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Retarding avalanches in motion with net structures

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ABSTRACT

Steel wire rope nets have become a common protection measure against snow avalanches in Europe, as they can prevent a release in potential starting zones. A novel approach in this context, is to retard the movement of an avalanche after it has been initiated. A full scale structure, the so-called Snowcatcher, was installed and instrumented with several load measuring pins, which record the dynamic loads caused by an avalanche. The motivation of the measurements is to observe the influence of net structures on snow avalanches. In the lab, scaled granular experiments were performed in two set-ups, investigating the influence of i) the net barrier angle and ii) the mesh size of the net. For both set ups various experiments with different chute inclinations were performed. The results from measuring the front velocities and flow depths showed that higher chute angles are accompanied with both, higher flow velocities and Froude numbers. Experiments with different net barrier angles showed that the effectivity increases with higher chute inclinations. Furthermore the results indicate that different barrier angles slightly influence the effectivity, e.g. for small chute inclinations, nets perpendicular to the flow direction lead to lower effectivities than inclined nets. Experiments with different mesh sizes indicate a velocity dependency of the effectivity corresponding to a certain ratio of mesh to grain size. Smaller mesh sizes in the range of the maximal particle grain size lead to an obstruction of the net, acting as a solid barrier and therefore reaching best effectivity, notwithstanding overflows. For large mesh sizes the effectivity of the net barrier increases with a higher velocity of the flow.

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) (Margreth et al., 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. 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; Johannesson et al., 2009). Herein a new system is proposed, using flexible wire rope nets: the Snowcatcher presents a viable alternative to avalanche dams for areas endangered by smaller avalanches. 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 one another. In Wendeler et al. (2006) a test site instrumented with flexible rope nets for debris flow mitigation is presented. A static system without posts is constructed in a narrow gully. Forces on the flexible net are recorded during debris flow events and are compared with numerical simulations. Events showed that the barrier could stop parts of the debris flow. Since debris flows are generally comparable with snow avalanches, such a system could be applied to snow avalanche mitigation (Nicot et al., 2004; Roth et al., 2010). A debris flow mitigation barrier that is constructed with supporting frames, similar to the prototype presented here, is described in Bichler et al. (2012): The barrier is instrumented with load gauges, but no data could be analyzed since no event has occurred to date. In summary it can be stated, that several tests on flexible wire rope nets have been performed and seem to confirm the desired retarding influence on rockfall and debris flow. However, our goal is to analyze the retarding influence of net barriers on granular flows, such as snow avalanches, by comparing a characteristic retardation length in granular experiments. This retardation length is related to the runout length. To our knowledge this topic has not been accounted for in previous works. In the case of snow avalanches only little information is available on the retardation behavior of steel wire rope nets. Therefore a full scale prototype of the Snowcatcher was instrumented with several load measuring pins, which record the dynamic loads

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caused by an avalanche. The main purpose of this setup is to measure normal and shear forces in the net supporting frame and the cable forces. The field tests were limited to force measurements and therefore restricted statements regarding the effectivity of a net barrier with respect to changing net set-ups are available.

Lab experiments were performed to analyze the influence of the net barrier on granular flows. Approved methods, such as velocity measurements and flow depth measurements, were used to carry out scaled granular experiments in order to simulate avalanches in the lab. To date, experiments have mainly been performed to investigate the interaction of granular flows with solid structures. Tai et al. (1999, 2001) and Gray et al. (2003) describe granular flows, deflected by a solid obstacle to protect the area of the Schneefernerhaus at the Zugspitze (Eastern Alps, Germany). Hákonardóttir and Hogg (2005), Faug et al. (2007), Pudasaini et al. (2007) and Pudasaini and Kroener (2008) investigated the interaction between granular flows and deflecting obstacles. They observed an increasing flow depth (run up), where the granular flow hits the obstacle. The experiments on breaking mounds were performed by Hákonardóttir et al. (2001, 2003). It was observed that the mounds dissipate a large proportion of the kinetic energy of the granular flow. In Hauksson et al. (2007) and Cui and Gray (2013), experiments on differently shaped mast-like obstacles were carried out, focusing on the flow behavior in the area around a single mast. Granular flows hitting vertical impermeable obstacles are investigated in Faug et al. (2003, 2004a,b) and Caccamo et al. (2010), where it was shown that the local energy dissipation significantly accounts for the reduction of the runout length. Experiments on net structures were performed by Koegl et al. (2009), Koegl (2009) and Rammer et al. (2009), where the determined energy dissipation is remarkable. However, in these experiments no analysis of runout lengths was carried out, and therefore a further parameter study, which is presented in this paper, was deemed essential. In the current experiments graphite coated plastic granules are used in a 5 m long chute to generate granular flows, representing the dense part of an avalanche. Experiments with varying net mesh sizes, release volumes and chute inclinations are conducted and front velocities and flow depths are measured. In Section 2 the prototype of the Snowcatcher is described and an example of measured forces in a single event is shown. The performed lab experiments are presented in Section 3, while the results are discussed in Section 4.

