Project Title: Exploring critical-state behaviour using DEM

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Abstract

The critical state soil mechanics (CSSM) framework originally proposed by Schofield & Wroth (1968) has been shown to capture the mechanical behaviour of soils effectively. The particulate implementation of the discrete element method (DEM) can replicate many of the complex mechanical characteristics associated with sand. This research firstly shows that the CSSM framework is useful to assess whether a DEM simulation gives a response that is representative of a real soil. The research then explores the capacity of DEM to extend understanding of soil behaviour within the CSSM framework.

The influence of sample size on the critical-state response observed in DEM simulations that use rigid-wall boundaries was examined. The observed sensitivity was shown to be caused by higher void ratios and lower contact densities adjacent to the boundaries. When the void ratio (e) and mean stress (p') of the homogeneous interior regions were considered, the influence of sample size on the position of the critical state line (CSL) in e-log(p') space diminished.

A parametric study on the influence of the interparticle friction (μ) on the load-deformation response was carried out. The macro-scale stress-deformation characteristics were nonlinearly related to μ and the particle-scale measures (fabric, contact force distribution, etc.) varied systematically with μ. The limited effect of increases in μ on the overall strength at high μ values (μ>0.5) is attributable to transition from sliding-dominant to rolling-dominant contact behaviour. A μ value higher than 0.5 leads to a CSL in e-log(p') space that does not capture real soil response.

True-triaxial simulations with different intermediate stress ratios (b) were performed. The dependency of strength on b agreed with empirical failure criteria for sands and was related to a change of buckling modes of the strong force chains as b increased. DEM simulations showed that the position of the CSL in e-log(p') space depends on the intermediate stress ratio b. This sensitivity seems to be related to the dependency of the directional fabric anisotropy on b. The link between the state parameter and both soil strength and dilatancy proposed by Jefferies & Been (2006) was reproduced in DEM simulations.

A new rotational resistance model was proposed and it was shown that the new model can qualitatively capture the influence of particle shape on the mechanical behaviour of sand. However, it was shown that the effect of rotational resistance is limited and to quantitatively compare the DEM simulation results with laboratory testing data, e.g., the critical-state loci, it is necessary to use non-spherical particles.