Avalanche Barriers in the starting zone exposed to rock fall: Range of capacity and 1:1 rock fall tests with flexible snow net

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ABSTRACT: Since the introduction of flexible snow nets in the 1950's it became obvious that such barriers provide a better performance on combined loadings of static snow pressure and dynamic rockfall impacts compared to stiff steel bridges. In various cases avalanche barriers in the starting zone have to be built under rock faces with frequent rockfall. On a qualitative basis it was found that rigid systems e.g. snow bridges made of steel are not able to withstand rock fall energies of more than 50 kJ. This is the result of a research project and case studies in Switzerland, Austria and Germany together with the alpS – Zentrum für Naturgefahrenmanagement and WSL- Institute for Snow and Avalanche Research SLF (Margreth 2006a and b). The investigations have shown that flexible snow nets have a higher energy absorption capacity which may be even more than 200 kJ. To obtain a better understanding of the interaction and performance of rock fall on snow nets and to quantify the capacity of snow nets a trial of 4 different 1:1 large scale rockfall tests with flexible snow nets have been done. With this testing it is possible to quantify the rockfall capacity of a new type of snow net. Integral part of this snow net is a rhomboidal spiral rope net with a load capacity of 220 kN/m'. The rockfall bearing capacity could be even increased by applying stronger spiral rope nets. As a result it was possible to achieve a rock fall capacity of up to 500 kJ which is ten times more compared to rigid structures. This rockfall adapted snow net system has been already installed in Austria. In this paper the project is presented and detailed information about the performed test series is provided. The results of our technical development are improved flexible avalanche supporting structures which can withstand rockfall energies up to 500 kJ leading to reduced costs for maintenance and repair respectively.

KEYWORDS: Rockfall, Snow Nets, Prevention structure

1 INTRODUCTION

Natural hazards, in particular rockfall and avalanches can cause extremely high risks to life and infrastructure. For both, rockfall and avalanches, technical solutions are found to minimize the risk where it is necessary. In general, the systems are designed for the hazard specific loads which are either rockfall or snow pressure. In an unfavourable topography, both hazards can occur at the same location. Therefore research and development has been made to adapt the systems for both load cases.

2 PROBLEM DESCRIPTION

Scree slopes are typical ground conditions with a risk of avalanche starting because of a slope angle between 30° - 50°. On the other hand, the scree slopes often end at the very top underneath a steep rock face. Therefore often a rockfall risk is also given, especially at the top of a scree slope.

Expected rockfall impact energies can vary according to the topography and failure conditions uphill. In general, the upper most line in an avalanche prevention area is exposed to the highest impact energies due to direct impacts into the system. Failures in this line can also cause damages for rows underneath. Between the lines of avalanche prevention barriers the impact energy can be expected significantly less because of a typical slope angle of 30°-50° and distance in the range of 25 m between the lines. Estimations have shown a max. impact energy of about 120 kJ between the lines, calculated with a boulder of 1000 kg. Therefore the objective is to have a system in the upper rows which can withstand the occurring impact energy to minimize the damage and maintenance in the lines further down.

Figure 1. Typical avalanche starting zone on a scree slope with rockfall source zone at the top.

The rockfall hazard to a defence structure can be roughly described for 3 different cases (Margreth 2006b):

Case 1: The defense structure is located on steep scree slopes with big blocks (Fig. 2). Blocks can start to slip. The impact energies are usually from negligible to small (<20 kJ).

Figure 2. Case 1: The avalanche starting zone consists of a steep scree slope where rockfall may occur.

Case 2: In starting zones with rockfaces (height <20 m) constructed acc. to the Guideline Defense structures in avalanche starting zones (Margreth 2007), rockfall problems can occur (Fig. 3). The impact energies are typically small to medium in size (<100-200 kJ).

Figure 3. Case 2: Within the starting zone Rietstöckli (Linthal GL) are rock cliffs with heights of less than 20 m.

