

Impact of solvent imbibition on architected structure mechanics

Master 2 Internship + PhD offer
Navier Laboratory, Champs-sur-Marne

Key words : Fluid-structure interaction, poromechanical coupling, architected structures.

In the context of sustainable construction, there is growing interest in developing new, more environmentally-friendly composite building materials, particularly bio-based and geo-sourced materials made from wood, clay, plant fibers, wood chips, and other natural constituents. These materials often exhibit organized, multiscale, and hierarchical microstructures and are hygroscopic : owing to their porosity, they have a strong tendency to interact with water, which is ubiquitous in their environment. However, water absorption and desorption can alter their mechanical properties, which leads to a major challenge for their use in construction. It is therefore essential to investigate and understand the underlying mechanisms of mechanical behavior of porous hygroscopic materials, while also developing innovative model materials with a controlled mechanical response.

This project aims to develop architected and functional structures for sustainable construction, made from soft materials that are saturated with solvent and responsive to physicochemical stimuli. On the one hand, this requires investigating **how a soft, architected structure made from a material with a strong affinity for the surrounding solvent interacts with solvent flow**. On the other hand, the influence of solvent uptake by the constituent material on the overall mechanical behavior of the structure must be investigated. Together, these questions constitute a multiscale fluid–structure interaction problem that has received little attention so far, particularly in the case of polymeric or bio-based materials.

A preliminary numerical work has focused on the mechanical response of a hydrogel structure consisting of four squares rotating around their hinges (Fig. 1A), immersed in water and subjected to an imposed displacement that causes it to close. Simulations based on finite element methods (FEM) have highlighted the crucial role of the hinges, which act as a “filter” through which fluid is expelled from the enclosed central region of the structure. Moreover, counterintuitive recirculation flows are observed along the poroelastic walls during closure, likely due to the porous nature of the material, which allows fluid exchange between the structure and surrounding water. Ultimately, these complex flows determine the mechanical response of the structure, and vice versa.

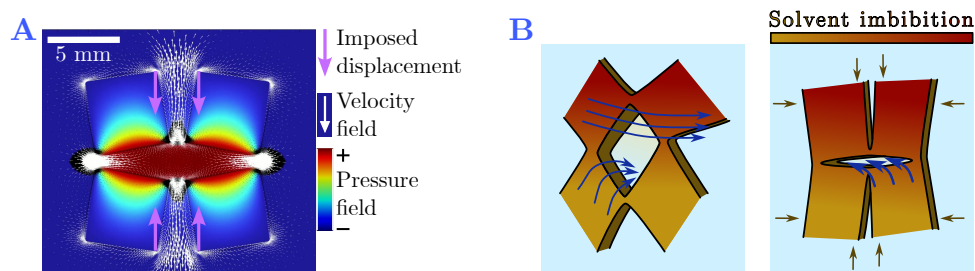


FIGURE 1 – **Porous and deformable auxetic structures.** **A :** Numerical simulation of a hydrogel structure immersed in water. Performed by Sofia Adellal. **B :** Introduction of solvent uptake gradients into the problem.

The aim of this internship is to **build an experimental setup** to investigate the mechanical response of macroscopic auxetic structures made of gelatin and immersed in a water bath. The subsequent PhD project will seek to **understand the mechanisms underlying the observed flows, their coupling with the overall mechanical response**, and the identification of an optimal geometry for the development of innovative sustainable building materials. More specifically, solvent uptake gradients will be explored as a design tool (Fig. 1B), for instance by controlling local porosity through the degree of polymer crosslinking.

Job requirements : In this project, the envisioned work is strongly experimental, complemented by theory. The internship will begin with the design and development of the experimental setup. A particular enthusiasm for experimental design and hands-on work (including building and tinkering with experimental apparatus) is expected. A background in soft matter physics and/or mechanics, with an emphasis on continuum mechanics, would be ideal. A fluent English is necessary.

Location and research environment : Navier Laboratory, Rheophysics and porous media team, Gustave Eiffel University, Champs-sur-Marne.

Supervision and contact : Caroline Kopecz-Muller, associate researcher ("*chargée de recherche*") caroline.kopecz-muller@univ-eiffel.fr

PhD funding : through application to the SIE doctoral school, decision expected around June 2027.

About the lab : The Navier Laboratory is a joint research unit of the Ecole Nationale des Ponts et Chaussées (ENPC), the Gustave Eiffel University and the National Center for Scientific Research (CNRS), located in the Cité Descartes in Marne-La Vallée. The staff (nearly 170 people) conduct research on mechanics and physics of materials, structures and geomaterials, and their applications to geotechnics, civil engineering, transport, geophysics and energy. The Rheophysics and porous media (RMP) team conducts multidisciplinary research on the physics of disordered and divided matter, suspension, granular or colloidal assemblies, natural or synthetic porous media, films and interfaces. An original combination of experimental tools (RMN, rheometers, optical tweezers, confocal...) and model materials are often used to better characterise the microscopic origin of studied behaviours.