Proposal for a Master 2 intership

Physics of granular materials reinforced with fibres

with Baptiste Darbois Texier (**baptiste.darbois-texier@universite-paris-saclay.fr**), Ladislas Wierzchalek and Georges Gauthier.

Laboratoire FAST, Université Paris-Saclay, CNRS 91405 Orsay, France

The incorporation of a small fraction of flexible fibers into a granular medium has been shown to significantly enhance its mechanical strength. This efficient and cost-effective technique is widely employed in engineering applications, including the improvement of concrete resistance, the reinforcement of soils against erosion, and the stabilization of fragile slopes susceptible to avalanches (Fig. 1a). Analogous mechanisms occur in natural systems, where plant roots exert a stabilizing influence on granular substrates.

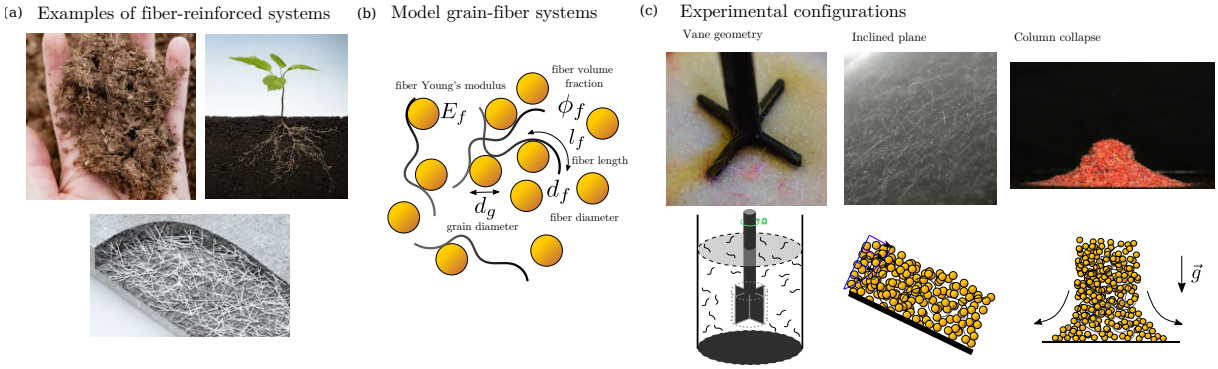

Figure 1: (a) Example of a fibre-reinforced granular material. (b) Schematic of the grain-fibre system with relevant parameters. (c) Experimental setup of interest.

Consequently, numerous applied studies have investigated the role of fiber addition and root development in modifying the mechanical properties of granular soils. Nevertheless, the fundamental physical mechanisms governing the influence of fibers on the effective behavior of grain-fiber mixtures remain only partially understood. Critical open questions include: How do fiber concentration, aspect ratio, and bending flexibility affect the macroscopic mechanical response of the mixture? Through what mechanisms do fibers entangle with grains to enhance resistance? How do fibers align, reorient, or segregate under flow conditions? Addressing these questions is essential for advancing the predictive understanding of fiber-reinforced granular systems, optimizing reinforcement strategies, and informing the development of sustainable approaches to mitigate geohazards in the context of climate change.

To address these questions, we conduct small-scale experiments using calibrated grains and synthetic fibers with varying aspect ratios and flexibilities (Fig. 1b). We investigate the influence of fibers on the effective properties of the mixture under different experimental configurations, including vane rheometry, avalanches on inclined planes, and the gravitational collapse of granular columns (Fig. 1c). In each case, we systematically characterize the flow behavior as a function of fiber concentration and mechanical properties. The results of these experiments aim to establish a physical framework capable of predicting the behavior of grain-fiber mixtures across diverse flow regimes. In parallel, we develop a physical model to describe the coupling between grains and fibers, ensuring consistency with our experimental observations. Within this internship, we will extend this approach by focusing on a specific flow configuration and systematically examining the role of selected parameters.

This internship will be carried out within the *Granular and Suspension* team, which specializes in the experimental investigation of granular materials and particle suspensions. It will benefit from the group's expertise on the mechanics of dry grain-fiber mixtures [1] and on dense granular flows [2].

[1] Ladislas Wierzchalek, Georges Gauthier, and Baptiste Darbois Texier. Vane rheology of a fiber-reinforced granular material. *Journal of Rheology*, 69(3):353–363, 2025.

[2] B. Darbois Texier, Y. Bertho, and P. Gondret. Downslope granular flow through a forest of obstacles. *Physical Review Fluids*, 8(3):034303, 2023.