Research Project Highlight

Micro-inspired Continuum Modeling Using Virtual Experiments

Project #1131-NCTRAJ

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Start-End Dates:
1/1/2018-12/31/2018

Abstract

The objective of the proposed project is to develop new hardening rules for the most common plasticity constitutive models by using accurate micromechanical simulations that can capture the main features of granular behavior under cyclic loading—a crucial feature for earthquake engineering applications.

Deliverables

As shown in Figure 1, the proposed project consists of four main steps or milestones. In Step 1, laboratory experiments aided with computed tomography will be obtained for both monotonic and cyclic triaxial tests in sands. This step will be achieved in collaboration with the University of Grenoble Alps, at no additional cost to the project. In Step 2, the level set discrete element method (LS-DEM) will be used and calibrated to realistically replicate the behavior of monotonic triaxial tests and to predict the behavior of the cyclic triaxial tests (obtained in Step 1). In Step 3, having demonstrated the ability of the LS-DEM to capture realistic monotonic and cyclic behavior of sands, the boundaries of the method will be expanded to probe loading conditions and activate stress paths that are not easily probed today with laboratory experimentation, hence developing a virtual soil mechanics laboratory with access to micro and macroscopic data. Finally, Step 4 will take the data developed under Step 3 and use the results to develop micromechanically-guided hardening laws for some of the most popular plasticity models for sands used in practice today (e.g., Manzari-Dafalias, PM4Sand within the OpenSees platform).

Research Impact

The LS-DEM work builds on 10 years of collaboration between the geomechanics group and the University of Grenoble Alps. Efforts have been supported by the National Science Foundation, the Defense Threat Reduction Agency (DTRA), and others. However, the work has been focused on the development of the LS-DEM tool and its potential application to monotonic loading. The work proposed

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herein is the first attempt to use the tool beyond monotonic loading and consider different stress paths, including cyclic loading. New experimental results demonstrate the ability of the LS-DEM technique to capture cyclic loading.

The potential impact on practice is large since this work could enable better predictions of soil behavior and help model challenging problems such as liquefaction instabilities.

Project Image

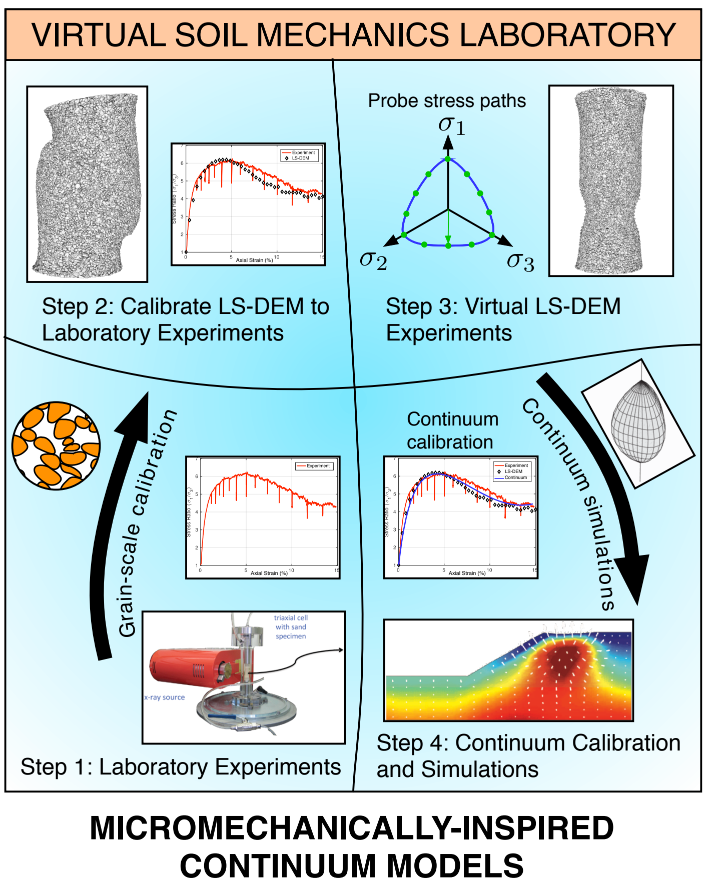

Figure 1. Schematic of proposed work. The main deliverable of this proposal is to develop micromechanically-inspired continuum models that can be used in the OPENSEES platform to predict soil mechanics behavior under complex loading such as cyclic loading. While current models such as Manzari-Dafalias have the appropriate mathematical form in order to capture the main behavioral features, the proposed work will inject physics into the evolution laws, such as the hardening modulus, where calibration is rather obscure due to lack of previous access to physical meaning. One aspect to specifically look at is the effect of fabric evolution and dilatancy on hardening.