Experimental report

29/06/2020

Proposal: UGA-73 **Council:** 4/2019

Title: Partial saturation in granular media

Research area:

This proposal is a new proposal

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Samples: H2O
Quartz spheres (SiO2)

Instrument	Requested days	Allocated days	From	To
D50 T	1	1	26/07/2019	27/07/2019

Abstract:

Report for experiment UGA-73: „Partial saturation in granular media“

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Experimental date: July 26th–27th 2019

1 Material and methods

1.1 Experimental set-up

In experiment UGA-73 (Milatz et al., 2019) the water retention behaviour of a specimen of Hamburg Sand, a medium coarse to coarse grained model sand used in geotechnical research at Hamburg University of Technology TUHH, was investigated on the grain-scale by means of combined neutron- and X-ray tomography using the NeXT-research facility and the instrument D50 T at Institut Laue-Langevin (ILL).

The experimental set-up consists of a miniaturized flow cell apparatus to enforce a flow of pore water to an initially water saturated cylindrical granular specimen with height/diameter ratio of $h/d = 12\,\mathrm{mm}/12\,\mathrm{mm}$. The flow is applied with a syringe pump. For the measurement of capillary pressure a pore water pressure sensor is applied. The full experiment consists of different drainage and imbibition steps that are controlled by a Raspberry Pi single-board computer. The whole set-up is fully described in Milatz (2020) and shown in figure 1 as assembled on site.

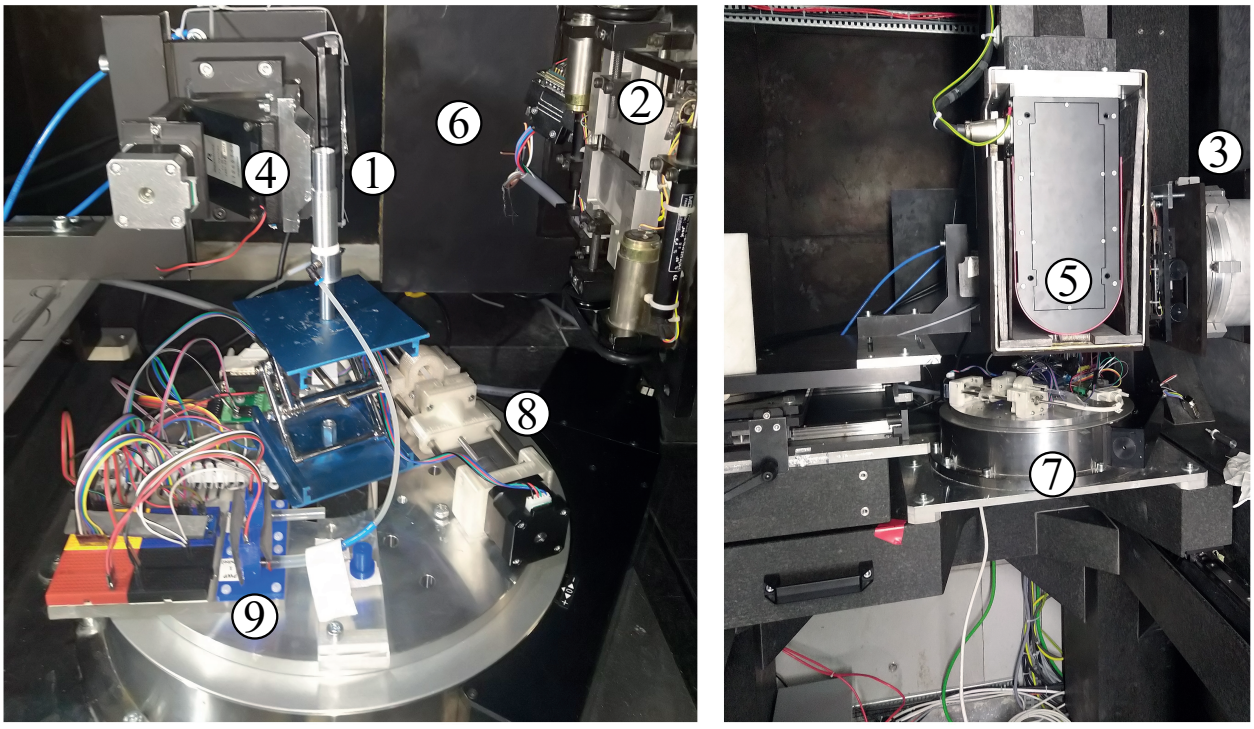

Figure 1: Experimental set-up in the NeXT research hutch at D50 T. Left: Water retention experiment placed on the rotation stage. Right: Same set-up centered in between neutron- and X-ray source, ready for the imaging experiments: 1: Sand specimen in aluminium tube, 2: Collimator slits of neutron source, 3: Neutron source, 4: Neutron detector with CCD-camera, 5: X-ray tube, 6: X-ray detector, 7: Rotation stage, 8: Syringe pump, 9: Pore water pressure sensor.

