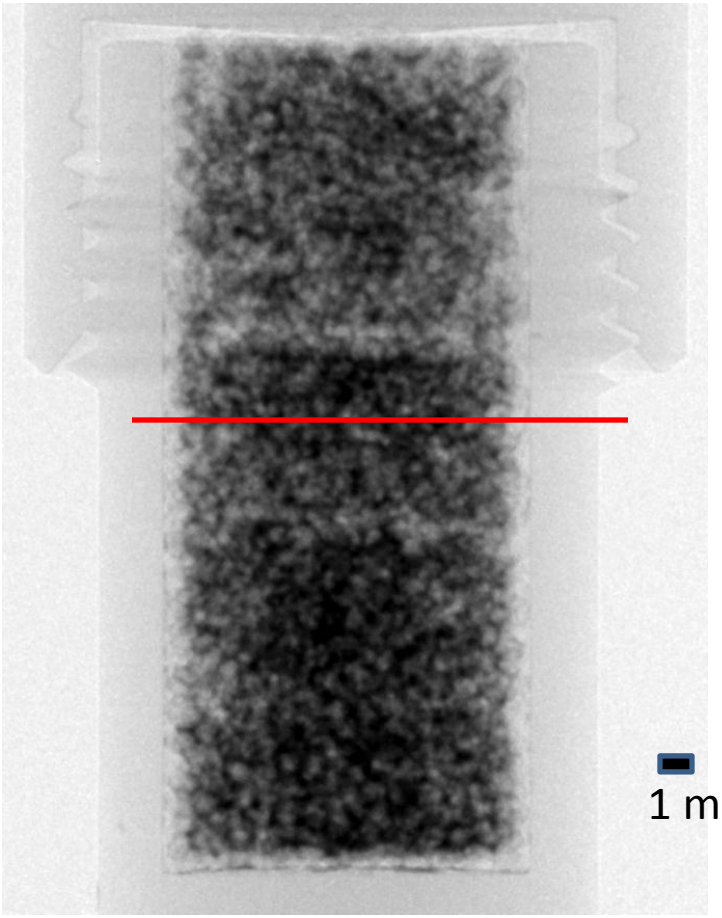

X-ray (11.25 µm/pixel)

Neutron (13.7 µm/pixel)

