Investigation on the effectiveness of the catch-fence "Snowcatcher" as avalanche protection system

Lambert Rammer[1*], Gernot Stelzer[2] and Martin Kern[1]
[1] Federal Research and training Center for Forests, Natural Hazards and Landscape (BFW), Institute of Natural Hazard and Alpine Timberline, Austria.
[2] Trumer Schutzbauten GmbH, Weissenbach 106, 5431 Kuchl, Austria,

ABSTRACT: To date, the only available structures for mitigating avalanches in motion in the track or run-out zones of avalanches have been rigid structures such as dams or walls. Described herein, a more flexible, cost-efficient and space-saving solution has now been developed that is deemed a "Snowcatcher".

The Snowcatcher consists of the highly flexible Omega-Net, bearing ropes, steel beam posts and energy dissipating devices. These primary components are all known from their use in dynamic rockfall protection barriers. The foundation of the system is realized using mono bar anchors. To investigate the effectiveness of these systems, a research project was initiated in 2008 for which a test site was built in an avalanche track in the ski area of Lech, Austria. A Snowcatcher system was installed with various force sensors throughout the structure to monitor forces during an event.

Prior to the release of an avalanche through explosives, the slope is scanned using a laser and again after the event. In addition, a radar system is used to record the velocities during the avalanche.

In this paper, the test site, the Snowcatcher system and the results from the first winter of tests (8 avalanches in total) is discussed.

KEYWORDS: avalanche protective structure, snow net system, force measurements,

1 INTRODUCTION

Permanent protective defense structures, such as snow bridges, installed in the starting zones are used extensively in the alpine region as they provide the maximum possible protection against avalanches, preventing avalanches to release. At the same time, they have a significant impact on the natural scenery in the Alps. Similarly, rigid structures in the run-out zones are often large and obtrusive. The number of such structures has increased over the years due not only to the rigorous compulsory constraints but also to the degree of land use. From the economic point of view, the installation of defense structures in the starting zone becomes prohibitive for small projects due to cost and ecological issues. Thus a need for an alternative permanent protective measure, in areas of lower risk arises.

To address this issue, a new protective structure called a "Snowcatcher" was developed and is presented. The ambition of the design is to bridge the gap between the traditional cost-intensive protection measures in the starting zone and the space-intensive rigid structures of the avalanche track or the run-out zone, while at the same time remaining cost effective, space saving and ecologically agreeable.

To date, there have been no fundamental investigations carried out on the effectiveness of such a snow catching system in an avalanche path. The research conducted and described herein focuses on experiments both in the field and laboratory with the goal to characterize the interaction of the net system with avalanches. Full scale experiments are conducted by the installation of a Snowcatcher in an avalanche path and through artificially triggering events several times during the winter season. Model tests are preformed in an especially engineered chute.

Figure 1. The Snowcatcher test site. Red circle middle: test net system, right: measurement shelter.

Corresponding author address: Lambert Rammer, Federal Research and training Center for Forests, Natural Hazards and Landscape (BFW)
Rennweg 1, 6020 Innsbruck, Austria
tel: +43 512 573933 5105;
fax: +43 512 573933 5250;

2 SELECTION OF THE TEST SITE

2.1 Field investigations

The test site is located on the southeastern exposed slope of Mohnenfluh Mountain (fig. 1), in the ski resort of Lech, Austria. The site was inspected during partial snow cover in June, 2008 and under completely snow-free conditions in July, 2008. Four avalanche release areas were subsequently identified and mapped.

2.2 Terrestrial laser scan of the summer terrain

A terrestrial laser scanner was used to create a digital terrain model of the site with a resolution of 1 metre. Seven reflectors were installed for use as reference points. The data obtained forms the basis for the calculation of the variation of snow depths throughout the winter.

2.3 Avalanche simulation with SAMOS

For various release scenarios, numerical avalanche simulations with SAMOS were performed on the digital terrain model of the slope to estimate the prospective flow depths, velocities and avalanche paths, (fig. 2). The information received from the simulations served for both fixing the optimal position of the test net as well as for the static calculation of the structure.

3 DESIGN OF THE “SNOWCATCHER”

An avalanche pressure of 50 kN/m²,assumed distributed over the entire net area of the structure, was used as the design event for the structural analysis of the snow net system. The Snowcatcher, (fig. 3), consists of the main components as follows:

- Omega-Net: serves as catching net. The permeability depends on the chosen mesh size.

- Supporting cables: span the net and dissipate the forces to the supporting structures and to the anchors at the periphery of the system.

- Energy dissipating devices: to confine the tension forces in the supporting cables and diverted to the anchors.