Case 3: Above the avalanche starting zone is a steep, high rockface more than 20 m. Falling stones define a hazard particularly for the top line (Fig. 4). The impact energy can be very large (>> 100-200 kJ).

Figure 4. Above the uppermost lines of snow nets is a cliff with a height of more than 50 m from which rockfall can occur. The snow net is heavily filled with caught blocks (Location: Hahnenspiel FL).

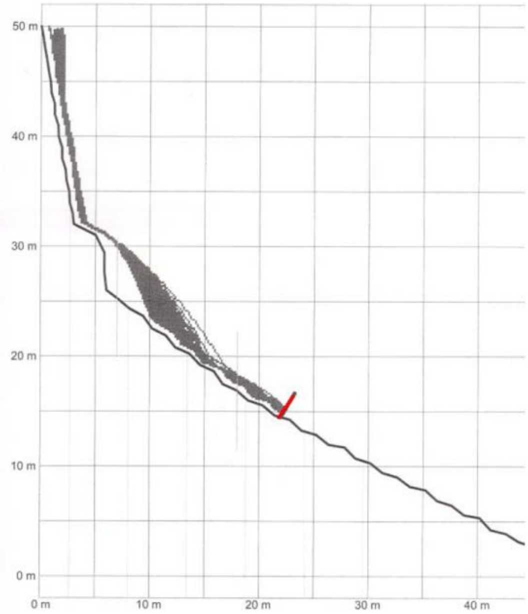

Figure 5. Rockfall simulation for the location Hahnenspiel FL.

3 COMMON PRACTICE

Different solutions and practice are in use to protect defense structures in the avalanche starting zone from rockfall. Depending on the expected impact energy, different types of rockfall barriers, snow nets or even wood reinforced rigid systems are common for the upper most lines where rockfall most likely occur.

Small energies up to 50 kJ can be absorbed by rigid systems and for snow nets a capacity of 150-200 kJ is possible without significant damages (Margreth 2006a). For energies above 200 kJ rockfall barriers have been used until now. But those rockfall barriers are heavily loaded by snow pressure during winter time. However rockfall barriers are not specially designed for that load cases. The requirements for the barriers can be even higher for snow pressure than for the rockfall impact they are designed for. Therefore different technical adaptions are necessary to improve the behavior of the barrier to withstand the high snow pressure loads e.g. reduced post spacing, reinforced post foundations, stronger retaining ropes and brake elements. Especially the brake elements in the ropes can be activated during winter and cannot work properly in a later rockfall event after snow melt. Additionally the adaptions can worsen the behavior in a rockfall event and decrease the rockfall capacity in some cases (Fig. 6).

Figure 6. Rockfall barrier above an avalanche defense structure. Most of the blocks were stopped by the rockfall barrier.

4 DEVELOPMENT

Depending on project specific requirements it is more and more desirable to install systems with the standard setup and a relatively high energy absorption capacity without brake elements. This is to keep maintenance costs at a minimum for projects as described with combined loadings from snow and rockfall. Thus Geobrugg AG has started a research project to find out the capacity of the standardized SPIDER Avalanche system and to achieve an energy absorption capacity of 500 kJ with a minimum of technical adaptations. 1:1 full scale field tests have proven a capacity of 500 kJ without changing the geometry or anchor positions compared to the approved snow net (Fig. 7).

Figure 7. 1:1 field test with 500 kJ on a SPIDER Avalanche System performed at Dynamic Test Center DTC in Vauffelin, Switzerland.