2. Snowcatcher prototype

The goal of this paper is to better understand the interaction between moving snow and net structures. Field tests are restricted, because the repeatability of events is limited, and the effort of changing the Snowcatcher set-up is high. Notwithstanding these limitations, the data serves as a valuable source for analyzing the dynamic loading of steel net structures in a natural environment. It has been previously observed that rockfall nets were not only able to stop small avalanches, but also that parts of the net structure were damaged in case the snow loads exceeded the rockfall design loads (Margreth and Roth, 2006, 2008). Hence wire rope nets exposed to snow pressure and avalanches need an additional design procedure, accounting for these loads.

Measurements of dynamic forces in net structures due to avalanches are rare, therefore field tests were carried out. A full size prototype of the Snowcatcher was installed above a ski piste in Lech, Austria (Fig. 1). The avalanche path is SE exposed at an altitude of about 2200–2400 m a.s.l. The slope of the release zone is 35–45° and 20° at the position of the Snowcatcher. In contrast to rockfall nets that are constructed with swivel supports, the Snowcatchers supporting structures are made up of frames (Gleirscher et al., 2012; Rammer et al., 2009). Between 2008 and 2012 the installed system recorded data from 34 avalanche events.Based on the information of local experts the position for the Snowcatcher was chosen. The advantage of this site is the possibility of artificial avalanche release by explosives. Computational avalanche simulations with the software SamosAT (Sampl and Zwinger, 2004) showed pressure values in the range of 50 kN/m^2, which is defined as the design load for the Snowcatcher. Anyhow the structure is overdesigned in order to withstand higher pressures in case of larger avalanches. The prototype of the Snowcatcher consists of the following parts (Fig. 2):

- Omega-Net: This is the structure that catches the avalanche. It is a specially braided net, built to resist energies of up to 5000 kJ. The mesh width is in the range of 130–180 mm (red arrows).
- Cables: Bearing and middle ropes stretch the net and redirect forces from the structure to the lateral anchors (blue arrows).
- Brake elements: They expand at a certain force level and limit the load in the cables during an avalanche event (green arrows).

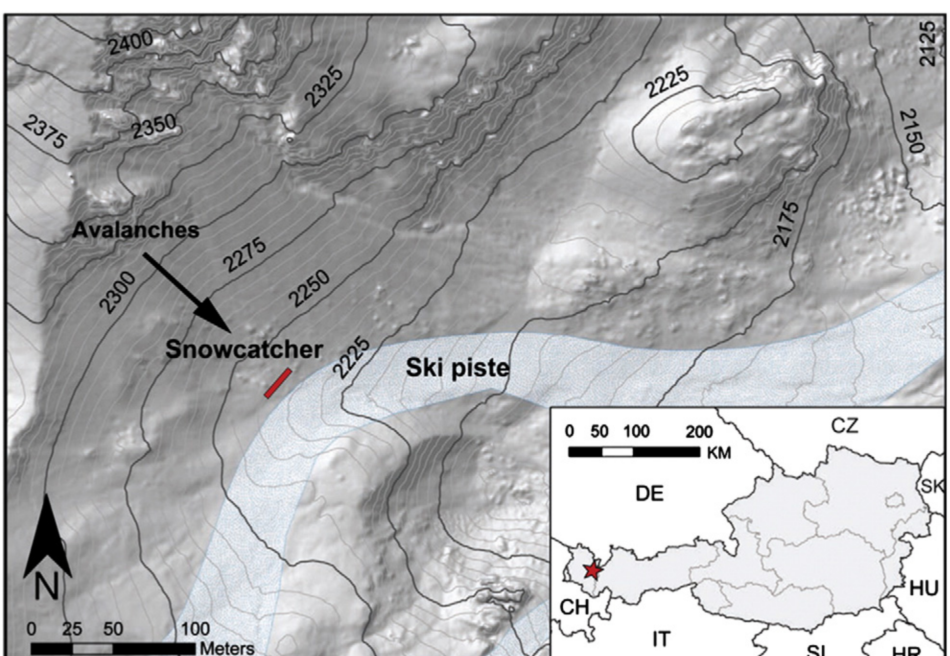

Fig. 1. Location of the test site in Lech.