Snowcatcher – full-scale test site in the Stubai Valley

Engelbert Gleirscher[1,2]*, Gernot Stelzer[3], Daniel Illmer[2], Ahren Bichler[4]

[1] *Austrian Research Centre for Forests (BFW), Rennweg 1, 6020 Innsbruck, AUSTRIA*
[2] *Ingenieurbüro Illmer Daniel e.U., Industriegelände Zone C11, 6166 Fulpmes, AUSTRIA*
[3] *Trumer Schutzbauten GmbH, Weissenbach 106, 5431 Kuchl, AUSTRIA*
[4] *Trumer Schutzbauten Canada Ltd., 720-999 West Broadway, Vancouver, CANADA*

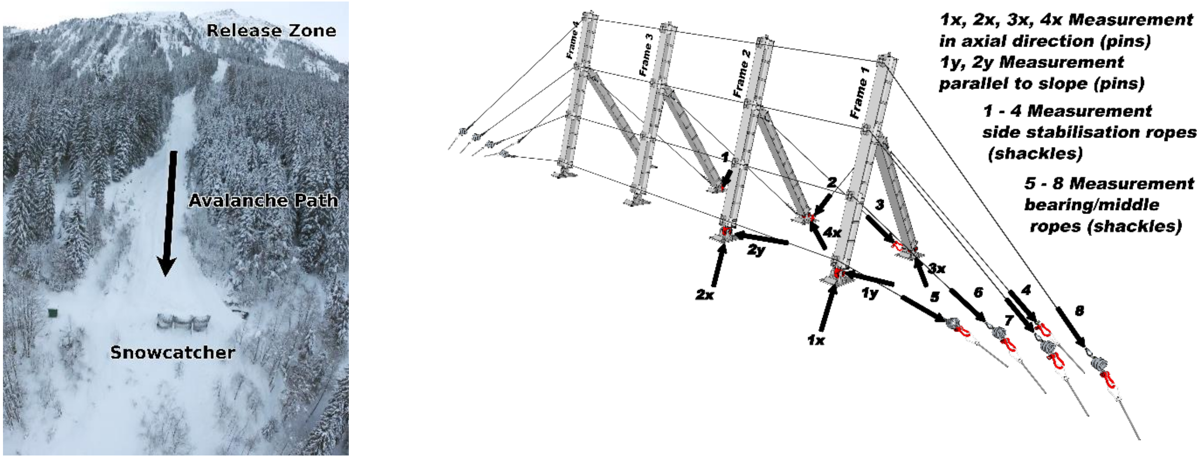
**Corresponding author, e-mail: engelbert.gleirscher@bfw.gv.at*

ABSTRACT

Avalanche protection structures such as snow bridges, rakes and nets in release zones, as well as dams for catchment or deflecting structures in run-out and deposition zones, have been successfully employed for many years. More recently, the idea of using flexible-net catchment fences as lightweight, space saving and economic alternatives, aimed at shortening the run-out distance of avalanches, has been proposed. A full-scale structure, the so-called Snowcatcher, was installed and instrumented with several load measuring pins, which record the dynamic forces caused by an avalanche. Two avalanche events were recorded and allow to investigate the temporal force evolution and observed peak values. The results indicate significant differences in the measurement results. It appears that the difference in size and structure-avalanche interaction, as well as the existence of debris material in the avalanche flow is of major importance for the observed forces. This additional debris material blocks the net surface, making it impermeable and prevent snow particles from passing the net surface. Further the debris – structure impact leads to peak forces that may damage parts of the structure.

1. INTRODUCTION

Permanent avalanche mitigation measures are either constructed in the release zone (e.g. snow bridges) or in the lower avalanche path/runout zone (e.g. dams) (Rudolf-Miklau and Sauermoser, 2011; Pudasaini and Hutter, 2007). Under certain topographical conditions one advantage of constructing measures in the runout zone, as opposed to the release zone, is the possible reduction of construction lengths, due to an often smaller avalanche width in the path. This has a major impact on the project implementation, especially with regard to space and time savings, resulting in lower construction costs and often less ecological impact. At present, the most common method of retarding an avalanche in motion are avalanche protection dams, which were subject to several scientific studies (e.g. Baillifard, 2007; Domaas et al., 2002; Hákonardóttir, 2004; Jóhannesson et al., 2009). Flexible rope nets for the protection against rockfall are common and have previously been investigated, (Gottardi and Govoni, 2010; Peila and Ronco, 2009; Volkwein, 2005). While rockfall nets are optimized to absorb high punctual impact energies, avalanche pressure acts over a much larger area and longer time period (Margreth and Roth, 2008). Therefore, results from rockfall and avalanche experiments on flexible wire rope nets can hardly be compared to each other. A mitigation barrier against debris flows constructed with supporting frames, similar to the prototype presented here, is described in Bichler et al. (2012). Herein a new mitigation measure against avalanches is proposed. For areas endangered by smaller avalanches the Snowcatcher presents a viable alternative to avalanche



