Scaling effects in Rockfill degradation using multi-scale Discrete-Element Modeling and Experiments

Ph.D. position under a joint collaboration between the Université de Montpellier (France) and Polytechnique Montréal (Canada) 2021-2025 (4 years).

Abstract: Several projects concerning civil, energy, and infrastructure employ large amounts of blasted or crushed rock. Nevertheless, such materials present very irregular shapes and broad size distributions impeding standard laboratory testing and characterization. Alternative small-scaling techniques have been proposed to tackle this issue. Yet, none has been found satisfactory, and the design of earthworks or the recycling of mining waste remains still today far from optimized. We want to propose a "double-scale" discrete modeling approach for the mineralogy and inner microstructure of grains combined with non-standard laboratory testing. The synergy of numerical and physical experiments will be an ideal framework to understanding the multi-scale phenomena in geomaterials and develop robust scaling laws for the mechanical behavior.

Background: The design of structures using geo-materials (rocks, sand, silt, clays, etc.) is often based on experimental testing and empirical observations. However, the quality and robustness of experiments are linked to reproducing the same mechanical and environmental conditions as in the field, and to test representative volumes of the materials. This last condition is quickly limited because of the dispersity of shapes and sizes of grains, so they cannot be tested in standard laboratory equipment. As an alternative, experiments are prepared using truncated grain size distributions by removing the largest families of grains, or by employing model materials. These approaches conduct nonetheless to contradictory results. Ultimately, structures using crushed rock (e.g., rockfill dams, railways ballast beds, rock waste dumps) have to deal with approximative material characterization underestimating costs, risks, and environmental impacts.

Objective: We are interested in the failure strength of geo-materials presenting some degree of anisotropy either in their composition (polydispersity in shape and size of grains) or their behavior (mineralogy and microstructure). Although the mechanical behavior of geomaterials is known to depend on the mineralogy, graining characteristics (e.g., shape and spatial distribution of minerals), cementation level, diagenesis (i.e., the physico-chemical process of transformation in rocks), and fissures, once one of these properties present a preferential orientation, the materials should be considered as inherently anisotropic. However, these inherent anisotropic properties are often ignored or later included in the modeling as *ad hoc* effects.

The objective of the Ph.D. student is to develop discrete approaches, physical experiments, and mathematical modeling for scaling laws arising from the mineralogy of grains up to the level of structures under a coherent and physically based framework. In particular, the student is expected to (1) develop methods to characterize the geometry of grains under several scales of description (shape, size, and microstructure), (2) develop the mechanical characterization of coarse geomaterials from the level of individual grains up to assemblies using non-standard and large scale laboratory equipment, (3) conceive evolving numerical methods based on the discrete-element approach, allowing for a systematic analysis of inherent anisotropic characteristics upon the compaction and shearing behavior of granular assemblies, and (4) develop numerical models to be tested before the physical experiments.

Candidate profile: Candidates must have experience with numerical modeling of materials. Experience with experimental set-up and testing of geomaterials, although not necessary, is highly appreciated. Experience coding with Python is essential. Students having a Mechanical/Civil Engineering or Physics background are invited to apply.

Research team: This Ph.D. project is proposed under a collaboration between the Laboratory of Mechanics and Civil Engineering (LMGC) at the Université de Montpellier (France) and the Research Institute on Mines and the Environment (RIME) at Polytechnic Montréal (Canada). The student will be enrolled in both universities and will spend similar periods in both locations.

The advisors in France will be:

- Emilien Azéma, Associated Professor. emilien.azema@umontpellier.fr
- Mathieu Renouf, Researcher CNRS. mathieu.renouf@umontpellier.fr

The advisor in Canada will be:

- Carlos Ovalle, Assistant Professor. carlos.ovalle@polymtl.ca
- David Cantor, Postdoc. david.cantor@polymtl.ca

In order to apply, we invite the candidates to send a motivation letter and bachelor and master transcripts to the contacts above. For more details please contact Emilien Azéma and Carlos Ovalle.

Note: The recruitment process will ensure that the principles of equity, diversity and inclusion are respected, and in the case of equal skills among candidates, preference will be given to the recruitment of women.