Predicting avalanches: Fracture characteristics of anticracks in highly porous materials

September 2 2024, by Michaela Hütig

Critical point of collapse. We use the back of a snow saw to cut into the weak layer until the released energy of the resulting cantilever beam is sufficient to initiate a crack. People: Melin Walet, Valentin Adam. Credit: Matthias Spieler

Even a single person in the snow can exert enough pressure on it to cause a buried weak layer of snow to collapse and the snow cover to slide away. In this case, experts speak of anticracks. The fundamental fracture properties that can lead to powerful slab avalanches are still largely unknown, but crucial in order to accurately predict when avalanches will occur.

In the journal *Nature Communications*, researchers led by TU scientist Dr.-Ing. Philipp Rosendahl are now presenting an innovative method that enables the fracture toughness of weak snow layers to be measured in the field under controlled conditions.

"Our study was motivated by the latest advances in avalanche research, which were driven by new experimental and numerical studies. These provided us with new insights into the fundamental fracture process responsible for triggering the avalanche, known as anticracking in weak layers of snow," says Dr.-Ing. Philipp Rosendahl, group leader at the Center of Snow and Avalanche Research at the Institute of Structural Mechanics and Design in TU Darmstadt's Department of Civil and Environmental Engineering.

"Despite this remarkable progress, the fundamental fracture mechanical properties of weak layers of snow remain largely unknown. However, such measurements are crucial for accurately predicting when avalanches will occur," adds Valentin Adam, who developed the new and unusual experimental setup for his doctorate at TU Darmstadt.

The study thus aims to close this important knowledge gap by introducing an innovative method consisting of two key components: firstly, the development of a new experimental technique that enables the anticracks to be created in weak snow layers in the field under controlled conditions, and, secondly, the use of a non-local mechanical model to analyze the global energy balance at the start of anticrack growth, whereby the researchers can derive the fracture toughness of the snow layers from the experimental data.

The researchers from TU Darmstadt, the WSL Institute for Snow and Avalanche Research SLF in Davos and the University of Rostock have developed an experimental setup to test how weak layers in the snow collapse under combined compressive and shear loads—the characteristic load causing avalanches.

To do this, blocks of snow containing weak layers are mounted onto a sled and tilted at various angles. With the aid of additional weights and cuts in the weak layer, a collapse of the snow column was triggered—the anticrack began to spread in an unstable manner.

The experimental setup made it possible to determine for the first time the fracture toughness of weak layers under a series of conditions from pure compression to pure shear.

Previous work had not succeeded in generating and measuring significant shear contributions for the growth of anticracks (collapse of the weak layer) in the snow in a controlled manner.

The results that have now been published show that resistance to crack propagation under a shear-dominated load is significantly higher than with pure compression—an observation that the researchers did not initially expect because avalanches occur more often in steep terrain, where shear loads dominate.

Nevertheless, this cracking behavior can also be observed in other materials exposed to a combination of tensile and shear loads. What is new is that the correlation has now also been demonstrated for simultaneous compressive and shear loads—as anticracks occur not only in snow but also in other highly porous materials such as sedimentary rock and metal foam.

The scientists were ultimately able to identify a power law that describes the threshold for crack propagation under a mixed load and states whether a crack will expand under the given load conditions. The findings make a significant contribution to understanding the fracture process that leads to avalanches and are central to improving avalanche predictions.

"In addition, the understanding of fracture behavior in porous media under compression is of great interest in other applied research areas, such as in aerospace, where lightweight constructions are often subjected to similar load conditions," says Rosendahl.

More information: Valentin Adam et al, Fracture toughness of mixed-mode anticracks in highly porous materials, *Nature Communications* (2024). DOI: 10.1038/s41467-024-51491-7

Provided by Technische Universitat Darmstadt

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