3rd International Conference on Tomography of Materials and Structures
Lund, Sweden, 26-30 June 2017, ICTMS2017-50

Grain scale study of sand-pile interface behaviour using x-ray tomography and 3D digital image correlation.

J. Doreau-Malioche*[1], G.Combe[1], and G. Viggiani[1]

[1]Université Grenoble Alpes, France

Keywords: pile installation, cyclic loading, grain scale, 3D analysis

Summary: The mechanisms occurring at the micro-scale at sand-pile interface during pile installation and cyclic loading were analysed quantitatively using x-ray tomography and a grain-based approach of three dimensional digital image correlation (3D DIC). Grain kinematics and density evolution are followed along with the macroscopic response of the interface.

1. INTRODUCTION

The mechanisms controlling the macroscopic behaviour of sand-pile interface during pile installation and following load cycles are complex and remain difficult to analyse from field tests. It is generally observed that cyclic loading, when the number of cycles gets very high, gives rise to significant changes in shaft resistance. This effect lacks a micro-mechanical understanding and must be investigated at the grain-scale.

Literature gathers numerous experimental studies conducted on laboratory models proposing links between sand kinematics, grain crushing, local density changes and the macroscopic behaviour of the interface ([1], [2], [3]). However, these mechanisms were observed using different optical methods either post-mortem or with plain strain devices and mainly during pile installation.

In the present work, the combined use of 3D tomographic imaging and analysis tools such as digital volume correlation allows for obtaining quantitative information at the micro-scale during pile installation as well as cyclic loadings.

2. METHODOLOGY

Experimental setup
The tests were conducted in a mini-calibration chamber in the tomograph of Laboratoire 3SR, in Grenoble, France. An instrumented cone-ended model pile was first installed in a dry calcareous sand sample under a confinement of 100kPa. The model pile was then submitted to a thousand axial displacement-controlled load cycles stopping after different amounts of cycles for image acquisition (1, 10, 50, 100, 500 and 1000 cycles). To extract information at the grain-scale, scans were taken in local tomography for a pixel size of 40μm. The region of interest was focused on the pile tip and the shaft.

Grain scale image analysis Field of displacements and strain were calculated using the 3D DIC code TomoWarp2 [4] both during pile installation and load cycles. Each grain was also tracked individually thanks to a recently implemented discrete version of the DIC code [5] taking into account the granular nature of the sand and of its mechanical response. In this approach, the correlation window is centred on individual grains and follows the actual shape of the grain. X-ray tomograms were then studied based on grey intensity changes to analyse local density variations at the interface and the production of fines by grain crushing.

3. RESULTS

The continuum approach of 3D-DIC has been successfully used to study displacement and strain fields during pile installation [6]. The results, fully three-dimensional, show distinct regions where main grains rearrangement

*e-mail: jeanne.doreau@3sr-grenoble.fr

concentrates. A "recirculation" of sand grains was also observed close to the tip during the penetration of the pile.

The measurement of the force induced by friction at the interface during cyclic loading indicates two different regimes in friction evolution. In order to study the origin of this phenomenon at the micro-scale, cyclic tests were analysed focusing on the discrete approach of DIC to capture the effect of grain breakage and fines evolution at the interface. Significant radial displacements towards the pile shaft were observed for the first hundred cycles when the friction is shown to be stable or slightly decreasing. Density measurements show a clear evolution at the interface during cycles within a very thin layer of about 2 to $4D_{50}$ thickness. This layer of soil is continuously densifying during cyclic loading.

Further image processing should lead to a better understanding of the link between grain kinematics, density changes and the different regimes in shaft friction evolution. A new technique using discrete DIC results is under development at 3SR in order to quantitatively assess grain breakage during both monotonic and cyclic loading.

