ARTIFICIAL RELEASE AND DETECTION OF AVALANCHES: MANAGING AVALANCHE RISK ON TRAFFIC INFRASTRUCTURES, A CASE STUDY FROM AUSTRIA

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ABSTRACT: The Austrian state road Paznauntal road B188 is located in the avalanche-exposed Paznaun Valley. Several sections of the road have to be closed regularly due to high avalanche risk. As the main economic activity of the Paznaun Valley is winter tourism and the Paznauntal road B 188 is a very important transport link, closing times of the B188 are very expensive for the region. Therefore, seven avalanche towers and a radar unit were installed for protection of one key section of this road, endangered by two avalanche tracks. For the first time, so called "temporary measures" (artificial release, detection) were implemented for road protection in Austria.

The radar device was placed down in the valley, monitoring the avalanche release area of one avalanche track. The radar is used on the one hand for verification of the actual avalanche release during operations of the towers and on the other hand for detection of spontaneous avalanche activity.

Preliminary results after the first winter showed that the combination of artificial avalanche release with a detection tool could significantly minimize the avalanche risk and closure times of the road. The radar device could detect artificial and spontaneous avalanche activity and set an alarm signal. After a few false alarms at the beginning it became clear that it is necessary to monitor a few days and events to calibrate the automatic detection parameters to the environmental conditions of the observed area.

1 INTRODUCTION

The Paznaun is a 40 km long valley in the southwest of Tyrol (Austria), surrounded by high mountain ridges of the Central Eastern Alps. The main economic activity in the valley is winter tourism and all main villages in the Paznaun (See, Kappl, Ischgl and Galtür) have its own ski resort.

The so-called Paznauntalstrasse (B188) is the main transport link in the valley, connecting the villages and the valley with Vorarlberg in the West and with Tyrol in the East. This road is endangered on several sections by snow avalanches. In the last decade several permanent mitigation measures such as supporting structures, deflecting dams, snowsheds and tunnels have been constructed to minimize the risk. Nevertheless the road has to be closed several times per winter.

This is unfavourable, especially on Saturdays, when several thousands of tourists want to leave or arrive in the valley for their ski holidays.

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In order to minimize the closure times, the community of Ischgl decided in Summer 2011 to initiate a pilot project, for the mitigation of two avalanche paths, endangering the road at the western periphery of the town.

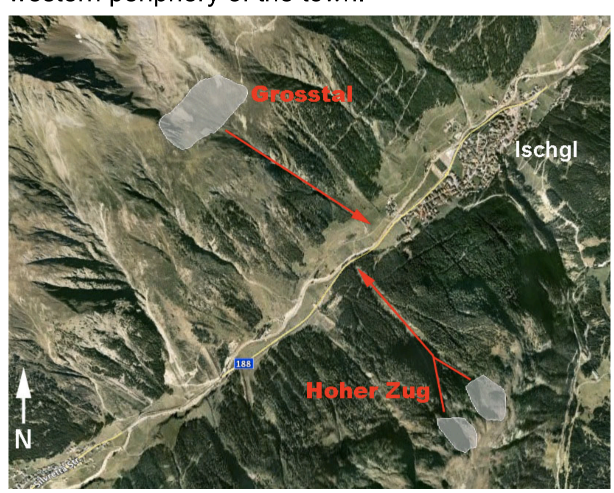

Figure 1: Overview over the „Großtal" and „Hoher Zug" avalanche tracks (red) and the endangered road B188 in the Paznaun valley. (Picture: Google Earth).

The objective of the project was to reduce the closure days of the road due to avalanche risk to a minimum. The Großtal and Hoher Zug avalanche paths (Fig. 1) not only endanger the Paznauntalstrasse B188, but also a local road, a cross-country track and in very rare, extreme situations the edges of the town.

It is well known that permanent mitigation measures have high investment and maintenance costs and constitute a significant impact on the landscape. In recent years the development of new technologies in artificial avalanche release and avalanche detection, enabled attractive alternatives for integral risk management (Rudolf-Miklau and Sauermoser, 2011). Therefore, a combination of artificial avalanche release, using Wyssen avalanche towers and avalanche detection, using radar technology, was installed for the protection of the Paznauntal road (B188). It was the first time, that so called "temporary measures" (artificial release, detection) were implemented for road protection in Austria.