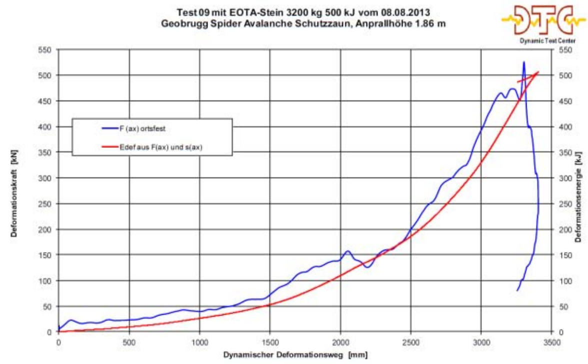

Figure 8. Energy absorption during the 500 kJ test (Graph DTC AG)

The tested standardized SPIDER Avalanche system consists of the same components as the classical snow net however with a spiral rope net with a load capacity of 220 kN/m' instead of the triangularly shaped wire rope nets with fixed connections. The achieved energy absorption capacity was slightly above 400 kJ.

Furthermore the system was tested with a spiral rope net with load capacity of 360 kN/m'. For this setup an energy absorption capacity of 500 kJ was proven without any failure (see figure 8).

The net itself is made out of high tensile spiral rope strands consisting of 3 or 4 wires depending on the strength of the mesh with 4 mm diameter each. Figure 9 is showing the geometry with rhomboidal shape. Main load direction is vertical along the shape y.

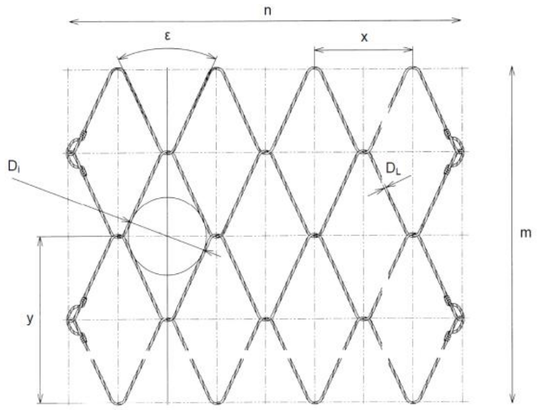

Figure 9. Geometry SPIDER Net (Data sheet SPIDER S3 -130)

Table 1 gives an overview on the rockfall capacities of different structures to classify the systems. As an addition we are highlighting rigid and flexible avalanche barriers in the starting zone in relation to their energy absorption capacity. Rigid avalanche barriers according to Margreth 2006a can withstand up to 50 kJ and flexible SPIDER Avalanche snow net systems with small adaptation up to 500 kJ according to the performed 1:1 field test.

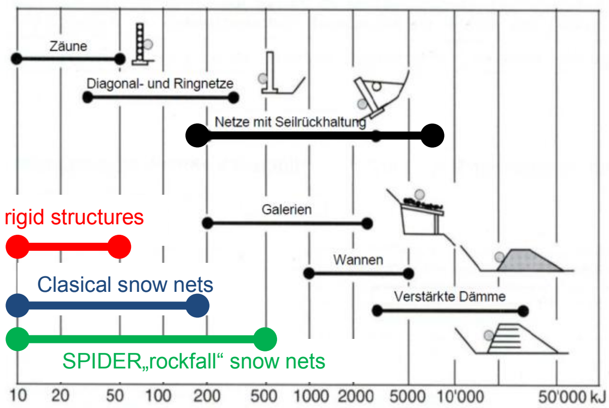

Table 1: Alignment of different systems (Amended picture ASTRA 2003)

5 CONCLUSION

For avalanche prevention systems in the starting zone maintenance costs are a regular budget part for communities. Thus it is desirable to design and install systems specifically adapted to the requirements. In many cases avalanche barriers are installed on talus scree below rock faces leading to snow pressure and rockfall. Rigid avalanche barriers have a limited energy absorption capacity of up to 50 kJ. Therefore damages caused by rockfall often occur because the impact energies of rockfall at the structure location is bigger than 50 kJ (Margreth 2006a). Practical experience with classical snow nets have shown an energy capacity of 200 kJ. We can now prove the energy absorption capacity of our standard homologated SPIDER Avalanche system of up to 400 kJ and with a slightly amended SPIDER Avalanche system of up to 500 kJ. These technical improvements will help to minimize the maintenance costs of avalanche prevention barriers loaded by rockfall and snow pressure.

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