Influence of particle shape on stiffness and strength anisotropy of pluviated granular materials

Masahide Otsubo*, Junming Liu*, Troyee Tanu Dutta*, Reiko Kuwano* and Sadegh Nadimi†

* Institute of Industrial Science, The University of Tokyo
4-6-1 Komaba, Meguro-ku, Tokyo 153-8505, Japan
e-mail: otsubo@iis.u-tokyo.ac.jp, j-liu@iis.u-tokyo.ac.jp, t-dutta@iis.u-tokyo.ac.jp, kuwano@iis.u-tokyo.ac.jp, web page: http://www.iis.u-tokyo.ac.jp

† Geotechnics and Structures (GEST), School of Engineering
Newcastle University
Newcastle upon Tyne NE1 7RU, UK
e-mail: sadegh.nadimi-shahraki@ncl.ac.uk, web page: http://www.ncl.ac.uk

ABSTRACT

Granular materials, such as non-cohesive sandy soils, deposited by dry pluviation exhibit inherent anisotropy in nature depending on particle shape. In-situ elastic wave surveys often report anisotropy of soil stiffness (Clayton, 2011). Stiffness anisotropy of soil has been studied intensively over the last decades (e.g. Kuwano & Jardine, 2002). Recent development of laboratory experimental technique including dynamic wave propagation approach enabled accurate measurements of stiffness anisotropy. Considering a Hertzian contact theory for ellipsoid, the compression wave velocity was found to increase in the direction of the longer ellipse axis (Santamarina and Cho, 2004). However, no consensus has been established on the effect of grain shape on soil stiffness, particularly for the shear wave velocity and thus the small-strain shear modulus.

On the other hand, strength anisotropy of granular material is also important to characterise the mechanical response of the granular assembly subject to external loads. Granular soil exhibits a greater peak strength when the direction of loading is normal to the bedding layer (Tatsuoka et al., 1990). This trend opposes that for stiffness anisotropy where small-strain stiffness is larger in the bedding plane. Such a strain-dependency of the behaviour of granular soils needs more research to be fully understood.

This contribution performed elastic wave propagation simulations using the discrete element method (Otsubo et al. 2017) to quantify the effect of particle shape on the anisotropy of elastic wave velocity. Clumped particles were used to model elongated particle shapes where the aspect ratio of particle shape was varied systematically. The elastic wave velocities observed in the bedding plane increased as the aspect ratio decreased, i.e. more elongated. Then discussions were extended to consider strength anisotropy of soil behaviour to understand the strain-dependent response from stiffness to strength.

REFERENCES

[1] C.R.I. Clayton, "Stiffness at small strain: research and practice", *Géotechnique*, **61**(1), 5-37 (2011).
[2] R. Kuwano and R.J. Jardine, "On the applicability of cross anisotropic elasticity to granular materials at very small strains", *Géotechnique*, **52**(10), 727-749 (2002).
[3] J.C. Santamrina and G.C. Cho, "Soil behavior: the role of particle shape", *In: R.J. Jardine, D.M. Potts, K.G. Higgins (Eds) Advances in geotechnical engineering: the Skempton conference, vol 1. Thomas Telford, London,* 604-617 (2004).
[4] F. Tatsuoka, S. Nakamura, C. Huang and K. Tani, "Strength anisotropy and shear band direction in plane strain tests of sand", *Soils and Foundations*, **30**(1), 35-54 (1990).
[5] M. Otsubo, C. O'Sullivan, K.J. Hanley and W. Sim, "Influence of packing density and stress on the dynamic response of granular materials", *Granular Matter* **19:50** (2017).