- Supporting structures: λ- shaped three hinge frame laterally stabilised with guy ropes.

- Anchorage: drilled and grouted anchors, type IBO R51.

Figure 3. The Snowcatcher structure.

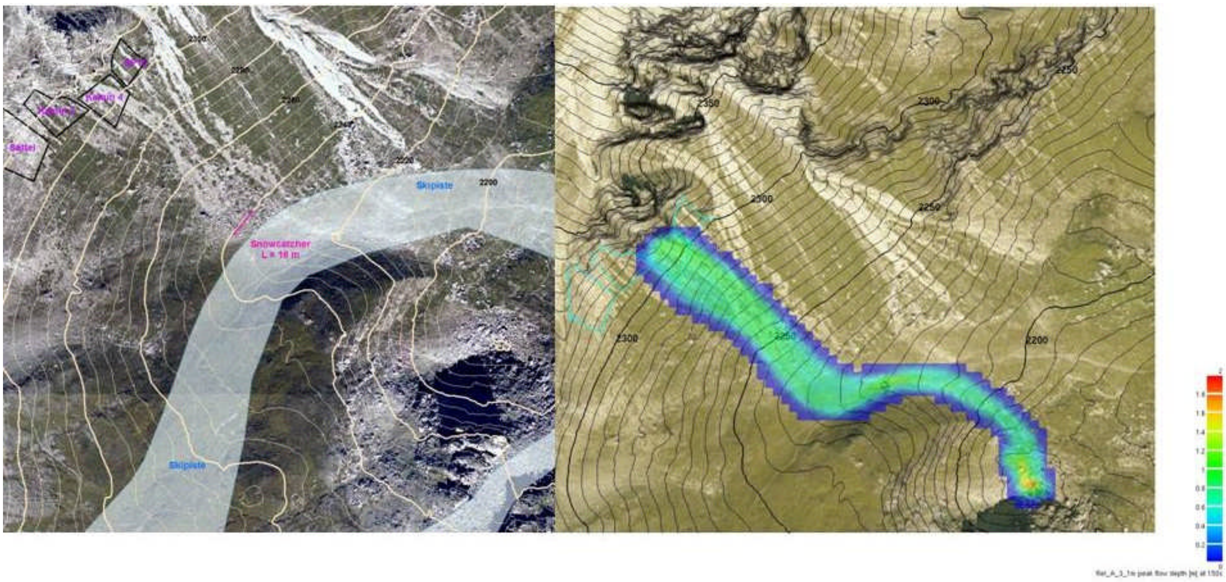

Figure 2. Left: Avalanche slope with installed Snowcatcher, grey area is a ski piste. Right: avalanche track and flow depths calculated with SAMOS.