1.2 Testing procedure

After specimen preparation by pluviation of dry sand into the initially water saturated aluminium tube and compaction of sand to the desired initial density[1], a series of 5 drainage and 4 imbibition steps is applied, in which the water degree of saturation S_r is changed. A combined neutron- and X-ray tomography is measured for the initial water saturated specimen state and after each hydraulic step, leading to 10 neutron and 10 X-ray tomographies of the whole sand volume. During the whole experiment the macroscopic water retention curve (capillary pressure–saturation relationship) was measured, as described in Milatz (2020).

The X-ray tomographies were recorded with tube and acquisition settings of 100 kV, 60 μA (6 W), 900 projections per continuous revolution, 6$\times$ averaging, leading to a scan time of ca. 46 min at a voxelsize of ca. 22.8 μm. The parallel neutron tomographies were measured at a voxelsize of ca. 15.2 μm with 3$\times$ averaging and binning 2. Due to time limitations of the experiment, the last scan was shortened by reducing the number of projections to 700. In order not to disturb the granular specimen, the rotation table movements were damped. Depending on the change of specimen degree of saturation, intermediate hydraulic steps took times of ca. 13.7 and 27.4 min.

2 Results

2.1 Combined X-ray and neutron tomography data

In the experiment 10 hydraulic states of the sand specimen could be imaged by means of neutron- and X-ray tomography. While the X-ray data are of very good quality, a failure of the neutron-detecting CCD-camera led to faulty images after the fifth scan, so that only the first 5 experimental steps are very well imaged by neutron tomography. The first five hydraulic specimen states during step-wise primary drainage in the form of reconstructed slices through the central vertical specimen axis are shown in figure 2. The data will allow a synchronization and further comparative analysis of microscopic pore water volumes imaged by X-rays and neutrons at the same time. In figure 2 the step-wise emptying of initially water-filled pores in between the sand grains becomes visible, with an especially pronounced contrast of the pore water in the neutron tomography images.

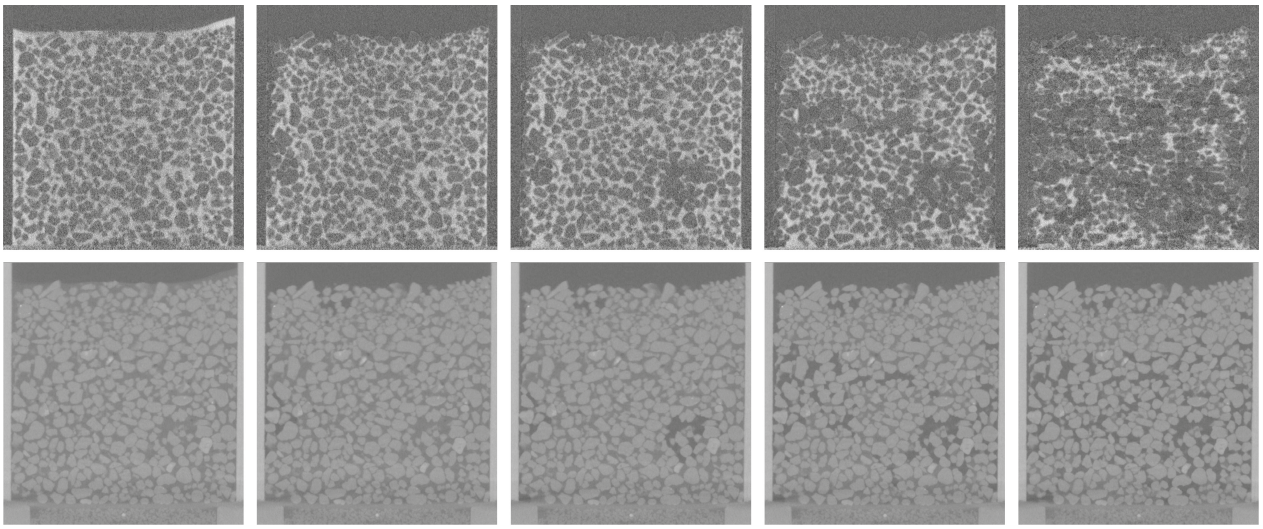

Figure 2: Vertical slices through the sand specimen, obtained from neutron tomography (top) and X-ray tomography (bottom) during step-wise water drainage through the specimen bottom. The left images show the initially water saturated state.