Dual – Modality of X-ray and Neutron

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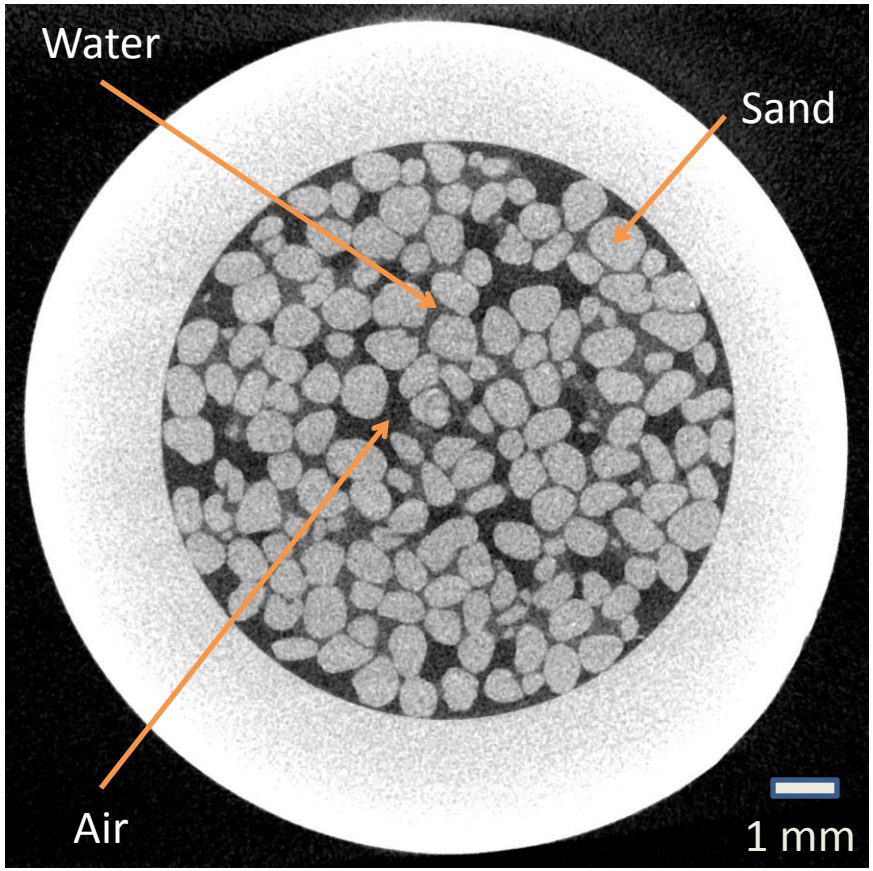
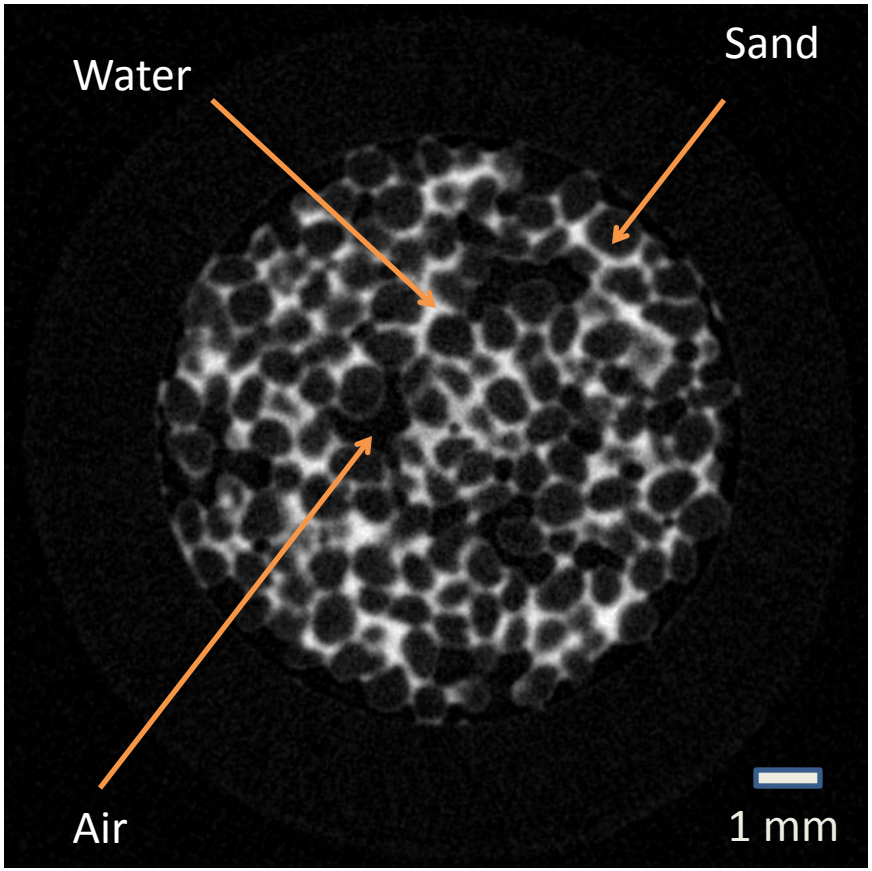


X-ray (11.25 µm/voxel)



Neutron (13.7 µm/voxel)

Image Registration (3D View)

