DRY SLAB AVALANCHES TRIGGERED BY SKIERS

(Extended abstract)

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INTRODUCTION

Most skiers buried and killed in a slab avalanche triggered "their" avalanche themselves. Avalanche forecasting should reflect this fact. In times of severe snowfall traditional avalanche forecasting is mainly based on the actual nivo-meteorological parameters. Naturally released avalanches dominate this phase, whereas slabs triggered by skiers are common in rather quiescent weather periods. At such times, forecasters follow the snow cover development closely. Analysis of snow pit data, "Rutschblock" tests and shear frame measurements represent so-called low entropy data (LaChapelle, 1980) and are most efficient for stability evaluation. Thereat it is essential to take into account the additional stress induced by the skier. Föhn (1987) explicitly introduced a stability index *S'* which incorporates this additional load. In the case of shallow slabs « 0.5 m) the human load is a substantial factor (Figure 1).

SLAB RELEASE MECHANISM

Avalanche forecasting has to rely on a specific slab release mechanism which can serve as a concise basic model for artificially triggered avalanches. Principally, a weak layer (the so-called "Gleitschicht") within the snow cover is a prerequisite for a shear failure the most likely type of failure to occur. Recent work on snow slab stability has focussed on the effect of superweak shear zones within the weak layer (McClung 1987, Bader and Salm 1990). According to this theory, spontaneous avalanching only seems possible if ductile shear failure starting at a superweak zone can propagate, since only this mechanism provides the necessary stress peak, the critical strain rate and the critical deformation for a brittle failure. If the brittle fracture can spread out, the slope will fail. It is now assumed that slab avalanches triggered by skiers may directly start with brittle failure, since the stress peak induced by a moving skier yields a

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sufficiently large strain rate to effect over the transition from ductile to brittle behaviour (Narita, 1980) and hence to initiate the fracture. For practical stability evaluation, the condition for slab release is simply that the sum of the gravitationally induced shear stress and the additional load of the skier has to exceed the shear strength. The crucial point is, of course, to assess the shear strength of the "Gleitschicht", and this depends on the rate of deformation. Strength values obtained from fracture line data and from shear frame measurements are supposed to be in the brittle range and hence serve our purpose. A further model starts with the collapse of the weak layer and then inducing the shear failure. This mechanism of pressure collapse may describe the type of avalanches which announce themselves with a "whumm"-sound.

PRACTICAL PROBLEMS

Assessing snow slope stability is a difficult, sometimes even dangerous task and several points are controversial. Shear frame measurements at the crown of released slabs often show mean shear strength values substantially larger than the shear stress calculated from the slab characteristics, the stability indices are larger than one and the slope should not have failed (e.g. Roch, 1966). This discrepancy may partly be solved by considering the skier's load. Furthermore, the fracture line position where the shear frame measurements were made is usually not representative enough for the slab area and the measurements are usually made with a time delay of some hours or days. Hence the ongoing sintering process may also affect the result. Additionally, the problem of snow parameter variability exists. However, the shear strength does not vary erratically, but in accordance with other snow characteristics such as density or snow depth. Thus the variation is thought to be due to local variation in the topography and to micrometeorological conditions. To take into account the snow strength variation, stability indices smaller than 1.5 are considered as critical.

CONCLUSIONS AND OUTLOOK

Based on the model of human triggered slab avalanches described above and considering the critical points in the data acquisition, it is believed that stability evaluation is a powerful tool for operational avalanche forecasting.

An analysis of about 300 shear frame measurements should supply weak layer characteristics and in particular typical shear strength values for the different snow types. The next steps will be to evaluate different load cases using the finite element method. Special attention will be focussed on the layering of the snow cover, e.g. the case where a thin crust overlies a layer of depth hoar. The stress analysis will be compared with the snow strength data to determine different degrees of release probability. Finally, it is hoped that this sort of stability evaluation based on daily snow cover data and on a snow cover simulation program (Brun et al., 1989; Gubler and Bader, 1989) will serve as an additional tool in operational avalanche forecasting in the future.

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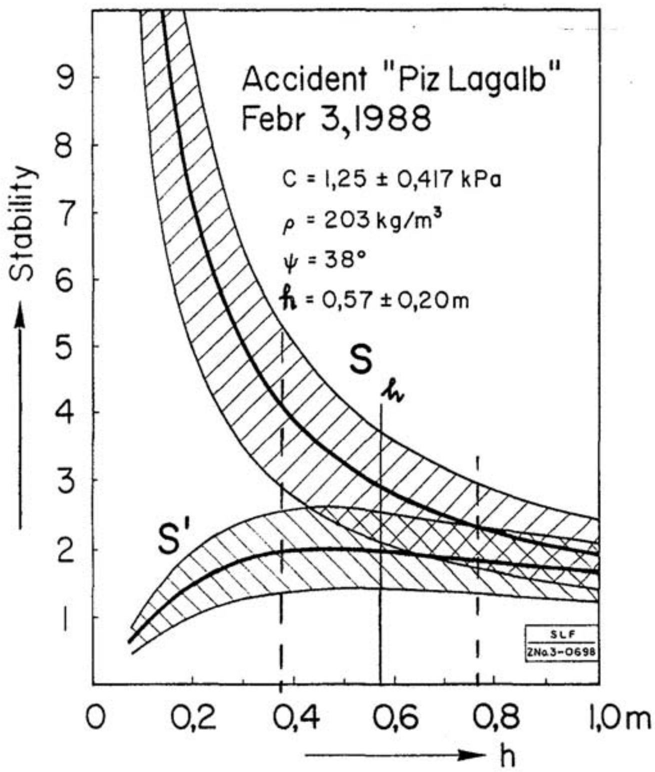

Figure 1 - Natural stability index *S* and stability index integrating human triggering S' (Eq. 1 and 2; Föhn, 1987) vs. slab height *h* (solid lines). Dashed areas give range of error in measurement. Data is from a slab avalanche accident at Piz Lagalb, Swiss Alps, Febr 3, 1988.

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