(a) Avalanche path

(b) Positions of measurement devices and force directions.

Figure 1: Test site overview

dams using flexible wire rope nets. Therefore, a full-scale prototype of the Snowcatcher was instrumented with several load measuring pins, which record the dynamic loads caused by an avalanche. The motivation of the measurements is (i) to investigate the resulting forces in the structure due to an avalanche and (ii) to observe the influence of net structure on the avalanche flow.

2. SNOWCATCHER TESTSITE

Since a major goal of our project is to analyse the effectiveness of a new protection measure against avalanches in motion, a location that meets several requirements had to be found. An avalanche path in the Stubai Valley (approx. 35 km from Innsbruck) was considered as location with advantages regarding avalanche frequency, avalanche size and reachability in winter. The location of the Snowcatcher allows easy access, being close to a forest road on 1300 masl in a narrow east-facing avalanche path, see *Figure 1*. The release zone of the avalanche is between 2000 and 2400 masl which leads to a vertical gap larger than 700 m. The release volumes of expected avalanches are in a range up to 35.000 m^3 corresponding up to a destructive size 3-4.

2.1 Snowcatcher Structure

The prototype of the Snowcatcher was designed to withstand impact pressures up to 50 kN/m^2, which corresponds to an avalanche simulation with a release volume of 7000 m^3 and a snow density of 300 kg/m^3. The structure of the Snowcatcher consists of the following parts:

- Omega-Net: This structural element catches the avalanche. It is a specially braided net with a mesh size of 185 mm and a wire diameter of 9 mm.
- Ropes: Bearing and middle ropes stretch the net and redirect forces from the structure to the lateral anchors. Side stabilisation ropes account for the lateral stability of the structure.
- Brake elements: They expand at a certain force level and limit the load in ropes and anchors during an avalanche event.
- Supporting structure: It is constructed as a three-hinged frame in the form of a λ, called “Lambda Frame”.
- Anchors: Hollow bar anchors IBO R51 were used to transmit loads from ropes and frames into the ground. The length of each anchor is approximately 9 m.

(a) incoming avalanche *(b) interaction with structure* *(c) avalanche deposit*

Figure 2: A sequence of the powder avalanche from 2019-01-13

Four Lambda Frames are installed with 4 m spacing, resulting in an overall width of the Snowcatcher of 12 m. The height of the net supporting beam is 5.3 m and the angle of the beam to the terrain is 85°, whereas the terrain angle is 25°. Lower angles between net surface and terrain reduce the effective height of the system and complicate the snow removal of avalanche deposits in the Snowcatcher. In contrast to currently used net structures, the Snowcatcher doesn’t have upslope retaining ropes, what allows the emptying of the deposit volume with machinery during the season.

