Master Thesis

Topic:

DEM study on the instability behaviour of a sand

Description:

Soil liquefaction has been often reported in undrained condition, in which pore water pressure is continuously generated until flow deformation. However, it has been also found that the flow deformation may happen in drained condition, due to lateral stress relief, for example [1]. Such phenomenon is not rare, but the knowledge about this condition is still not fully understood – even though the instability of granular materials under fully drained conditions has been previously considered in experimental studies. While these laboratory experiments could provide macro-scale insight into instability behaviour, the micro-mechanics under such conditions are yet to be explored.

In this regard, numerical simulations with the Discrete Element Method (DEM) [2] are a powerful and promising alternative for the parallel investigation of the macroscopic behaviour and the evolving microstructure of the granular soils. In the DEM, the mechanical response of the medium is obtained by modelling the interaction between individual particles as a dynamic process, by using interaction laws and considering relevant soil characteristics. By using the DEM, boundary conditions as used in laboratory experiments can be imposed to assemblies of computational avatars of soil samples, in order to simulate and predict the soil response. More general initial conditions and loading directions can also be applied. These features allow for a better understanding of the global mechanical response and the related evolution of the microstructure of granular materials, providing significant insight into the constitutive modelling of soil.

Based on this, this research intends to test the hypothesis that the use of suitable idealized granular assemblies can lead to a better understanding of the instability behaviour of granular materials, especially under a stress path called constant-shear drained (CSD) [3].

Scope of work:

The scope of this master thesis is DEM simulations on the instability behaviour of granular materials (e.g. determination of the so-called instability line or surface), under undrained conditions – but especially on the constant-shear drained (CSD) stress path. More specifically, the simulations are intended to cover standard undrained monotonic tests on a sub-angular sand [4], using spheres for the DEM numerical model. First, a comprehensive literature review covering the fundamentals of DEM and the tests [triaxial and direct simple shear (DSS)] shall be carried out. In addition, for the analysis, DEM codes (using the software PFC 3D) should be developed, in order to validate (e.g. oedometric compression) DEM parameters previously

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calibrated and to reproduce the macro-mechanical response of Karlsruhe sand [4]. Some of the tasks include:

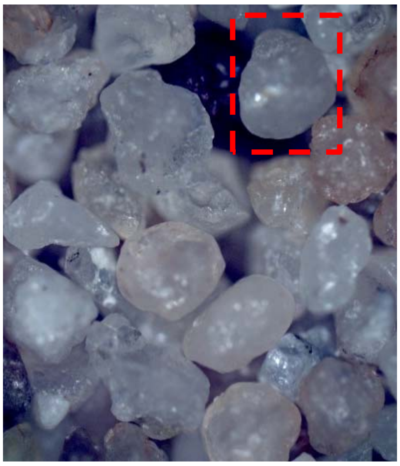
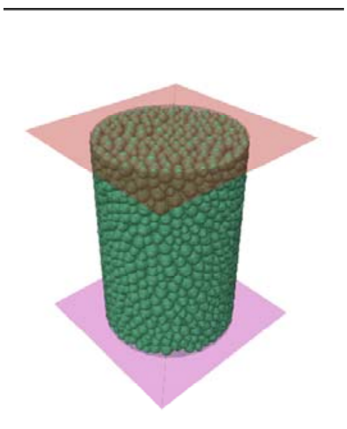
1) Initially, DEM simulations of the triaxial tests with monotonic loading and undrained (constant-volume) conditions in [3] are to be carried out, in order to validate the numerical model.

2) The response of the granular systems, under different loading conditions [e.g. initial mean effective stress (p'_0), relative density and shearing rates] – which can lead to instability or an undesirable response – will be analysed.

3) The effect of different ranges of initial states at the beginning of CSD condition [3] such as different initial mean effective stress (p'_0), relative density and deviatoric stress (q) on the instability behaviour will be analysed.

4) Micromechanical parameters such as the coordination number, anisotropic coefficients (geometric and mechanical) will be extracted to assist in characterising the instability behaviour of the granular material.

5) The results will be compared with data from literature and discussed in detail.

		
Microscopic image of Karlsruhe Sand	DEM setup of a Triaxial Test with spheres	DEM setup of a Direct Simple Shear Test with spheres

Special requirements and comments:

Interest in pursuing Discrete Element Formulation using the DEM software PFC 3D (Itasca). Programming knowledge is desired but not mandatory.

Literature:

[1] Chu, J.; Leong, W. K.; Loke, W. L.; Wanatowski, D. (2012): Instability of Loose Sand under Drained Conditions. Journal of Geotechnical and Geoenvironmental Engineering, Vol. 138, Issue 2.

[2] Cundall, P. A.; Strack, O. D. L. (1979): A discrete numerical model for granular assemblies. Géotechnique, Vol. 29, No 1, pp. 47–65.

[3] Lashkari, A.; Khodadadi, M.; Binesh, S. M.; Rahman, M. M. (2019): Instability of Particulate Assemblies under Constant Shear Drained Stress Path: DEM Approach. International Journal of Geomechanics, Vol. 19, Issue 6.

[4] Wichtmann, T.; Triantafyllidis, Th. (2016): An experimental data base for the development, calibration and verification of constitutive models for sand with focus to cyclic loading. Part I: tests with monotonic loading and stress cycles. Acta Geotechnica, Vol. 11, No. 4, pp. 739-761.

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