References

[1] Yang, Z. X., Jardine, R. J., Zhu, B. T., Foray, P. & Tsuha, C. H. C., Géotechnique **60**, No. 6, 469-482 (2010)

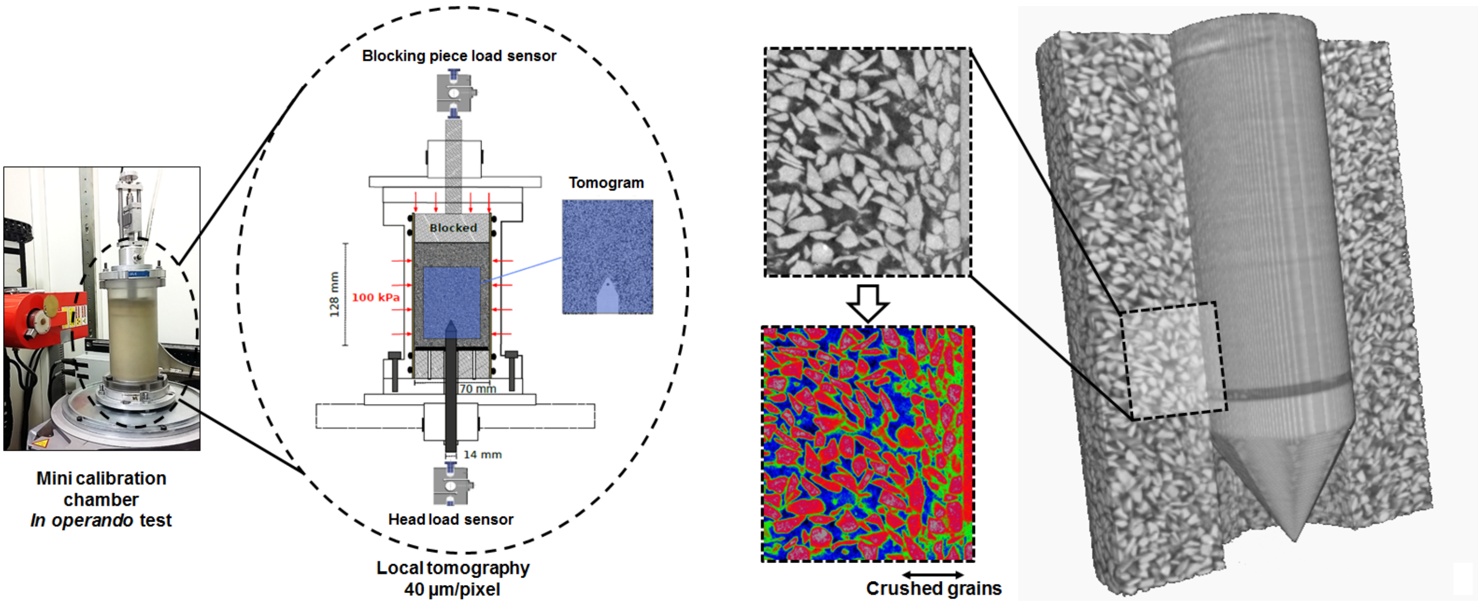
[2] Arshad, M. I., Tehrani, F. S., Prezzi, M. & Salgado, R., Géotechnique **64**, No. 7, 551-569 (2014)

[3] Tsuha, C. D. H. C., Foray, P. Y., Jardine, R. J., Yang, Z. X., Silva, M. & Rimoy, S., Soils and foundations, **52**, No. 3, 393-410 (2012)

[4] Tudisco, E., Hall, S. A., Charalampidou, E. M., Kardjilov, N., Hilger, A. & Sone, H., Physics Procedia. **69**, 509-515, (2015)

[5] Tudisco, E., Andò, E., Cailletaud, R. & Hall, S. A., TomoWarp2: a local Digital Volume Correlation code, submitted to Software XC, (2016)

[6] Silva, M. & Combe, G., Sand displacement field analysis during pile installation using x-ray tomography and digital image correlation. International Symposium on Geomechanics from Micro to Macro. Sept. 1-3, Cambridge, UK, 1599-1603, (2014)



(a) (b)

Figure 1: (a) Mini-calibration chamber during x-ray tomography. (b) 3D reconstructed volume after pile installation in local tomography showing a zoom on the interface (red: grains and pile, blue: air and green: fines).