2.2 Instrumentation

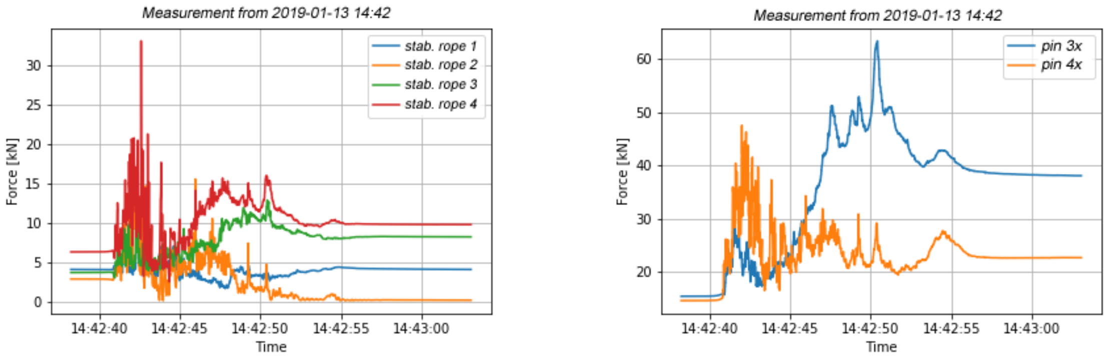
Several load measurement devices are installed in the system to record dynamic forces exerted by an avalanche. Two Lambda Frames of the structure (frame #1 at the edge and frame #2 in the middle) are instrumented with load measurement pins (four pieces) similarly to the set up of Rainer et al. (2008). The arrows (*Figure 1*b) indicate the direction of the force measurement in the Snowcatcher. eight shackles record tension forces in selected ropes of the system. Data loggers with a rate of 100 Hz collect the data from all sensors. Further two cameras are installed to record the avalanche interaction with the Snowcatcher. Camera #1 is situated 30 m lateral to the structure and camera #2 is placed in a distance of 250 m. The recording frame rate of both cameras is 100 fps.

3. AVALANCHE EVENTS

In this contribution we focus on 2 different avalanches that occurred in an avalanche cycle in January 2019. One avalanche occurred on 2019-01-13 at 14:42 and the other one the following morning 2019-01-14 at 4:34. The avalanches differ in size, related volume and the interaction with the structure. This includes the direction of impact and the interacting cross section which specifically depend on the change of the flow path due to previous deposits.

3.1 Avalanche Event 2019-01-13 14:42

After a heavy snow fall an avalanche release led to a powder snow avalanche that hit the Snowcatcher, see *Figure 2*. The maximal tension force in the ropes reached a value of 33 kN (*Figure 3*a). The highest compression forces were measured in pin #3 at the foot of the bracer of the Lambda Frame #1. Here forces raised to a value of 63 kN (*Figure 3*b). The videos of camera 1 indicate a front velocity of 25 – 30 m/s before the powder cloud hit the Snowcatcher. Turbulences and a side passing suspended snow leads to a bad visibility and therefore the assessment of the velocity after the interaction with the Snowcatcher is not possible. Nevertheless, the video of camera #2 shows a deflecting and retarding effect of the structure to the avalanche. The pictures indicate that the net surface remained permeable, leading to particles passing the net surface. This is in correspondence to the results of laboratory



(a) tension forces in the side stabilisation ropes

(b) compression force in the bracer (Lambda Frame)

Figure 3: Force measurements of the powder avalanche event 2019-01-13

experiments performed by Gleirscher and Fischer (2013). During the event the electric chord of shackle #5 was damaged, hence no measurement of this device exists. The volume of the avalanche deposit is estimated to approximately 1000 m³ which corresponds to an avalanche size 2.

3.2 Avalanche Event 2019-01-14 4:34

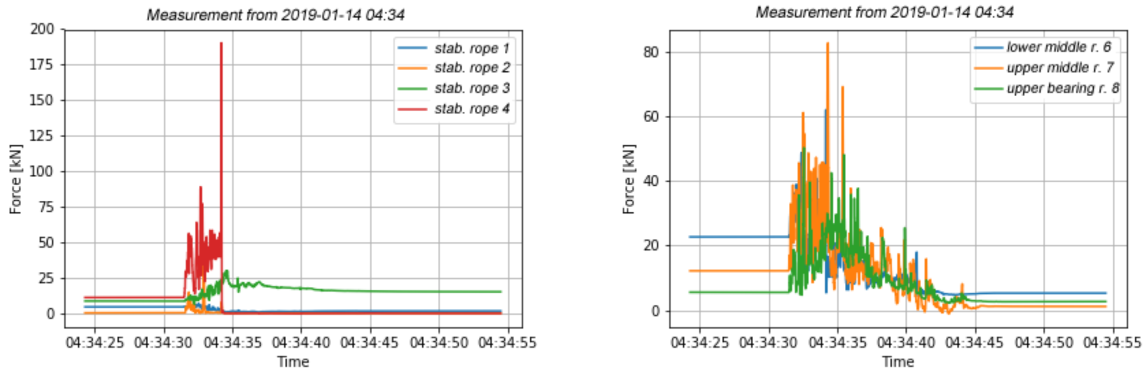
This avalanche event happened in the early morning. Due to the darkness at this time no video data is available. The deposit volume is estimated to approximately 5000 m³, indicating a destructive size of 3 and therefore a bigger size than the avalanche characterized in 3.1. Further the deposit of this avalanche shows many branches that block the permeable net surface *(Figure 4)*. The maximal deformation of the Omega-Net was observed in the field between frame #1 and frame #2 and the maximal force occurred in frame #2, leading to the assumption that here the avalanche had the biggest impact. The maximal tension force in the side stabilisation ropes reached a value of 190 kN and for bearing/middle ropes a value of 83 kN. While the bearing/middle ropes are equipped with braking elements, limiting the forces in these ropes, the side stabilisation ropes are fixed without braking elements. During the avalanche event, the side stabilisation rope #4 broke probably due to an interaction with a trunk. Immediately before the fracture the measurement in this rope indicates a force increase from 40 kN to 190 kN in between 10 milliseconds *(Figure 5a)*. 83 kN was the maximum value of the forces recorded in the bearing/middle ropes *(Figure 5b)*. The measurements in the pins #1 and #2 show similar courses *(Figure 5c)*. The axial force has a negative sign, which indicates a tension force in the beam. The values in pin #1 (referring to frame #1, see *Figure 3*) are considerably higher than in pin #2. Highest values in axial- and slope parallel-direction are -142 kN and 137 kN in pin #1. *Figure 5d* indicates a remarkable higher compression force (298 kN)in pin #4 referring to frame #2 than in pin #3 (174 kN) referring to frame #1. This effect might ascribe to a higher force application point in frame #2 than in frame #1.