[1]Initial macroscopic porosity: $n = 0.394$, dry mass of sand: $m_\mathrm{d} = 2.1711$ g

2.2 Water retention data

During the experiment the macroscopic specimen degree of saturation S_r can be calculated from the change in water content, applied by the syringe pump, while matric suction s (capillary pressure) is continuously measured with a pore water pressure sensor, connected to the hydraulic tubes of the drainage system. The combination of degree of saturation with measured capillary pressure or matric suction allows to plot the macroscopic water retention curve.

However, the measured capillary pressure suffers from measurement noise and a data drift with data jumps especially during tomography scans on the primary drainage path, compare figure 3. While the noise can be reduced by data filtering, the data drift, which might be due to the influence of radiation or the movement of cable connections during specimen table rotation, can only be corrected by comparison of the measured pressure data to other experimental data, which might be possible in future evaluations.

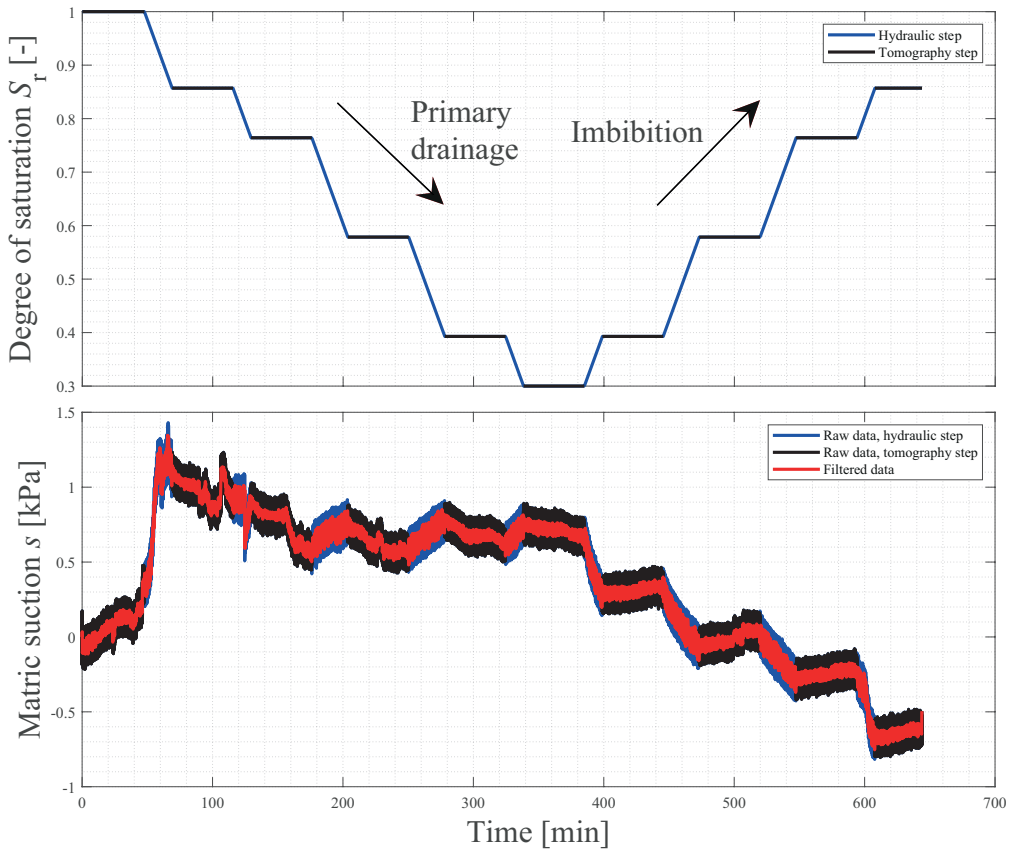

Figure 3: Applied change in degree of saturation (top) and measured response of matric suction (capillary pressure) in the sand specimen (bottom) during step-wise water drainage and consecutive imbibition with intermediate acquisition of tomographies.

References

Milatz, M. (2020). "An automated testing device for continuous measurement of the hysteretic water retention curve of granular media." In: *Acta Geotechnica*. DOI: 10.1007/s11440-020-00922-y.

Milatz, M., E. Andò, L. Helfen, N. Hüsener, and A. Tengattini (2019). *Partial saturation in granular media.* Institut Laue-Langevin (ILL). DOI: 10.5291/ILL-DATA.UGA-73.