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Editorial: Experimental micro-mechanics for geomaterials

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Just one month ago a group of experts interested in the micromechanics of soils came from different locations around the world to participate in a workshop that was both informal and informative. We heard inspiring contributions and thought-provoking ideas from colleagues and friends and departed with new ideas and burgeoning new collaborations. Some of these contributions were submitted to *Géotechnique Letters* to form this themed issue. This issue differs from the 2010 themed issue of *Géotechnique* on 'Soil mechanics at the grain scale' as it focuses on the experimental side of the micromechanics of soils, a somewhat risky bet considering this is still a narrow field. What we have in this issue therefore is a collection of papers that demonstrate experimental evidence of fabric, grain and pore morphology, their evolution and their effect on soil behaviour. This was made possible through the expert use of advanced technologies, most of them borrowed from other disciplines, such as x-ray computed tomography from medicine, or scanning electron microscopy, mercury intrusion porosimetry and digital image correlation from other fields of material sciences. These new data should prove valuable to understanding physical phenomena at the micro-scale and help refine numerical models.

More often than not the discrete element method uses spheres as analogues to soil particles and it can be difficult to find a correlation between observed and predicted results. Experiments on spherical particles, such as glass ballotini, can help us understand fundamental mechanisms at the origin of the soil behaviour seen at the macroscopic scale. By using these 'particles' of homogeneous shape and surface texture, the role of fabric (or arrangement of particles) on coarse-grained soil response to mechanical loading can be investigated. Camenen *et al.* (2013) show us that the material inherent fabric (including wall effects) created during preparation of a specimen of glass ballotini by pluviation can be reproduced using the discrete element method in three dimensions. The effect of a particle's roughness can be easily studied by altering their surface by mechanical or chemical weathering. The action of roughening the surface of smooth particles enables the effect of the surface texture on the behaviour of soil at the specimen size to be observed, such as the effect on the internal friction angle. Hanaor *et al.* (2013) used roughened aluminium rods to show how the angle of friction of an assembly of rods is related to the fractal dimension of the surface. On the other hand, the roughness of 'real' sand particles can be determined, for example by interferometry, and can be coupled with measurements of contacts between two particles. Using a specifically designed apparatus on sand grains of different mineralogies, Senetakis *et al.* (2013) determined the tangential load–deflection behaviour between two particles. Their findings show that the grain surface roughness decreases during loading, but that this does not affect the contact tangential stiffness. This suggests that other characteristics of grains are important, such as mineral hardness. We learn that the initial tangential load–deflection behaviour at the contact between two particles is initially highly non-linear and predominantly plastic, quite the contrary to what is often assumed in particulate modelling.

The strength and stiffness of granular soils determined from laboratory element tests may be affected not only by the surface characteristics but also by the internal structure of the grains. Orense *et al.* (2013) used x-ray computed tomography to show that pumice sand, known for its apparent density lower than water, has internal and surface voids within the grains that make them highly crushable and affect the whole mechanical behaviour of the soil. In clinker ash, a lightweight waste product with potential geotechnical applications, the strength of individual particles can be related to the angle of friction of the material at the specimen scale (Winter *et al.*, 2013). Particle crushing has been of interest for the past 15 years, and it is accepted that granular soils reach an ultimate grading upon loading which corresponds to a fractal distribution of particle sizes. Zhang & Baudet (2013) show that gap-graded soils do not necessarily reach that ultimate fractal grading during compression to high stresses but that the fabric remains. In hard soils like sandstones, grain damage can be accompanied by degradation of bonding between grains. The use of x-ray micro-tomography enabled Fonseca *et al.* (2013) to track individual grains and monitor the formation of a shear band in a sandstone specimen by localisation of damage and dilation at the grain scale. They show that initial fabric and bonding play a key role in the localisation patterns leading to specimen failure. Bruchon *et al.* (2013) used x-ray tomography to study imbibition in unsaturated sand. They used statistical analyses to characterise the specimen's homogeneity and determine the suitable size of the representative volume element for a locally inhomogeneous material.

Although non-plastic coarse-grained soils are normally used for performing micro-mechanical experiments and numerical simulations, old and new techniques can be applied to characterise plastic soils such as clays and silts at the microscopic scale. For example, free swelling and irrecoverable strains of crushed argillite subjected to a wetting–drying cycle can be detected from environmental scanning electron microscope photographs using digital image correlation (Wang *et al.*, 2013). Mercury intrusion porosimetry can be used to measure changes in fabric during lime stabilisation of silty soil and how it is affected by the initial water content and curing time, thus providing an insight into the micro-mechanisms underlying stabilisation (Russo & Modoni, 2013).

This issue is not a state-of-the-art issue to file but rather presents current research that continues to evolve with advances in technology and our curiosity to try them on soils. The issue shows the successes and difficulties of looking at soil at the grain scale. In our view, its main

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achievement has been to bring together theoreticians and experimentalists. Ideas already accepted have been challenged, thus showing us the way forward for further work in experimental micro-mechanics for geomaterials.

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