# Elementary mechanisms of inertial transition in granular media

*PhD position starting in 2018 at Irstea, Aix-en-Provence, France [www.irstea.fr](http://www.irstea.fr)*

**Application:** The $G^2DR$ group of Irstea Aix-en-Provence and the $MGeo^3$ group of Irstea Grenoble are pleased to invite applications for a PhD position (3 years) to investigate the elementary mechanisms of inertial transition in granular media. This phase transition plays a key role in earth dike failure as well as natural hazards such as landslides or avalanches. The successful applicant will develop and use theoretical and 2D/3D numerical tools. This work will be supervised by A. Wautier, S. Bonelli and F. Nicot from Irstea.

## Thesis project

Granular media have an apparent simplicity on the grain scale but have a rich and complex behavior at the scale of a set of grains. Depending on the microstructure (density, grain arrangements ...) and external loadings, the same granular medium can be assimilated either to a solid or to a fluid. This change in behavior is known to play an important role in the triggering of natural hazards such as debris flows, landslides and avalanches. It is also known to play a key role in the mechanical destabilization of dikes or dams subjected to internal erosion [1] [2].

From a more fundamental point of view, the inertial transition in granular materials is the key stone in understanding:

- how a compact granular medium may abruptly pass, in response to a small perturbation, from a static state to an inertial motion;
- how can a quasi-static zone coexist with an inertial one within shear granular flows [3];
- how can an inertial volume fraction of granular material coexist with a static one in the case of internal erosion.

So far, the quasi-static problem has been mostly attacked from a solid mechanics perspective (Lagrangian point of view) in which a limit state is defined through a plastic flow rule [4]**.** On the other side, the fully dynamic problem has been tackled within the framework of fluid mechanics (Eulerian point of view) with a modified rheology [5] [6]**.** As a result, there is still no unified and consensual formalism at the continuum scale to describe the inertial transition in granular materials.

The objective of the thesis work is to go back to the discrete nature of granular material in order to analyze and understand the elementary micro-mechanisms leading to the sudden appearance of kinetic energy, signature of a static/inertial transition. A particular attention will be paid to two types of quasi-static/inertial transition: i) the mechanical instability of a granular medium; ii) the erosion of a granular medium under water flow.

## State of the art

*Instabilities in granular materials:* Since its introduction by Hill in 1958 [3], the second order work criterion has proved to be a versatile tool to identify instable states at the material point scale [4] [5]. Provided a suitable incremental loading is applied, unstable materials will exhibit unbounded brutal increase in kinetic energy. The vanishing of the second order work for some incremental loading directions is certainly a necessary condition to observe fluidization in granular materials.

*<u>Non-locality and mesostructures:</u>* Because of their discrete nature, granular materials have an internal length which cannot be accounted for in continuum mechanics models. As a result, several non-local macroscopic laws have been developed but their microscopic physical justification is still widely open [6] [7]. Another upscaling approach may be found through micromechanical models in which structures of a few grains are considered and considered to be representative of the micromechanics in granular materials [8] [9]**.** This approach is motivated by the fact that the macroscopic behavior of granular materials widely rely on mesoscopic structures of a few grains [5] [6] [16]. The interplay between force chains and grain loops is for instance able to provide a physical explanation to the softening behavior of granular materials at the macroscale [7] [4]. These mesostructures surely play an important part in the inertial transition with respect to their ability to generate and transport velocity fluctuations [10].

*<u>Micro-aspects of erosion threshold:</u>* Erosion is a macroscopic concept which has no meaning at the microscale. Locally a grain may be either blocked through contacts with its neighbors or fluidized and move freely under the action of a fluid. Usually the transition between these two states is characterizes through a "Shield" threshold [8] [9] reference which generalization to non-horizontal flows or to cohesive materials is still debated.

**Required knowledge and skills**

The candidate should have a master or an engineering degree in geomechanics, civil engineering or mechanical engineering. As the PhD subject will be at the interface between solid and fluid mechanics and will involve multiple scales, notions in fluid mechanics and homogenization will be appreciated. Previous experience in programming would be appreciated. A good level of scientific English (speaking and writing) is mandatory.

**Application**

The submission of the application is to be done online on

http://www.irstea.fr/nous-rejoindre/nos-theses/campagne-de-theses

The PhD thesis is planned to start in October 2018 (with some flexibility).

**PhD contract and term**

Scholarship will be paid at the standard rate of about 1700 € gross/month. The position is scheduled starting in 2018 for a period of 36 months. The PhD student will be enrolled at the Doctoral School 353 "Engineering Sciences" in Aix-Marseille University (AMU).

**Location**

The PhD candidate will be hosted in Aix-en-Provence center of IRSTEA (National Research Institute of Science and Technology for Environment and Agriculture).

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## References


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