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Abstract

In recent years neutron diffraction scanning has been successfully used as an experimental tool for studies on granular media under load, to infer force/stress distribution from the crystallographic (grain) strains of the material (Hall et al., 2011, Wensrich et al., 2014). The main goal of this PhD research project is the development of the neutron diffraction technique for granular geomaterials, through a specially designed plane-strain loading apparatus (Figure 1), to map spatial variations and evolutions of granular strains under loading and to investigate how forces are transmitted through the material and how this evolves with (localised) deformation.

The presented work considers a novel plane-strain biaxial experiment (Figure 1) performed on a Fontainebleau NE 34 quartz sand specimen (height: 60 mm, width: 30 mm, thickness: 20 mm, D_{50} = 210 μm) at the neutron diffractometer SALSA, at the Institut Laue-Langevin in France. Neutron diffraction scanning provided the opportunity to measure over a grid of gauge volumes the averaged "d-spacing changes" in the crystal lattices of the constituent grains (i.e., the "grain strains") of each gauge volume of the sample, during mechanical loading and as a function of an applied boundary load. From these data, full-field 2D mappings of the grain-strain distribution evolution were acquired, as well as single d-spacing average values for each of the produced diffraction mappings (Figure 2).

The loading was realised in steps over a load-unload cycle (Figure 2) with a confining pressure of 3 MPa. At each load step the loading was paused with a fixed piston displacement while scanning diffraction measurements were made over a 2D grid of 50 points, using rows of five 2x2x2 mm^3 gauge-volumes through the thickness of the sample. The 2D diffraction mappings of the crystal strains at each load step show a spatially structured grain-strain distribution, based on the averaging of the sum of the 5 small volumes at each point of the 2D grid.

Further experiments are underway with a new optimised version of the loading device, in terms of both the experimental approach and neutron scattering. More specifically, the new apparatus incorporates simultaneous Digital Image Correlation (DIC) measurements. As a result, a multiscale characterisation of the total, "macroscopic" strain field (through DIC) and the force transmission (through neutron diffraction) in the sample will be possible. The new configuration will also involve smaller sample size and improved boundary conditions, which will lead to both higher scanning coverage of the sample and shorter scanning time for each grid point.

References

S. A. Hall, J. Wright, T. Pirling, E. Andò, D. J. Hughes, and G. Viggiani, Granular Matter 13, 251-254 (2011)

C. M. Wensrich, E. H. Kisi, V. Luzin, U. Garbe, O. Kirstein, A. L. Smith, and J. F. Zhang, Physical Review E90, 042203 (2014)

Figures

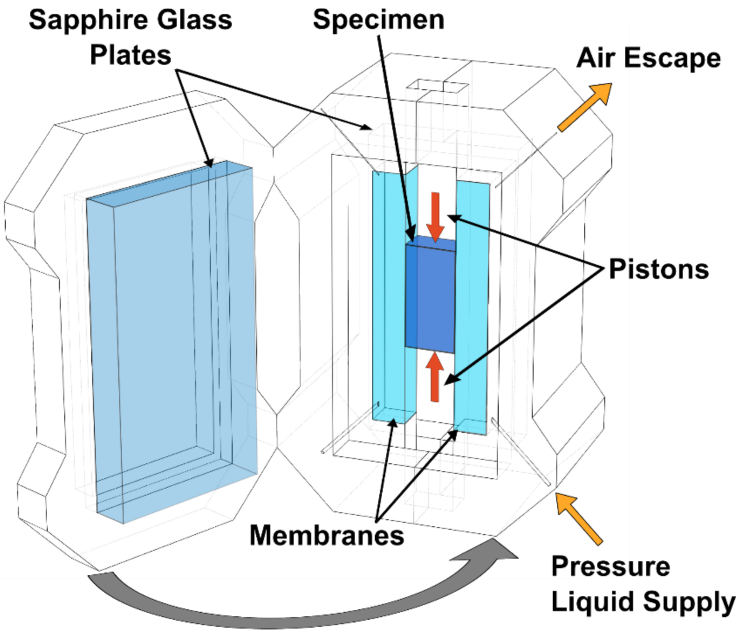

Figure 1 : *Schematic of the plane-strain loading apparatus.*

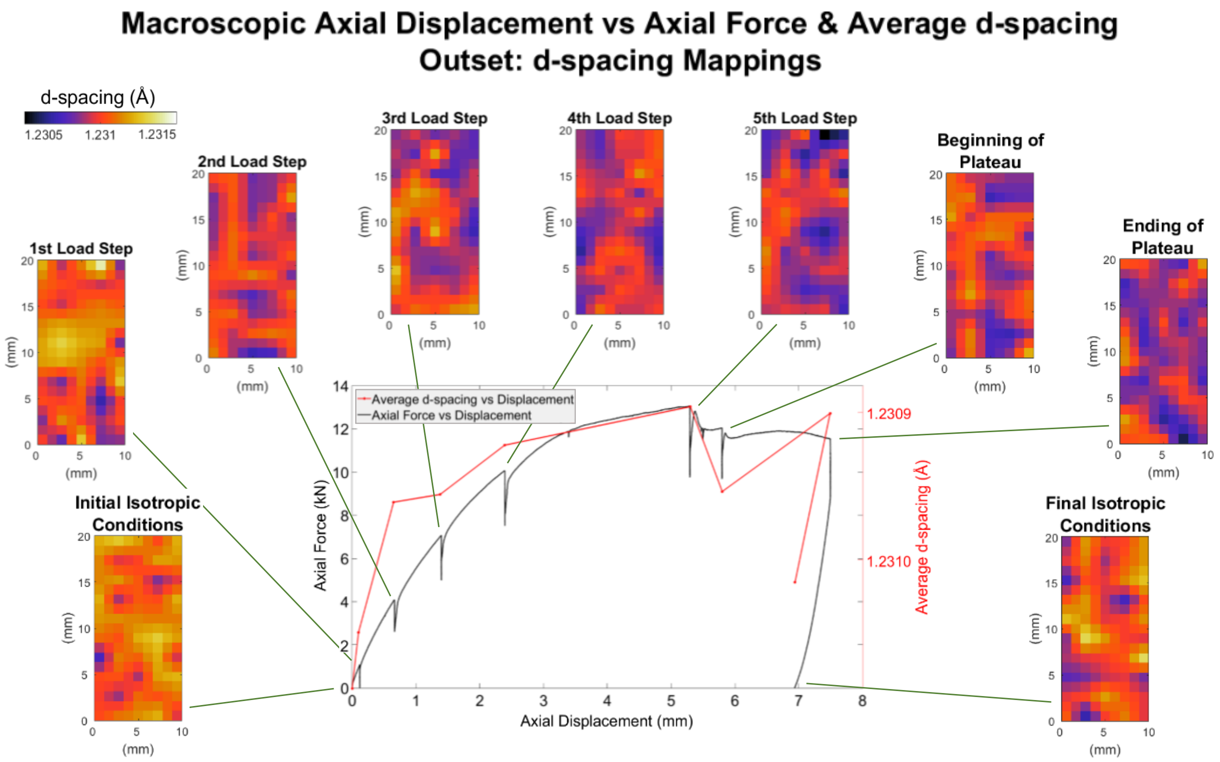

Figure 2 : *Inset: Macroscopic axial displacement as a function of the axial force and the average d-spacing. Outset: 2D grain-strain mappings per load step (darker colours being more compressed and lighter being less).*