**20th European Mechanics of Materials Conference - EMMC20**
Florence, Italy | May 27th-29th, 2026
www.emmc20.unifi.it

# Understanding Freeze-Fracture in Soft Model Hydrogels

**Muriel M. Scherer[1], Arturo Chao Correas[2], David Kammer[3], Lucio Isa[4], Robert W. Style[5]**

[1] Department of Materials, ETH Zurich, 8093 Zürich, Switzerland, Switzerland. muriel.scherer@mat.ethz.ch
[2] Department of Civil, Environmental and Geomatic Engineering, ETH Zurich, 8093 Zürich, Switzerland, Switzerland. arturo.correas@ifb.baug.ethz.ch
[3] Department of Civil, Environmental and Geomatic Engineering, ETH Zurich, 8093 Zürich, Switzerland, Switzerland. dkammer@ethz.ch
[4] Department of Materials, ETH Zurich, 8093 Zürich, Switzerland, Switzerland. lucio.isa@mat.ethz.ch
[5] Department of Materials, ETH Zurich, 8093 Zürich, Switzerland, Switzerland. robert.style@mat.ethz.ch

*Paper ID: 207*
*Symposium S8: Fracture, and damage of materials*
*Extended Abstract*

## Abstract

Freezing-induced damage in soft, porous materials is a widespread problem that is still poorly understood, but which impacts many disciplines such as geology, and material and food sciences [1]. There are two key challenges that have made it hard to make progress on this problem. Firstly, most samples of interest are not transparent, so it is hard to directly visualize freezing damage processes. Secondly, materials like food, tissue and clay have complex fracture properties, and so they break in complex ways. Thus, although freezing damage strongly resembles a fracture process, it has been challenging to directly applying fracture mechanics to understand it. Here, we develop a model freezing system, using transparent hydrogels. When we freeze these gels at a constant rate, we observe the formation of beautifully periodic, ice-filled cracks. By bringing order into the damage process, we now have an excellent testbed to understand freeze-fracture. We find that the cracks depend on certain parameters such as temperature gradient, freezing speed and sample geometry thickness, and explain this dependence with a simple fracture mechanics model to our system. However, while fracture mechanics describes many of our experimental observations, there are some surprising discrepancies - such as the observed crack tips being much larger than

expected from theory. Our results demonstrate the great potential for understanding fundamental questions in freeze damage by applying well-established concepts from fracture mechanics.

**Keywords:**

Hydrogels Fracture Freezing

**References:**

[1] D. Gerber, L.A. Wilen, F. Poydenot, E.R. Dufresne, &R.W. Style, Proc. Natl. Acad. Sci. U.S.A. 119 (31),e2200748119.