2 WYSSEN AVALANCHE TOWER

Since the terrain at the avalanche starting zones Großtal and Hoher Zug are extremely rough and inaccessible in winter, a remote controlled and reliable system was needed. Furthermore the steep topography demands high efficiency for the release of small portions of snow and a big effective range was needed, allowing a minimum number of installations in the large starting zones. Due to the good experiences in the nearby ski resorts of Ischgl and Galtür with the reliability and the effectiveness of the Wyssen avalanche towers as well as the high service level, the choice felt to this product.

The system (Fig. 2) consists of a simple tower that supports a finger type docking system for a compact magazine that includes 12 charges of up to 5 kg, the control electronics and a transceiver system. For recharging, maintenance and storage during summer the complete module is moved by helicopter to a base station of the operation. Further technical details about the avalanche towers have been reported in Gubler (2002).

From the theory of slab avalanche formation in a dry snow cover as well as from practical experience it is well known that detonations above the snow cover stress the snow over a wider area than those in the snowpack (McClung and Schaerer 2006). The explosive used should detonate at a medium to high detonation speed (approx. 5000 m/s) and produce a large gas volume at a high working factor. Experimental studies showed that these types of explosives and charge positions above the snow surface produce the largest effective ranges (Gubler, 1977). Measurements of the air pressure and the deformation rate in the snow pack showed, that with a charge of 5 kg, the Wyssen avalanche tower has an effective range of 130 m in radius.

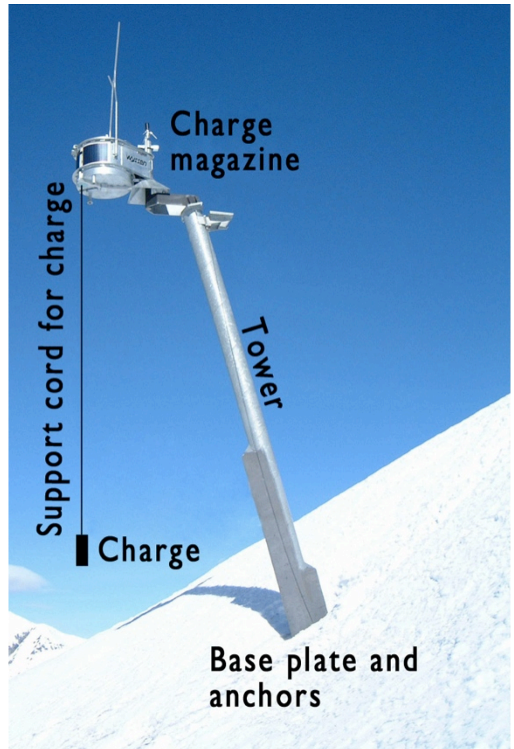

Figure 2: Overview over the Wyssen avalanche tower with the main components highlighted.

3 AVALANCHE RADAR

Even though artificial avalanche release offers an efficient and reliable possibility of avalanche mitigation, for realistic risk assessment, the verification of the actual avalanche release is of crucial importance. In addition, it is essential for the avalanche control team to know about spontaneous avalanche activity, especially under bad weather conditions. Consequently, a radar device for the detection of the avalanche activity was installed and tested within this pilot project. The radar is located in the valley on the opposite site, facing the avalanche release area of the Grosstal avalanche (distance 1.800 m). It is used on the one hand for verification of the actual avalanche release during operation of the towers and on the other hand for detection of spontaneous avalanche activity for road protection.

The device permanently monitors the avalanche track with a Pulsed-Doppler radar, which can reliably detect avalanche activity up to a distance of 2.5 km. In case of the exceedance of threshold values, an alarm is set off. These alerts are transmitted via mobile network as a text message to specific centres (avalanche control team, road patrol, community).

Figure 3: The radar device installed down in the valley facing the Großtal avalanche track in Ischgl, Austria.

The avalanche radar is capable of measuring velocities ranging from one km/h to about 300 km/h. Furthermore it provides the possibility to divide the monitored area into different sections, so-called “range gates” (Fig. 4), which allows in consequence to use only some of the sections for signal analysis. False alarms are significantly reduced by this technique because sections causing a lot of interfering signals can be neglected. Further information about Doppler radar and range gates can be found in Gauer (2007) and Rammer (2007).

