Call for an outstanding PhD candidate working for an institutional collaborative project:

Role of particle rotations in continuum-scale displacement gradient of granular materials: application to rockfill modeling

Background

In a context of fast urbanization and global climate change, civil engineers face critical challenges in maintaining sufficient supply of water and energy in an increasingly uncertain environment. Geomaterials (sand, clay, rock and concrete) are at the heart of these challenges, as they represent the main constituent of our natural environment. Their mechanical integrity is highly texture dependent. While non-associated hardening plasticity forms the general framework of the major constitutive models for geomaterials, the relevant internal variables and their evolution reflect the specific texture (grains, voids, cracks, slip planes...) of each material remains unresolved. The role of particle rotations with respect to the material strength and deformation is a mystery yet to be resolved. They are important missing factors in conventional continuum-based constitutive modelling, and have been the focal points of a considerable amount of research work for more than three decades.

In particular, many rockfill dams are being designed or under construction in Western China to utilize the vast reserve of clean and renewable hydroelectric energy. Some of them are setting the new world-record of height in the rockfill dam construction history (for example, the 233m Shuibuya 水布垭 rockfill dam). Besides recent developments in data collection/monitoring and risk management, the safe construction and efficient operation of these nationally important infrastructure requires, now more than ever, a reliable scientific guidance, which will be deeply rooted in improved prediction in the deformation and crack developments of these earth structures. It requires an improved understanding of the underlying physical mechanisms of granular materials, with rockfill as a typical example, often occurring over several magnitudes of length and temporal scales. Predicting and preventing the occurrence of excess deformation and crack-associated damage within rockfill dams is of paramount importance to improve the robustness of the dedicated computational tools.

The project is proposed from this context and sets out to tackle the challenging issue of the multiscale numerical simulation of failure in geo-materials. Recognizing the basic properties of granular materials are deeply related to the specific kinematics of the grains, it focuses on studying the relationships between the micro-scale characteristics of particles and the macro-scale or continuum-mechanical features. Particular patterns of granular packing/pattern may be investigated. These patterns evolve over a given loading path, due to the fact that grains may slide or may rotate at contacts, possibly leading to the opening of the contact (or disruption of the contact). Alternatively, additional contacts may be created due to grains moving towards one another. These mechanisms are all of primary importance and should be addressed in order to improve the relevance of the modeling of geomaterial constitutive behavior. Among them, particle rotations are thought to play a key role.

Tasks

The objective of this study is to study the influence of particle rotations on the continuum response of a granular specimen, with a special emphasis on the displacement gradient, including both the strain and the rigid-body rotation of the representative volume element.

Preliminary analyses have already established, under some simplifying assumptions, the equivalence of average particle rotation and continuum-scale rigid body rotation. These analyses seem to confirm what can be observed from computational simulations based on a Discrete Element Method. In the proposed research a comprehensive investigation will be made to investigate this relation, and delimitate the conditions of validity. Discrete Element Methods simulations will be performed to obtain the required multi-scale information.

The influence on the average particle rotation and the continuum rotation of the following parameters will be investigated:

- Inter-particle friction coefficient
- particle shape
- particle size distribution
- initial packing density
- loading conditions

These numerical investigations will be complemented with analytical developments, carried out to highlight the main microstructural ingredients governing such equivalence, and to build a rational framework to support it.

Institutional collaboration

The PhD project will be executed within the framework of the international research group GdRI Multiphysics and Multiscale Couplings in Geomechanics. The GDRI GeoMech was created in January 2016, taking place after the GDR MeGe. During its 8 years' life span, GDR has gathered the main French groups involved in the broad field of geomechanics, with a special focus to environmental applications. Taking advantage of the existing collaborations and connections that the partners had developed with foreign universities, extending the network with an international perspective was a natural ambition. The goal of the network (GDRI) is thus to gather and promote the French community in geomechanics, to strengthen its national and international visibility.

Today, the GDRI GeoMech involves more than 25 partners, coming from countries including The Netherlands, Italy, Spain, Canada and China. Structuring the existing community working on Multi-Physics and Multiscale Couplings in Geo-environmental Mechanics, the main lines of research are:

- Catastrophic failures and triggering mechanisms
- Safety of storage reservoirs
- Energetic geomechanics.

GDRI Geomechanics aims at sharing and spreading the up-to-date research on the subject, developing international collaborations as well as organizing international scientific meetings and other related events.

Specifically, the research will lead to a PhD thesis, to be defended at Southeast University or Grenoble-Alpes University. Partners in this project are:

- Dr. Xia Li, Southeast University (China)
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- Dr. Francois Nicot, Irstea, Grenoble-Alpes University (France)
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The PhD student will be stationed at these institutes for various periods, and will benefit from the scientific workshops organized regularly by this international network. The project will be conducted in an open and collaborative environment, aimed at maximising the advancement of science and the personal development of the PhD student.

References

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