DESIGN PROCEDURE FOR FLEXIBLE ROCKFALL BARRIERS LOADED WITH AVALANCHES AND SNOW PRESSURE

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OVERVIEW

In the last 10 years the behaviour of rockfall barriers was 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. 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. Thus, if not properly designed, rockfall barriers can be damaged. After the successful application of flexible barriers to stop and retain debris flows, 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.

INVESTIGATIONS

In winter 2003 – 2006 we investigated the interaction of flexible rockfall barriers with avalanches and snow pressure on a study site in Fieberbrunn, Austria. Two specifically designed ring net barriers with a height of 5 m were built in a small but very active avalanche path. The behaviour of the structures was closely monitored in winter and summer. Each winter the barriers were hit by several avalanches and the height of the stopped snow was up to 5 m. The maximal deposit volume behind the barrier was 38 m^3 per meter barrier length. The maximal avalanche pressure was estimated to be around 55 kN/m^2. However, the main problem turned out to be the insufficient retention capacity during the whole winter and the structural behaviour. The weakest points were the retaining ropes and the post foundations. In 2005 the test barriers were completely re-adjusted. All foundations were reinforced with a concrete base. Winter 2006 demonstrated that the readjusted barriers withstood high avalanche and snow pressure loads without any damages.

To enlarge the base of experience on the behaviour of these constructions and to understand their limits better, a survey through Austria, South Germany and Switzerland was made. Sites with damaged respectively undamaged rockfall barriers were investigated in winter and summer. Winter 2006 was very rich in snow in central and northern Austria. In several locations the barriers successfully stopped small wet snow avalanches. We analysed the loading and structural behaviour of rockfall barriers in the area of Wildalpen and Attersee,

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which were hit by wet snow avalanches in February 2006. The internal forces of the barriers due to avalanches and snow pressure were determined by using the finite element software FARO that was especially designed to simulate highly flexible systems. The software FARO combines new approaches in simulating the single barrier components through discrete elements with main focus on the loosely connected net rings and the suspension ropes. The dynamic behaviour of the barrier is simulated in many short time-steps by the central differences method. The calculation results could be verified by analysing the deformation of brake rings of the barrier. The internal forces calculated with a simple static model were by a factor of 1.3 to 1.5 higher compared to the FARO simulations. The main reason for the differences might be the dynamic deceleration respectively the long braking distance of the ring net barrier.

DESIGN PROCEDURE

Based on our findings a design procedure for an optimized application of rockfall barriers in areas exposed to avalanches and snow pressure was developed (Fig. 1). The main goal is to compare the rockfall load with the avalanche and snow pressure load and to choose the barrier type and dimensions respectively. In areas with an abundant snow pack attention should be paid to the release point of the brake elements in the retaining ropes and to the foundations of the posts. If avalanches or snow pressure cause higher forces than rockfall the barrier system must be adapted. Stronger structural members, a reduced post spacing, replacement of rated break points, a direct fixation of the support ropes to the posts and foundations of the supports reinforced with a concrete base or steel base plate should be chosen. However if avalanches cause much higher forces on a barrier than rockfall alternate mitigation measures such as rockfilled dams may be necessary.

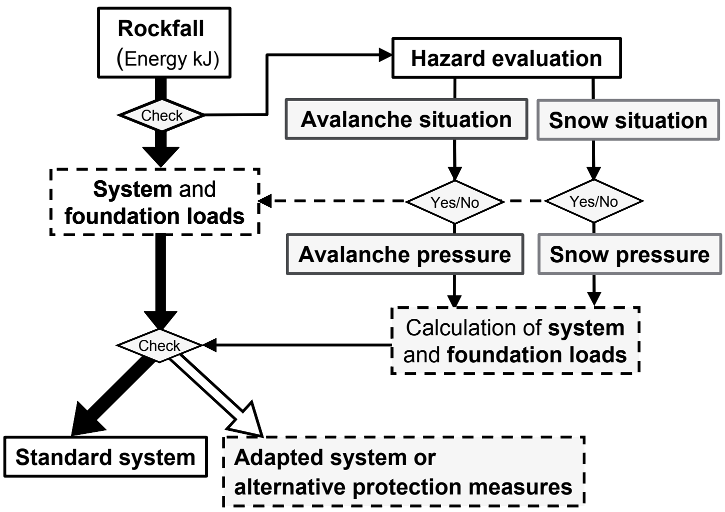

Fig. 1: Procedure for an optimized application of rockfall barriers in areas exposed to avalanches and snow pressure.

Keywords: Rockfall barrier, avalanche protection, snow pressure.