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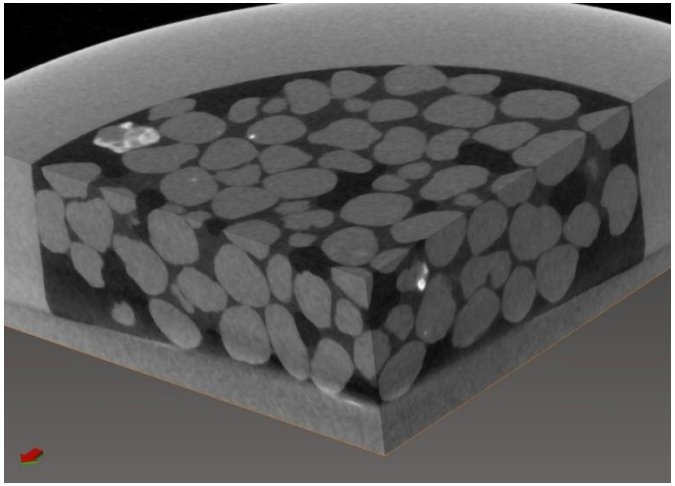
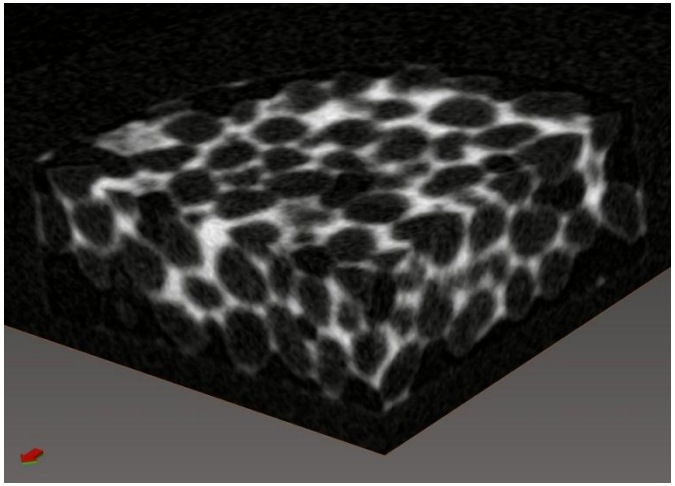
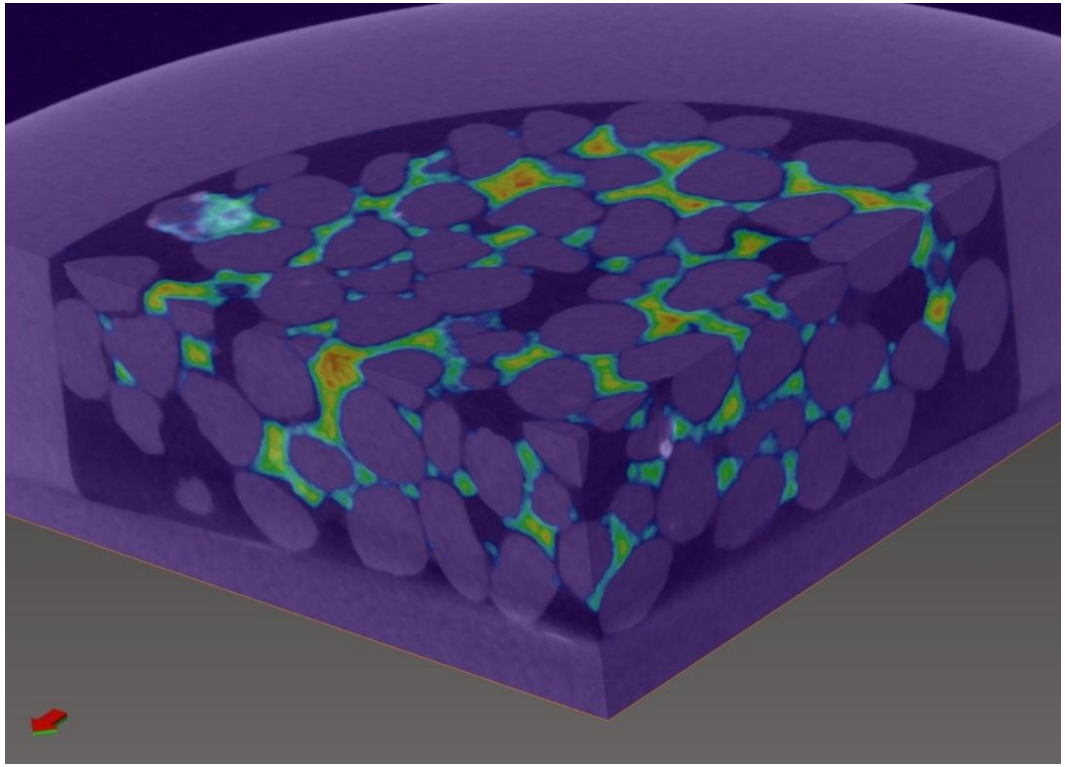


