China Scholarship Council / Université de Lyon
Scholarships for doctoral mobility

Call for Thesis subjects: 2025

RESEARCH SUBJECT TITLE:

Study of the hydromechanical behaviour of soils using a meshless approach to model large soil movements close to geo-structures

Name of the laboratory: Tribology and Systems Dynamics Laboratory (LTDS).
Website: http://ltds.ec-lyon.fr

Name of the research team: Geomaterials and Sustainable Construction (GCD)
Website: http://ltds.ec-lyon.fr -> "Géomatériaux et Construction Durable"

Name of the supervisor: Benoît PARDOEN (CR, supervisor, HDR defense around march 2025)
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Doctoral School: Mechanics, energetics, civil engineering, acoustics (MEGA, ED 162)

Lab Language: English and French

Minimum language level required:

- English: Good / Fluent (in accordance to the doctoral school admission rules)
- French: -
- Other: -

Expected duration of the thesis: 48 months

Keywords: geo-structure stability, unsaturated soils, multi-physical modelling, meshless approach.

Abstract:

CONTEXT

With global warming, climate cycles are increasing in intensity with their effects becoming more destructive. Concerning civil engineering and geo-structures, the alternation of wet and dry periods of great magnitude inducing significant swelling and shrinkage hence important ground movements (settlements, upheaves) has led to significant damages to overlying structures. Other examples are related to slope stability subjected to variation of water content leading to soil instabilities and gravitational sliding hazards. Large movement of soils and rocks are also encountered in various fields of geotechnical and underground structures. Therefore, it is urgent to improve the design of such structures and to review the construction dispositions in order to avoid these incidences in the future. This requires better quantitative prediction and control of the hydro-mechanical coupled behaviour of in situ soils during construction and the complete life cycle.

Most of the classical design calculations in civil engineering are performed by the finite element method, which has become standard practice but is poorly suited to situations involving large displacements and/or deformations. This is for example the case of river embankments subject to cyclical variations in water level. An excessive distortion of the mesh due to large strains deteriorates the numerical precision. It also occurs for finite element modelling of large strain localisation in shear bands [1,2]. For the latter, in continuum FE modelling, mesh-dependency can be tackled by using regularisation methods [1,2]. These methods introduce for instance an enhancement of the constitutive law or of the continuum kinematics. However, various types of excessive distortions can be tackled by advanced numerical methods. Recently, new "meshless" methods have been proposed [3-7], which are interesting alternatives without this mesh-dependent defect. This proposal deals with one of them: the method entitled "Smoothed Particles Hydrodynamics (SPH)", which seems particularly promising.

OBJECTIVES

The research aims to extend the SPH method, which dealt classically with problems of monophasic media (fluids and solids), to that of multiphase porous media, more specifically the case of unsaturated soils [8,9]. To do this, two approaches are possible. The first, more fundamental, uses different sets of particles to model different phases in mutual interaction. Thus, a saturated soil - a two-phase medium - is modelled by a set of solid particles and a set of liquid particles, moving and interacting in a common spatial domain [4]. A new approach is proposed. It is based on only a single set of particles, which carries both the mechanical (stress, displacement, deformation, porosity) and hydraulic (pressure) fields. This new approach therefore requires a theoretical reformulation of the problem comprising a new and unprecedented spatial discretisation scheme.

METHOD

The key elements of the proposed PhD thesis are: the development of a new numerical multi-field scheme, the consideration of the multi-physical behaviour of soils, and the numerical modelling of large soil mass movements close to geo-structures.

Step 1 – *Numerical scheme development:*
A crucial part is the development of a new formulation of the SPH method to tackle a multi-field problem. In fact, the resolution requires developing a new numerical scheme. A new algorithm is also required to consider the different hydromechanical boundary conditions.

Step 2 – *Hydromechanical soil behaviour:*
To progress in the direction of increasing level of difficulties, the case of fully saturated, bi-phasic media, is firstly considered, followed by the case of partially saturated, tri-phasic media.

Step 3 – *Large soil movement modelling:*
A hydromechanical numerical modelling of large soil movements related to soil instabilities will be performed. The effect of the variation of hydraulic conditions (e.g. water content/level, fluid overpressure, etc.) on the soil mass movement hazards will be studied. These hazards will concern important practical problems (e.g. geotechnical and underground works) as the triggering of gravitational slope sliding or underground excavation failure. For instance, the application of this discontinuous meshless numerical method for underground excavation (e.g. surrounding failure, excavation face instability, etc.) would bring a better understanding of hydromechanical large strain and failure problems, previously considered with continuous regularisation methods [1,2,10]. This will allow to demonstrate the usefulness and relevance of the approach and of the numerical tool.

INNOVATIVE CHARACTER AND EXPECTED RESULTS

The application of the SPH method in the case of a multiphase material such as soils and rocks is relatively recent. In fact, the modelling of such materials by a single set of solid particles is new and innovative. Furthermore, the results of this thesis will find many applications for important practical problems in the field of geotechnical and

underground structures. This thesis work will provide engineers with a new tool for the design of geotechnical structures likely to be in large displacements and large deformations. Consequently, this thesis is both fundamental (understanding of complex physical phenomena coupled to one another) and applicative (design tools for engineers).

References:

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