Master Thesis

Topic:

Liquefaction behaviour of tailings in triaxial and direct simple shear condition: a DEM approach

Description:

The collapse of a mine tailings dam in Brumadinho (Brazil, 2019) resulted in over 8 kilometres of destruction and at least 249 fatalities. Unfortunately, this failure was only the most recent in a long list of catastrophic tailings dam accidents. Numerous incidents in the last decades emphasized how tailings dams and liquefaction of these materials have been posing significant risks to environments, economies and communities. However, despite its potential to cause enormous destruction to life and property, the physics underlying mine tailings and liquefaction behaviour is still very poorly understood – and consequently more failures are predicted for the next years.

A powerful and promising alternative to help in understanding liquefaction and instability behaviour of granular materials (such as mine tailings) are numerical simulations with the Discrete Element Method (DEM) [1]. In the DEM, the mechanical response of the medium is obtained by modelling the interaction between individual particles as a dynamic process and by using interaction laws 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.

In the wake of recent tailings dam failures, special efforts should strive for identifying the true triggering mechanisms and the underlying causal factors that are critical for the prevention of future accidents. Considering these aspects, this research aims to contribute to the understanding of the mechanics behind mine tailings and liquefaction, based on the simulation, modelling, qualitative and quantitative prediction of the static liquefaction behaviour of gold mine tailings.

Scope of work:

The scope of this master thesis is the DEM simulation of standard drained and undrained monotonic tests [triaxial and direct simple shear (DSS)] on a gold mine tailings material (which was studied previously and has an available database of results from laboratory tests) – using spheres for the calibration of the DEM numerical model. First, a comprehensive literature review covering the fundamentals of DEM and the tests to be simulated shall be carried out. More specifically, the research comprises:

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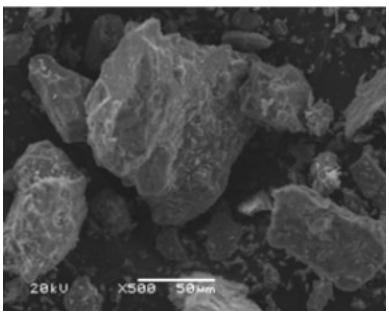
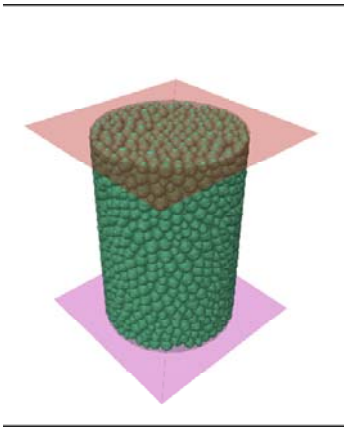
1) For the DEM analysis, DEM codes (using the software PFC 3D) should be developed and the DEM model parameters for spheres have to be calibrated, in order to capture the behaviour of the tailings material.

2) DEM simulations of the tests with monotonic loading under drained and undrained (constant-volume) conditions on DEM gold mine tailings assemblies are to be carried out, in order to validate the numerical model.

3) The response of the granular systems, under different loading conditions and shearing rates [2] – which can lead to an unstable or an undesirable response – will be analysed.

4) A microscale behaviour investigation will be carried out, on the formation and evolution of force chains in the system during different testing stages.

5) The results are to be compared with previous experimental results and to be discussed.

		
Microscopic image of the gold mine tailings	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] Cundall, P. A.; Strack, O. D. L. (1979): A discrete numerical model for granular assemblies. Géotechnique, Vol. 29, No 1, pp. 47–65.

[2] Nguyen, H. B. K.; Rahmann, M. M.; Fourie, A. (2021): The critical state behaviour of granular material in triaxial and direct simple shear condition: A DEM approach. Computers and Geotechnics, Vol. 138, 104325

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