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Modelling the deformation and collapse of a weak snow layer

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Weak snow layers are thin layers of low cohesion and density, naturally occurring in the snowpack. The understanding of their mechanical behaviour is considered to be of great importance as they are believed to have a decisive effect on dry slab avalanche releases. These layers can be viewed as porous structures of sintered ice grains that collapse under loading, withdrawing support to the overlaying slab layer of snow. Field observations show that weak layers are usually formed by very distinct snow types and microstructures. The extremely fragile nature of these layers makes systematic laboratory experiments notoriously difficult. Here, to investigate the mechanical response of a weak layer under loading, we perform numerical experiments based on the actual microstructure of snow. The simulations are based on a discrete element model (DEM) of the weak layer that utilizes X-ray tomographical images of snow structure as input information. Individual grains are identified in the binary image of the snow matrix and then represented in the DEM model by a computation-efficient approximation based on sets of spheres. A medial axis-based algorithm has been developed in order to obtain a chosen level of grain shape approximation with the minimum number of spherical discrete elements. The optimal level of grain approximation is determined through a sensitivity analysis of different geometrical measures of grain shape to the approximating parameters. Thereby, an optimal balance can be found between computational efficiency and accuracy of the developed DEM model. Finally, by accounting for the fragile cohesion between individual grains of the snow matrix, the model gains ability to follow the material through different stages of deformation - from a porous network of sintered grains to the final stage of a decomposed granular material. The model is applied to multiple snow samples to reveal the effect of microstructure on the macroscopic mechanical response of snow. The objective of this research is the formulation of microstructure-based constitutive laws for weak snow layers.