X-ray



Neutron



Registered

Direct Numerical Simulation (Full Morphology Method)

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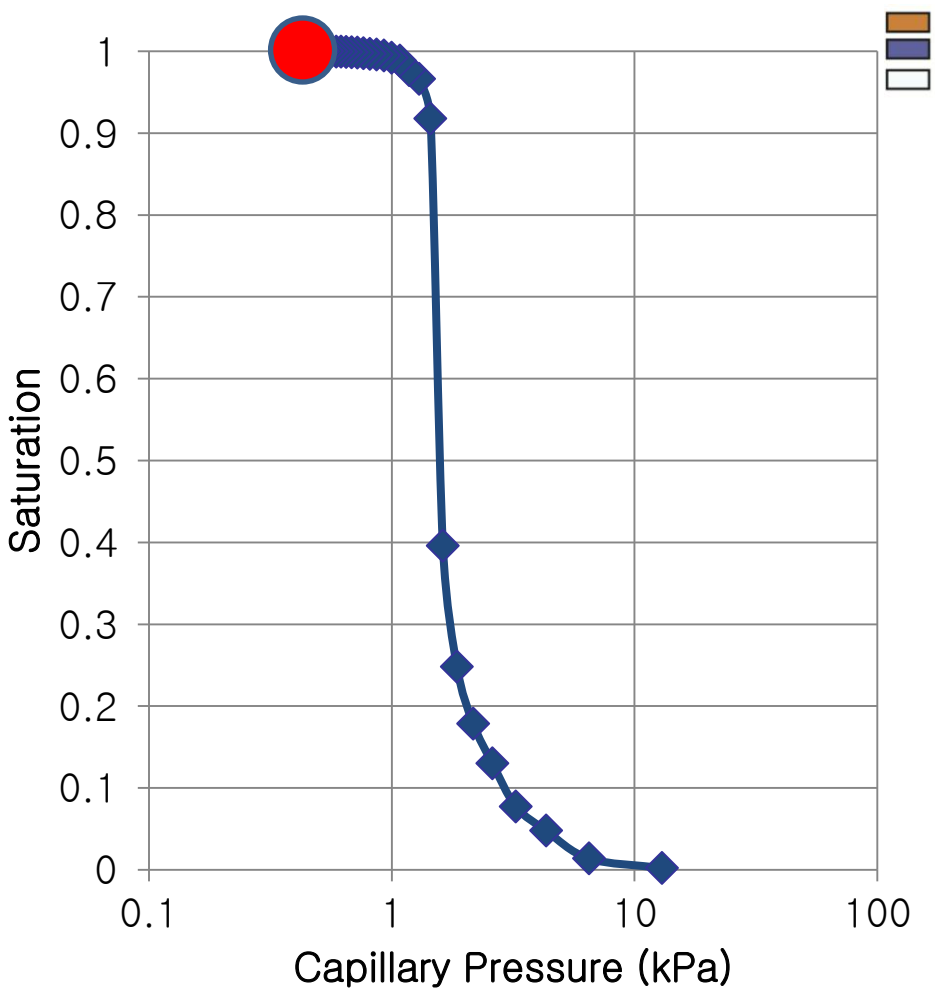
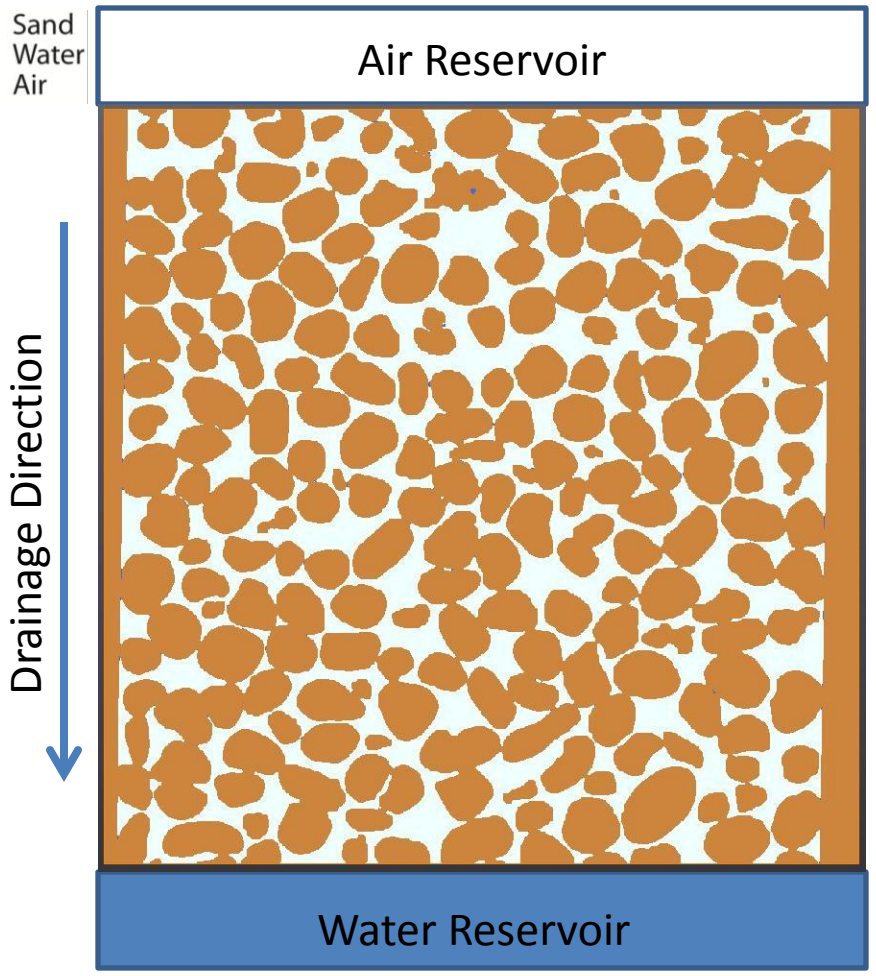


Capillary Pressure – Saturation Curve



Simulated Two Phase (Water and air) Distribution

Conclusion

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- Dual-modality of neutrons and X-rays of partially saturated sand specimens were presented
- Dual-modal contrasts can be used to study different phases of the material without using a contrast agent
- Image registration technique was used to align the dual modality data into same place or more accurate phase quantification
- Direct Numerical Simulation (DNS) was performed to obtain a simulated capillary pressure – saturation curve based on actual sand geometry obtained from X-ray tomography
- The dual-modal imaging of X-ray and neutron has great potential to be utilized to the study of penetration of projectiles through sand and other geomaterials as a function of water saturation, in-situ fluid flow and solid deformation, and the tomography data can be directly compared with image based simulation results.