THESIS PROPOSAL
(2017-2020)

Multiscale modeling of unsaturated cohesive soils
Application to the failure of hydraulic structures

INTRODUCTION

France has several thousands of large dams and thousands kilometers of river and sea levees. Levees protect about 2 million people from floods and hundreds of thousand people are threatened by the risk of dam failure. The numerical modeling of these structures plays a key role in their design and justification of their stability with respect to the various external hazards. The efficiency of these numerical simulations depends very much on the choice of relevant constitutive laws.

The engineering of hydraulic structures faces today a double challenge regarding design projects which must be optimized both from the economic and the environmental point of view. On the one hand, the main need identified in terms of modeling in recent international projects is to take account of partial saturation of soils during transient flood phases. On the other hand, the requirements in terms of sustainable development will lead to design projects using fewer materials, solutions minimizing the environmental impact and more energy-efficient methods of construction. Reusing soils *in situ* will certainly become one of the keys to future projects.

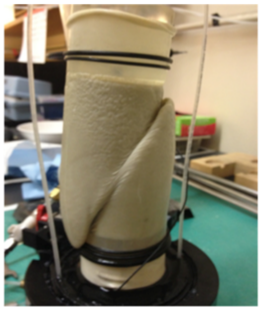
There is therefore a strong need to develop numerical tools capable of modeling, in saturated or partially saturated conditions, the entire range of soils used in the construction of hydraulic structures or encountered in their foundation: sands, silty-sands, clays, tailings, residual soils (laterites), treated soils (lime, cemented or bio-cemented soils).

DESCRIPTION OF THE SUBJECT

The determinant role of the microstructure in the initiation of mechanical instabilities in granular media has been experimentally demonstrated for some twenty years. The explicit consideration of the effect of microstructure on the constitutive laws has however long been a major scientific problem. Scientific works carried out over the past ten years by several research teams, including at Irstea Geomechanical Group, have significantly improved our understanding of granular soils behaviour and the development of multi-scale models opened the way to numerical simulations taking into account the effect of microstructure at the Representative Elemental Volume scale [1]. Among these models, the H-microdirectional model, developed at Irstea, has demonstrated its ability to reproduce most of the mechanical features of non-cohesive granular soils. Its recent implementation in the finite difference calculation software FLAC has pioneered the use of a multi-scale model for numerical simulations at the structure scale.

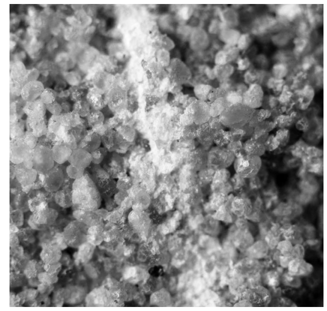
This thesis is part of the work carried out on the reliability of hydraulic structures, in the continuity of recent developments in which the H-micro-directional model and the criterion of

[1] Smallest volume over which to it is possible to measure quantities representative of the material behavior on the macroscopic scale.



(a) Triaxial test on a bio-cemented sand (www4.ncsu.edu).

(b) Effect of suction on the mechanical resistance of sand.



(c) Shear band development in sandstone (folk.uib.no).

material instability have been implemented within a finite difference numerical calculation code in the two-dimensional case.

The objective of the present thesis will be to extend the H-microdirectional model to cohesive granular media. This will require to introduce a set of contact forces will be introduced to model i) capillary forces or ii) solid bridges in the inter-grain contact law. The transition from the microdirectional model to the three-dimensional case will be possibly conducted on the basis of the results obtained from another ongoing thesis.

WORKING ENVIRONMENT

The PhD student will be registered at the Doctoral School 353 of Aix Marseille University (*Mécanique, Physique, Micro et Nanoélectronique*). The PhD will be supervised by Pierre Philippe, research director at the RECOVER research unit (Irstea, Aix-en-Provence) and François Nicot, research director at the Irstea Erosion Torrential Snow and Avalanche Research Unit (Irstea, Grenoble). Supervision will be provided by Guillaume Veylon, research engineer, head of the Civil Engineering Group (Irstea, Aix-en-Provence).

The PhD student will also take part in meetings and symposia organized by the GdR International *GeoMech* built around multi-physical and multi-scale coupling in geomechanics, by the *ALERT Geomaterials* network, which gathers most of the Geomechanical modeling specialists in Europe, and by the international research group *Bifurcation and Degradation in Geomechanics*.

CANDIDATE PROFILE

The candidate must hold a Master's degree in *Geomechanics*, *Civil Engineering* or *Solid Mechanics*. He will have to demonstrate strong skills in the fields of soil mechanics and numerical modeling of geomaterials. He / she must also possess a good level of English and proven redaction skills (particular attention will be paid to these points). A previous experience of the FLAC software or DEM modeling will be an advantage.

PRACTIVAL INFORMATIONS

Beginning of the PhD : octobre 2017.
Treatment : 1,500 euros net.
Geographical location : Irstea, Aix-en-Provence.
Submission of applications : guillaume.veylon@irstea.fr (+33 4 42 66 79 36).