IV International Workshop on Modern Trends in Geomechanics
G. Viggiani, D. Salciarini, F. Silvestri, C. Tamagnini, G.M.B. Viggiani
(Eds) Assisi, May 16–18, 2016

MICROMECHANICAL INSIGHTS INTO THE BEHAVIOUR OF UNSATURATED GRANULAR MATERIALS: EXPERIMENTS AND MODELLING

Jean-Michel Pereira

École des Ponts ParisTech, Laboratoire Navier – CERMES, France
e-mail: jeanmichel.pereira@enpc.fr

Keywords: Unsaturated sand, Wetting collapse, X-ray tomography, Multiscale analysis.

Summary. This communication gives some insights into the role played by the microtructure on the behaviour of unsaturated granular materials. In a first part, the wetting induced collapse of an unsaturated sand specimen under oedometric conditions is presented. X-ray computed tomography has been used to track changes occurring inside the specimens during wetting. This test is characterised by heterogenous water content and strain distributions at the local scale. Interestingly, the local behaviour at the scale of the REV as tracked using Digital Image Correlation is fully consistent with the average behaviour as observed at the scale of the specimen itself. In a second part, different modelling strategies accounting for microscale features of the material are discussed. Numerical simulations of the experiment were performed using different techniques. These results are finally presented and discussed.

1 WETTING-INDUCED COLLAPSE OF A LOOSE SAND

1.1 Material and methods

The material used in this study is Hostun sand (reference HN31, median grain size D_{50} of 300 μm, coefficient of uniformity C_u of 2). It has been decided to remove the smallest grains (cut-off at 250 μm) to avoid too small grains and menisci that would have made quantitative analyses more difficult. A sand-water mixture was prepared at a water content $w = 7.19\%$, with which a loose specimen was prepared in an oedometric cell. The water pressure in the specimen was controlled using the negative water column technique.

Imbibition of the specimen was performed by steps. X-ray CT scans were acquired at two different scales (global specimen and smaller region of interest (ROI) in the centre of the specimen) at each imbibition step. For each scan, 1,440 projections on a specimen rotation of 360° were recorded and obtained by averaging 10 radiographies at each rotation angle. Local scans have been partly segmented (voids from one side and sand-water mixture from the other side) and used to compute local water content and specimen deformation.

1.2 Results

Strain and water content fields have been evaluated through DIC (for displacement field) and using also the evolution of grey levels (for water content changes). Results are shown in Figure 1. The main observations from these plots is that not only the vertical and volumetric strain, but also the water content are not distributed homogeneously in the specimen. Furthermore, this heterogeneity increases with the imbibition steps. Despite this strong heterogeneity, it has been shown that the average behaviour as observed at the macroscale was fully consistent with local relationships between the main quantities of interest (deformation, water content and capillary pressure). The segmented images permitted the analysis of the evolution of the specimen microstructure. It has been shown that the initial microstructure is marked the presence of sand-water clusters, with two families of pores, one inside these clusters and one between them. Specimen collapse became perceptible when the small pores were filled with water and the clusters started to merge.

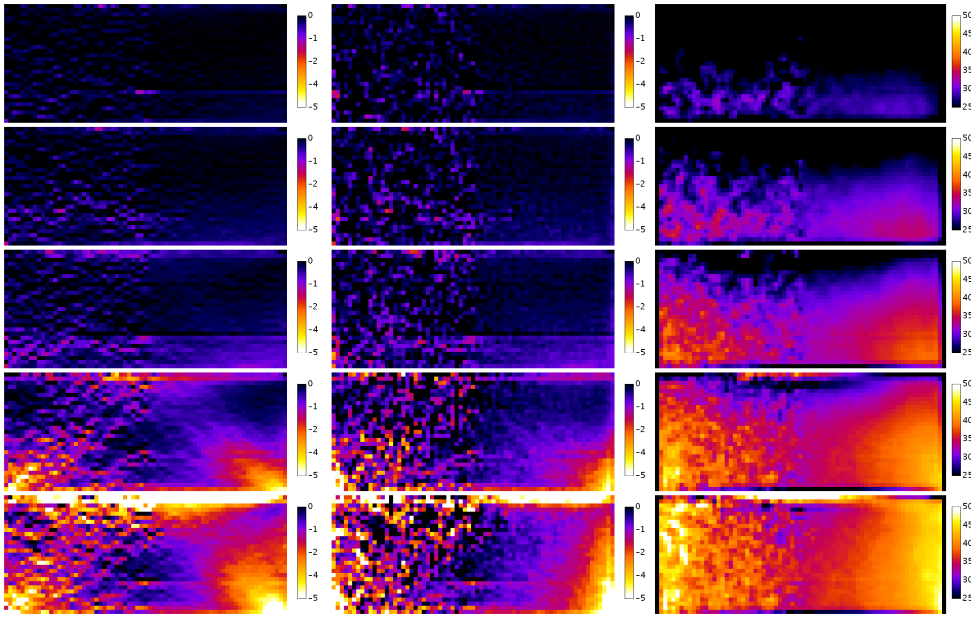

Figure 1: Maps of vertical strains (left), volumetric strains (centre)and water content (right) for advancing imbibition steps (from top to bottom). Each map is the juxtaposition of a half vertical slice in the xz plane (left half of the map) and a radial-average (right half of the map). Scale of color bars is percentage values. The central vertical axis of the maps and the central axis of the specimen coincide. Picture from [1].

2 NUMERICAL SIMULATIONS

The strongly heterogeneous nature of the collapse test presented above, with evidences of strain localisation (see figure), makes it almost impossible to use continuum mechanics based models to reproduce the test.

One natural technique is the use of the distinct element method (DEM) to describe in a rigorous manner the micromechanics at the grain scale, accounting for capillary forces between grains. However, one difficulty when trying to predict the collapse test presented here is the modelling of the transition between pendular and funicular regimes of saturation (see [**?**] for instance).

Another direction is to have recourse to micropolar continuum theories, which enrich the description of the continuum transformation with quantities that hold a physically-based origin (rotation of grains at the microscale for instance). Following this line, a Cosserat medium has been used to simulate the behaviour of unsaturated granular materials.

3 ACKNOWLEDGMENT

The author would like to express his deepest gratitude to M. Bornert, J.-F. Bruchon, S. Brisard, Y. J. Cui, P. Delage, M. H. Khalili, N. Lenoir., J. Muñoz-Castelblanco, J.-N. Roux, I. Stefanou, A. M. Tang, V. D. Than and M. Vandamme who immensely contributed to the work presented here.

REFERENCES

[1] J.-F. Bruchon, J. M. Pereira, M. Vandamme, N. Lenoir, P. Delage, and M. Bornert. Full 3D investigation and characterisation of capillary collapse of a loose unsaturated sand using X-ray CT. *Granular Matter*, 15(6):783–800, 2013.

[2] V. D. Than, S. Khamseh, A. M. Tang, J. M. Pereira, F. Chevoir, and J.-N. Roux. Basic mechanical properties of wet granular materials: a DEM study. *Journal of Engineering Mechanics*, 2016.