Master Thesis

Topic:

Digital models to investigate the incremental response of Karlsruhe fine sand through stress probing experiments using the Discrete Element Method (DEM)

Description:

In the current master project, a computational framework for virtual experiments on granular materials (Karlsruhe Fine Sand) by means of the Discrete Element Method (DEM) is to be developed to investigate the incremental response of sand through stress probing experiments.

The cornerstone of experimental investigations on granular matter is stress probing, a technique that relies on achieving multiple incremental stress paths originating from an identical initial state. Physical (lab) stress probing experiments encounter significant challenges due to their limitations in reproducibility and control of both initial state and boundary conditions. Additionally, understanding the continuum response of a granular assembly requires decoding the evolving kinematics of particles, driven by frictional forces at interparticle contacts, thereby requiring access to grain-scale information. Achieving this experimentally is particularly intricate, for example measuring interparticle forces, a critical aspect in understanding constitutive behavior.

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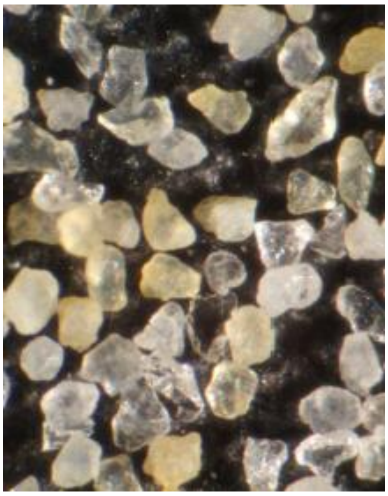
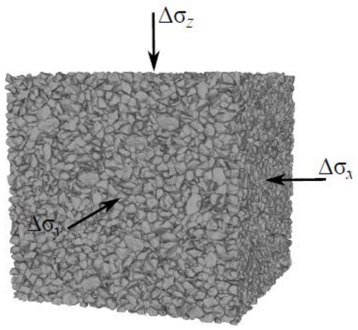
<td></td>
<td>
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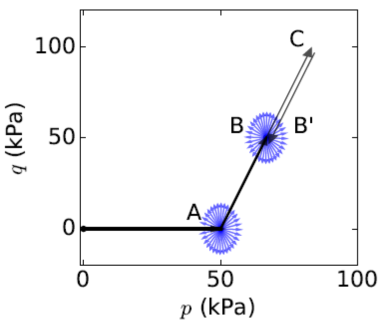
<td>
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<td>Microscopic image of Karlsruhe Fine Sand</td>
<td>Computational specimen under 3D stress conditions</td>
<td>Stress states and probing protocol in p-q plane</td>
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This virtual experiments framework with DEM aims to address these limitations by relying on a) the accurate mathematical description of particle interactions (contact law model), b) the control over the initial state of the assembly and c) the enforcement of boundary conditions following a predefined experiment protocol, leading to a systematic exploration of stress space. The

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goodness of numerical experiments with DEM can be fully exploited during the testing phase, since they enable the exact replication of any generated initial state and the implementation of arbitrary mixed boundary conditions. This allows the investigation into key aspects of the response of granular materials such as elasticity and reversibility, yielding and plastic flow, as well as fabric evolution within the strong and weak force networks, which are all fundamental for their constitutive modelling.

Scope of work:

Good progress work covering the numerical model selection is available from previous in-house research projects.   Main tasks of this master project are:

1. Literature review of the DEM and related aspects such the simplified mathematical representation of particle morphology, contact law governing interparticle interactions (model has been previously validated against conventional stress paths such triaxial compression and shear experiments), and model calibration to capture quantitatively the macroscopic (stress-strain), among others.
2. DEM-modelling. Controlling initial sample state – includes initial stress, density, etc. The state may be generated by simulating a sample preparation protocol designed to target particular state properties (Isotropic consolidation, anisotropic consolidation and preloaded anisotropic consolidation).
3. Systematically investigate the incremental response of the numerical material through multiple stress probing experiments (Gudehus, 1979). Stress probing protocol consists of 32 axisymmetric probes, uniformly distributed in the Rendulic angle $\alpha_{\Delta\sigma} = \arctan\left(\frac{\Delta\sigma_1}{\sqrt{2}\Delta\sigma_2}\right) \in [0°,\ 360°)$, forming a circle in the Rendulic plane. Characteristic probes include: isotropic (IE), triaxial (TE) and deviatoric (DE) extension, as well as isotropic (IC), triaxial (TC) and deviatoric (DC) compression.
4. Analyze and gain insight into the strain response envelopes due to stress probing. Quantifying the elastic (recovered upon loading) and reversible-irreversible (due to dissipation-free grain-scale mechanisms) decompositions of strain.
5. Analyze and gain insight into the evolution of the micromechanical state of the sample due to stress probing a) in terms of mobilized friction angle at the contact scale; b) in terms of the evolution of fabric, meaning the change in orientational distribution of contact normal that belong to the strong and weak network respectively.

Literature:

(1) Gudehus, G., 1979. A comparison of some constitutive laws for soils under radially symmetric loading and unloading. Can. Geotech. J. 20, 502–516.

(2) Karapiperis K., Harmon J., Andò E., Viggiani G., Andrade J.E., 2020. Investigating the incremental behavior of granular materials with the level-set discrete element method. Journal of the Mechanics and Physics of Solids, Volume 144, 104103, ISSN 0022-5096, https://doi.org/10.1016/j.jmps.2020.104103.

Special requirements and comments:
Prior attendance of courses of the master studies in geotechnical engineering.

The Master Thesis will be supervised by Zentrum Geotechnik.

Themenstellung am:

Ausgegeben an:

Ausgegeben am:

Supervisor:
Lehrstuhl und Prüfamt für Grundbau, Bodenmechanik, Felsmechanik und Tunnelbau.

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