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# Interaction of flexible rockfall barriers with avalanches and snow pressure

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## Abstract

Rockfall barriers are optimized to absorb high punctual impact energies. In mountain areas the barriers are also loaded by avalanches and snow pressure. Snowpack forces and dynamic avalanche pressures act over a much larger area and over longer time periods. Thus, if not properly designed, rockfall barriers can be damaged. In winter 2003–2006 we investigated the interaction of flexible rockfall barriers with avalanches and snow pressure on a study site in Fieberbrunn, Austria and in other areas. In several locations the barriers successfully stopped small wet snow avalanches. However, the main problem turned out to be the insufficient retention capacity during the whole winter and the structural behaviour. The weakest points are the retaining ropes and the post foundations. For an appropriate design of the barrier the main input factors determining snow pressure and avalanche pressure have to be assessed.


*Keywords:* Avalanche protection; Rockfall barrier; Avalanche dynamics; Snow pressure

## 1. Introduction

In the last 10 years the behaviour of rockfall barriers has been studied with full scale tests. The result of these tests was an optimized generation of flexible ring net barriers which absorb impact energies of up to 5000 kJ. The energy is mainly dissipated by the ring net and brake devices (Gerber et al., 2003). Flexible barriers are widely applied to protect settlements and traffic lines from rockfall. However, in mountain areas with an abundant snowpack, the flexible barriers are also loaded by avalanches and snow pressure. A rockfall event produces a large dynamic load on a relatively small barrier area. The interaction of the snowpack and avalanches with the barriers is very different. Snowpack forces and dynamic avalanche pressures act over a much larger area and over longer time periods (Table 1). Thus, if not properly designed, rockfall barriers can be damaged. After the successful application of flexible barriers to stop and retain debris flows (Roth et al., 2004), first trials were made to stop small avalanches. To obtain a better understanding of the interaction and performance of rockfall barriers with snow pressure and avalanches, case studies were performed in Switzerland, Germany and Austria. We summarize the data and experiences obtained.

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## 2. Description of the study site in Fieberbrunn

In the ski resort Fieberbrunn in the Kitzbühl Alps (Austria) the 460 m long ski run “Jägersteig” has to be closed during long periods of time every winter because of avalanche hazard. The ski run is situated below a 180 m long 40° steep slope at an elevation of 1310 m a.s.l. (Figs. 1 and 7). The slope is partly covered with deciduous trees. After each snow fall period avalanches are released artificially by explosives. The main concern is warming periods and the consequent release of wet snow avalanches, which are much more difficult to control. At the elevation of the starting zone the 100 year snow depth is estimated at 360 cm and the mean yearly new snow sum at 620 cm. A protection project with several lines of snow supporting structures was established to reduce the avalanche risk. Because of the high cost alternative protection measures in the form of rockfall barriers were proposed. The rockfall barriers should brake and catch the avalanching snow masses. In a first step it was decided to investigate the suitability of rockfall barriers to stop small avalanches in a research project funded by the Centre for Natural Hazard Management alpS.

The main goals were to study the behaviour of the structures and to optimize their resistance against snow pressure and avalanche impacts. In 2002 a 20 m (termed A) and a 15 m long barrier (termed B) of the system FATZER AG Geobrugg RX-avalanche with heights of 5 m were built in the most frequent avalanche zones 30 m above the ski run (Fig. 2). The posts and ground plates correspond to a 3000 kJ barrier and the rope assembly to a 2000 kJ barrier with an additional down slope rope. The post spacing was reduced from the normal design width of 10 m to 5 m. Because of the areal load, a weaker ring net was chosen compared to a corresponding rockfall barrier. The ring net was covered with a wire netting having a mesh opening of 50 mm. The barriers were closely monitored during winter, recording the snow distribution, the snow height with probing, the snow density and the geometry of the system by measuring the inclinations and deformations of the main structural elements. Snow data were collected daily at the nearby observation field “Kogel” at 1600 m a.s.l. and in Fieberbrunn (780 m a.s.l.). The avalanche activity in the study site was surveyed by ski patrollers.

Table 1
Comparison of different loads on a ring net barrier

| Criteria | Rockfall | Avalanche impact | Snow pressure |
|---|---|---|---|
| Load distribution | Single peak load | Areal load over a part of the barrier area | Areal load over total barrier area |
| Impact time | 0.2–0.5 s | 1–5 s | Weeks–months |
| Deformation | 5–8 m | 2–3 m | 1–2 m |

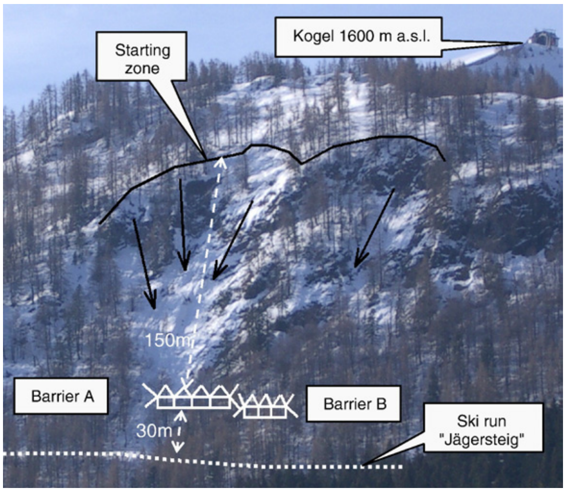


Fig. 1. Overview study site in the ski resort of Fieberbrunn, Kitzbühl Alps, Austria.

## 3. Meteorological and avalanche situation during the 4 test winters in Fieberbrunn

In the winters 2003 and 2006 the snow heights were slightly above average (Table 2). The first test winter had the smallest snow pack and was not very valuable for an evaluation. During the last 2 winters however large snow heights were recorded. The new snow sum of winter 2006 had a return period of estimably 10 years. In every winter at least 11 avalanche days were counted. Most of the avalanches hit the barriers. In winter 2004

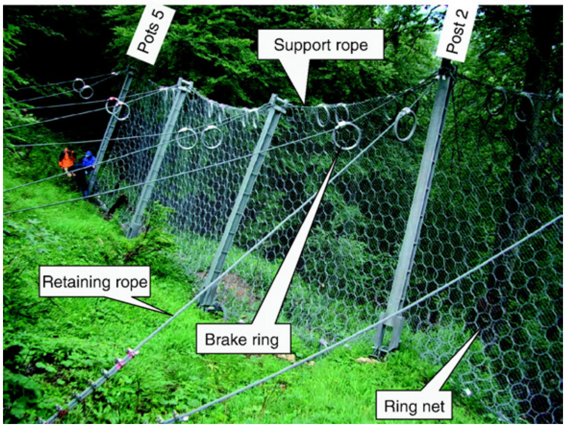


Fig. 2. Study site, RX-avalanche ring net barrier A (5 posts, total length 20 m).