## Master internship – PhD position 2024–25

# Experimental study of the solidification of a capillary bridge

**Contacts :**

Axelle Amon, Institut de Physique de Rennes, Rennes, France – axelle.amon@univ-rennes.fr

Isabelle Cantat, Institut de Physique de Rennes, Rennes, France – isabelle.cantat@univ-rennes.fr

Freezing in presence of capillary effects is a particularly complex phenomenon and leads to surprising features such as singularity of the free surface during freezing ([1] and figure 1). How phase change and capillary effects interact in the case of phase transition of water in an unsaturated porous material is still largely not understood. This problematic is in close connection with the understanding of the structure of soils in the periglacial domain and of the evolution of permafrost with global warming.

FIGURE 1 – Ice drops obtained by freezing millimeter sized water drops on a cold plate. Coupling of expansion due to solidification and capillarity effects leads to the formation of the pointy tip [1].

Indeed, a soil can be modeled as a mixture of grains and water. In presence of a temperature gradient encompassing the phase transition of water from liquid to solid, capillary flows are observed towards the frozen front leading to the formation of areas of pure ice segregated from the surrounding granular material (figure 2). The formation of those ice lenses is still not understood while it is responsible of the severe deformations observed at the surface of grounds in the periglacial domain.

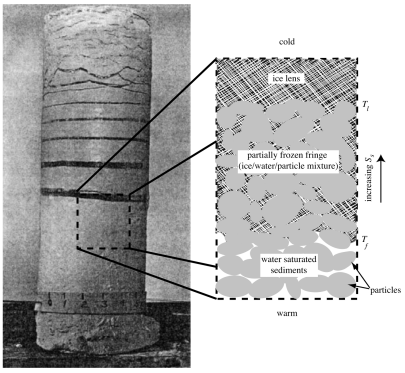


FIGURE 2 – Left : ice lenses (dark strips) orthogonal to a static thermal gradient in an initially homogeneous sample of clay (from [2,3]). The sample is freezed from the top (see schematics of the internal microstructure of the system on the right).

Among the reasons of our partial understanding of the behaviour of the freezing of a mixture of grains, water and air is the lack of measurements at the scale of a pore. **The aim of the internship is to provide direct measurements of the dynamics of the solidification of a capillar bridge between two solid surfaces** as well as the mechanical forces at play due to the volume expansion of water during its phase change.

During the internship, a setup to obtain a well-controlled temperature gradient will be built, and an imaging bench allowing the visualization of a capillary bridge will be designed. The dynamics of the advancing freezing front will be studied as well as the modification of the bridge's shape due to the volume changes expected during the freezing process. The effect of the presence of solutes or surfactants, which modify both the contact angle between solid and liquid and the freezing dynamics, will be studied. Measurement of the force exerted by the bridge on solid surfaces will be developed during the PhD project.

The internship will suit a student who enjoys experimental physics. A good background in continuum mechanics and thermodynamics is required. It will be supervised by Axelle Amon and Isabelle Cantat at the Institut de Physique de Rennes (Rennes, France).

The internship can be followed by a PhD thesis funded by the ANR ModAFroSt (Modeling the Action of Seasons on Frozen Soils).

[1] J. H. Snoeijer and P. Brunet, *Am. J. Phys.*, **80**, 764 (2012).

[2] S. Taber, *J. Geol.*, **38**, 303 (1930).

[3] A. W. Rempel, *J. Geophys. Res.*, **112**, F02S21 (2007).