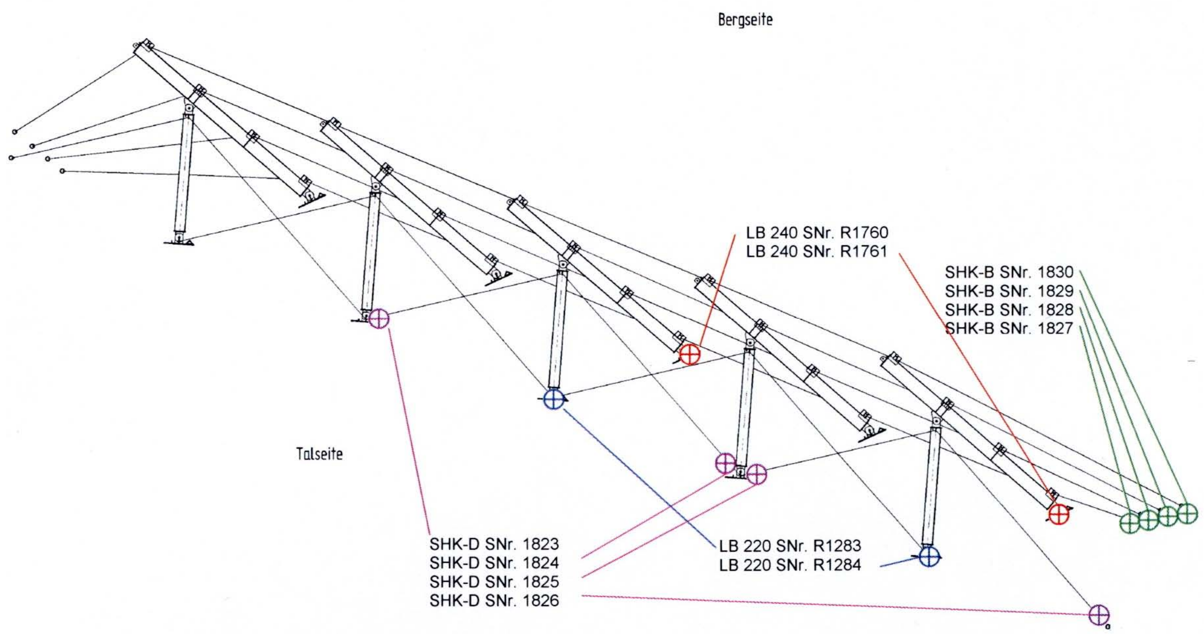

Figure 4. Position of the sensors in the Snowcatcher structure: LB 240 SNr. xxxxx: axial and transversal forces at the base of the girder of the support frames, LB 220 SNr xxxxx: axial forces in the columns, SHK-B SNr. xxxx: tension forces in the support cables, SHK-D SNr. xxxx: Tension forces in the guy ropes.

4 INSTRUMENTATION

The middle support frame and the edge support frame, orographic left, are equipped at the base points with load measuring pins. At the girders, the axial and transversal downstream forces are recorded while at the columns only the axial forces are measured.

Intstrumented shackles are connected at each of the four supporting cables in order to measure tension forces. In the same way, the tension forces of the guy ropes from the monitored columns of the support frames is measured, (fig. 4).

The measuring center is installed in a stainless steel case that is positioned in a well casing in the ground below the net. It consists of two data loggers Campbell CR1000 for signal recording and a GSM modem for data transfer. The sample rate is 20 Hz. Recording is triggered when the force in the columns exceed a certain trigger level. After logging 3500 measuring cycles, the equipment switches to its standby mode and is again ready for the next avalanche event to be recorded.

On a crest opposite the test site, a small container is set up on which two solar panels for the power supply of the measuring center are positioned.

5 MODEL TESTS

A new chute was designed in order to perform model tests. It is equipped with optical sensors for velocity measurements, as well as three video cameras and one high speed camera.

Various tests were conducted to determine the applicability of different model materials, ranging from wood balls to Ppolystyrol balls, to find the best interaction with ambient air. Satisfactory results were obtained using Neopor balls, a special antistatic graphite-foam-plastic material.

6 MEASUREMENTS

6.1 Results of force measurements at the test structure Snowcatcher

During the winter 2008/09, a total of nine avalanche events at the test site were recorded, (fig. 5). Some avalanches were released artificially by means of explosives, while others were naturally occurring events. The measurements of the forces recorded in the test net system during the avalanche impact were successfully logged by the automatic measuring system. Figure 6 shows the time dependent devolution of the forces recorded at the Snowcatcher during the major avalanche event that occurred on April 5th, 2009. Even though the net system was completely filled up, no avalanche snow reached the ski track passing near downstream side of the system. The range of the recorded forces was at maximum 10% of the measurement range of the installed sensors.

Figure 5. Filled up Snowcatcher after an avalanche event.

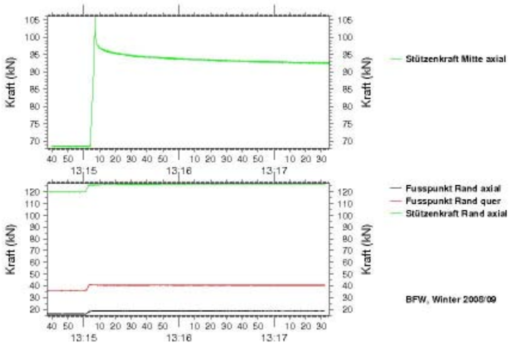

Figure 6. Force measurements during avalanche impact at the test net system.

6.2 Measurements with laserscanner at the Snowcatcher test site

During tests with artificially released avalanches, it is planned that the snow cover surface both before and after the event is scanned and the snow depth difference calculated. Two tests were carried out in the winter of 2008/09, but in both cases the laser scanning was unsuccessful. On the first date, the sight conditions changed and no scanning was possible, while on the second date the temperature was below -15°C which prevented the instrument from functioning.

6.3 Measurements with radar at the Snowcatcher test site

Velocity measurements using a pulsed Doppler radar are taken during the artificially released avalanche events. The radar is capable of taking velocity readings in the avalanche track with a spatial resolution in the flow direction of 25 m. Unfortunately, at both of the two tests, an insufficiently large avalanche was released so that only velocities of marginal parts of the avalanches could be measured.

6.4 Measurements in the lab chute

To make analysis of the mode of action of the Snowcatcher, a model in the scale of 1:50 was mounted in the chute, (fig. 7).

By means of high speed video recordings it can be shown that the front of the model avalanche first interfuses the mesh. Over the duration of the avalanche movement, a splitting in interfusing flow and over the net system diverted flow takes place, (fig. 8).