4. RESULTS AND OUTLOOK

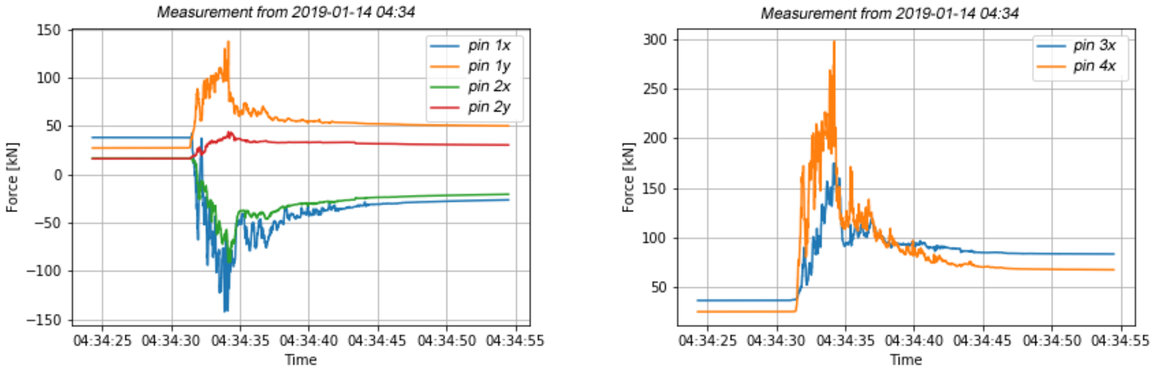
This study is an attempt to better understand the interaction of snow avalanches with flexible net structures. A prototype of a new mitigation measure with several load measuring pins was installed in an avalanche path to record forces during an avalanche event. We want to provide a first step in analyzing the forces acting in parts of a mitigation structure that could be a novel

(a) branches in the net *(b) deposit of the avalanche*

Figure 4: The test site after the avalanche event from 2019-01-14



(a) tension forces in the side stabilisation ropes *(b) tension forces in the bearing/middle ropes*



(c) axial, slope parallel forces in pin 1 and 2 *(d) axial forces in pin 3 and 4*

Figure 5: Force measurements of the avalanche event 2019-01-14

measure against avalanches. Herein we highlight two avalanches that differ in size and avalanche–structure interaction. The interaction of a powder avalanche (destructive size 2) with the Snowcatcher led to maximal rope forces of 33 kN and to maximal compression forces of 63 kN in the measuring pins, which account for the base plates of the Lambda Frames. Another avalanche event represents a destructive size 3 avalanche. This event led to remarkable higher forces in the structure. Because of that, plastic deformations of parts of the structure were observed: One side stabilisation rope broke probably due to debris impact at a peak load of 190 kN. Further six brake elements were permanently strained. The maximal force at the base plates of the Lambda Frame was recorded in pin #4. The compression force reached a value of 298 kN.

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