The Cryosphere Discussions

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Reply on RC3

Philipp Weißgraeber and Philipp L. Rosendahl

Author comment on "A closed-form model for layered snow slabs" by Philipp Weißgraeber and Philipp L. Rosendahl, The Cryosphere Discuss.,
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Dear reviewer, thank you for your comments and suggestions, which help us to improve our paper. Please find our response to each concern and remark of the review below:

The Authors propose a closed-form analytical model for the mechanical behavior of stratified snow covers adopting the first-order shear deformation theory of laminated plates under cylindrical bending. The weak layer is modelled as an infinite set of smeared springs with normal and shear stiffness at the base of the plate. The problem is worth to be studied and it is of large interest for the scientific community. There are some points that must be clarified and further investigated.

1. It is not clear the remind to De Saint Venant's principle (l. 246) and how it can be applied in the model proposed by the authors as the localized stresses and effects are of primary importance for the release of the avalanche.

The question is well answered by Wikipedia: "Saint-Venant's principle, named after Adhémar Jean Claude Barré de Saint-Venant, a French elasticity theorist, may be expressed as follows: the difference between the effects of two different but statically equivalent loads becomes very small at sufficiently large distances from load." (https://en.wikipedia.org/wiki/Saint-Venant%27s_principle).

For the model this means that introducing the skier loading as distributed loads (width of the skis) or concentrated into one force (statically equivalent) has the same effect on weak-layer stresses.

We will include this clarification in the revised manuscript.

2. The authors must clarify how the concentrated load applied on the surface of the slab enters into the solution of the first-order system of Eqn. (11).

The ODE system is obtained by using the constitutive equations and condition of equilibrium of the slab-weak-layer system (Appendix A and B in the manuscript). The concentrated loads are introduced in the next step, when boundary and transmission conditions are considered (see Appendix C for details). A concentrated force introduces a discontinuity in the equilibrium of lateral forces and, hence, requires a transmission condition. We will included this clarification in the revised manuscript.

3. The authors must clarify how the size of the crack tip can be effectively measured in a real snowpack as it affects the results of the stability analysis.

In the case of the most relevant experiment for analysis of the fracture behavior of weak layers – the propagation saw test – the crack length corresponds to the critical cut length at which the PST fails.

4. The authors confuse the energy release rate with the failure criterion. To let the crack to propagate, it is necessary that the G term equals the critical G in the mixed mode. It is worth to mention that, in fracture mechanics, Mode 1 refers to an opening mode, differently from what the authors state in their approach. This point must be addressed in order to avoid misunderstandings.

The present work does not consider failure or a failure criterion but aims at providing all quantities necessary for a failure assessment. In our view, the most important ingredients are weak-layer stresses (normal and shear) and weak-layer energy release rates (collapse and sliding). Eq. (19) provides the equations for the latter. That is, Eq. (19) enables the formulation of mixed-mode weak-layer failure criteria.

An example of how mode I and mode II energy release rates can be considered individually is given in Figure 16 that analyzes the effect of slope angle on the mode mixity of the energy release rates in propagation saw tests.

Note that we have proposed a mixed-mode finite fracture mechanics approach for non-layered slabs in an earlier work [Ros2020b] and we will incorporate the present model for layered slabs in this framework in the future.

When we speak of mode I anticrack propagation, we refer to the symmetric nature of the deformation field [Bro1999]. Because we consider anticracking, mode I corresponds to weak-layer crushing and collapse. Further details of this definition are given in a previous The Cryosphere publication by the authors [Ros2020b]. We will revise the manuscript to make this more clear.

References used in the response:

[Bro1999] Broberg, K. B. (1999). Cracks and fracture. Elsevier.
[Ros2020b] Rosendahl, P. L., & Weißgraeber, P. (2020). Modeling snow slab avalanches caused by weak-layer failure–Part 2: Coupled mixed-mode criterion for skier-triggered anticracks. The Cryosphere, 14(1), 131-145.