In particular the 2D velocity pattern of the model avalanche during the impact on the Snowcatcher model could be evaluated by means of correlation of subsequent video frames.

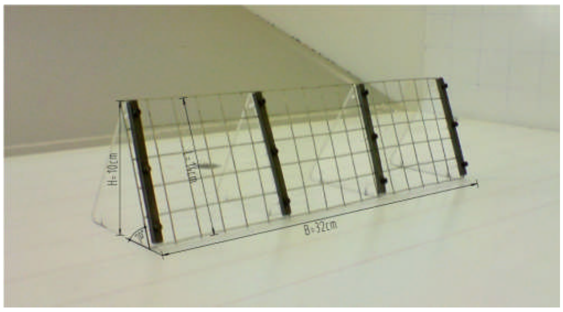

Figure 7. Model of the Snowcatcher mounted in the chute.

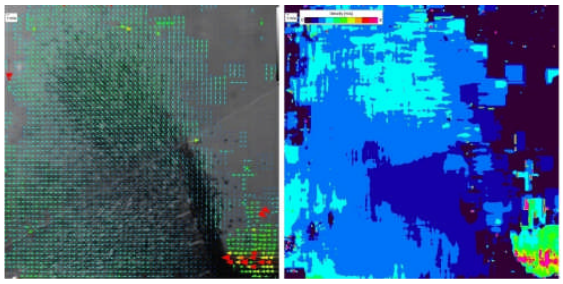

Figure 8. left: Flow behaviour at time of the impact on the model, right: 2D velocity pattern of the model avalanche during the impact

7 CONCLUSION

The primary intention of this investigation is the quantification of the effectiveness of the Snowcatcher. The initial goals set are to measure both the loading of the structure and of the anchors. These results are intended to serve as the basis for the dimensioning and improvement of the structure. Furthermore, the optimisation of the Omega-net must be carried out. In three project-winters, it is intended that the optimum mesh aperture and the tension of the wire ropes is found that are best suitable to achieve the highest dissipation effects.

With regards to the inclination of the net area, a compromise must be found that optimally reconciles the requirements of effectiveness and user friendliness: Note that the area above and below the net must be cleared after an avalanche impact to ensure full effectiveness of the system.

The results of the measurements over the past winter indicate that the loads induced by the avalanches are, up until now, far below the design loads. At the same time, the model experiments with the scaled Snowcatcher are promising in terms of the energy dissipation. On both fronts, much more data is required to draw any conclusions and upcoming tests are greatly anticipated.

8 REFERENCES

Baillifard, M.-A., 2007. Interaction between snow avalanches and catching dams, PhD thesis, ETH Zürich, Zürich.

CADZIE Final Report, 2003: Deliverables. Faug, T., Hákonardóttir, K.M., Johannesson, T., Kern, M. Lachamp, P., Naaim, M., Tiefenbacher, F., Vila, L.P., Bartelt, P. (Wp Leader) WP2: Interaction between defence structures and dense flow avalanches

Bacher,. M., Frey, P., Heiligenstein, L., Kleemayr, K., Naaim, M., Ousset, F., Sampl, P., Swoboda, K., Naaim, F. (WP Leader) Interaction of powder avalanches with defence structures

Chu, T., McClung, D., Ngun,R. und R. Sherkat, 1995: Experiments on granular flows to predict avalanche runup. Can. Geotech. J., 32(2), 285-295.

Faug, T., Naaim, M. und F. Naaim-Bouvet, 2004: Experimental and numerical study of granular flow and fence interaction. In: Annals of Glaciology, 38.

Faug, T., Naaim, M., Bertrand, D., Lachamp, P. und F. Naaim-Bouvet, 2003: Varying dam height to shorten the run-out of dense avalanche flows: developing a scaling law from laboratory experiments. Surv. Geophys., 24(5-6), 569-585.

Faug, T., Lachamp, P. und M. Naaim, 2002: Experimental investigation on steady granular flows interacting with an obstacle down an inclined channel: study oft he dead zone upstream from the obstacle. Application to interaction between dense snow avalanches and defence structures. Nat. Hazards Earth System Sci. 2 (3-4), 187-191.

Kapeller, G., 2006: Experimentelle Untersuchung turbulenter Fließlawinen. Diplomarbeit. Leopold-Franzens Universität Innsbruck.

Kögl, J., 2009. Simulation von turbulenten Fließlawinen im physikalischen Modell. Diplomarbeit, Universität Innsbruck, Fakultät für für Bauingenieurwissenschaften.

McClung, D und P. Schaerer, 1993: The Avalanche Handbook, Seattle, WA: The Mountaineers.