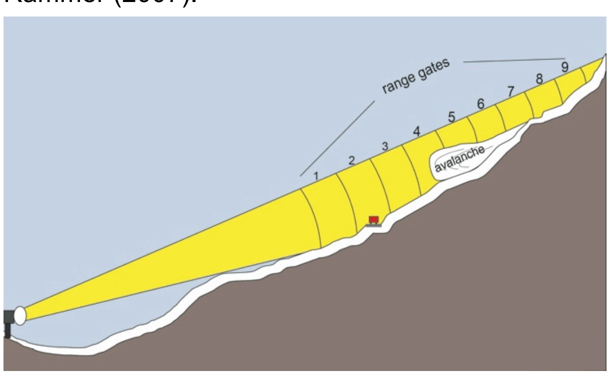

Figure 4: The radar offers the possibility do divide the monitored area into different sections, so called „Range Gates“.

Additionally to the alarm signal, the avalanche control team can visualize the radar data using the corresponding PC software. The software uses the intensity of the reflected radar signal, to give a rough estimate of the avalanche size, depicted by different colors (red to green). In addition the range gates enable the visualization of the avalanche movement down the track.

Restrictions of the avalanche radar are the limited detection distance (max. 2.5 km) and the rather small opening roll of 5°, leading to a 170 m wide stripe monitored.

4 INSTALLATIONS AT GROSSTAL UND HOHER ZUG AVALANCHE

4.1 Grosstal avalanche

The Großtal avalanche path, in the north of the Silvretta road (B188), has a starting zone of about 16 ha. Figure 5 gives an overview of the potential release areas with the position of the five avalanche towers (AT) and the effective range marked in different colors. The main avalanche starting zone is a huge concave cirque (AT1 to AT3) with some steeper gullies in the west (AT4 and AT5). Above AT1 to AT3 the terrain forms a bench with lower incline and consequently no avalanches are expected from this area. The open slope around AT1 to AT3 allows full development of the effective range (r=130 m).

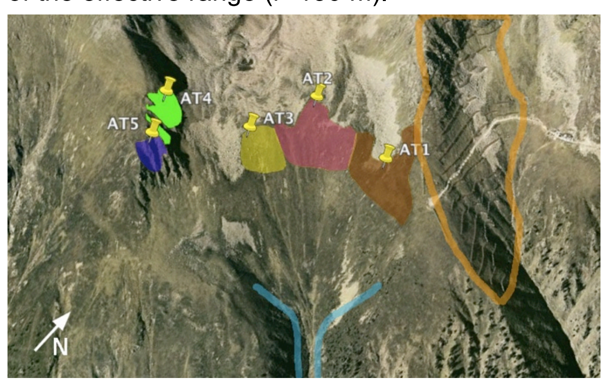

Figure 5: Overview of the five Wyssen avalanche tower (AT) installations at Großtal starting area with effective range indicated in different colors. The blue line marks the channeled avalanche track and the orange margin highlights classic snow bridges in the nearby bowl. (Picture: Google Earth).

The narrow gullies in the west (AT4 and AT5) are separated by ridges, which produce a natural barrier for the stress wave generated by the explosion. Consequently, the avalanche towers have i) to be placed closer together ii) to be placed on the ridge to have a clear line of sight on both sides and iii) higher tower heights in order to cover all areas without shadow zones. Besides analysing the slope inclination, exposition and snow drift, the position of the towers has also been chosen according to experiences made with helicopter bombing in previous years. Pictures taken from the starting zone, after the avalanches released, facilitate the determination of the tower positions. The avalanche track, is a narrow channel, followed by the run out zone down in the valley bottom harming the Silvretta road (B188) (Fig. 6).

4.2 Avalanche radar at Grosstal avalanche

The avalanche radar is installed down in the valley bottom, focused on the starting zone and the upper track of the Großtal avalanche (Fig. 6). It is placed next to a tennis court, which allows power supply by cable and good coverage of mobile network (Fig 3). In addition, the place is easy to reach also in wintertime, which was crucial within this pilot project for control and maintenance. The area monitored by the radar includes the effective range of avalanche towers 2 and 3 (AT2 and AT3 in Fig. 5) and the upper part of the channelled avalanche track (see Fig 6).

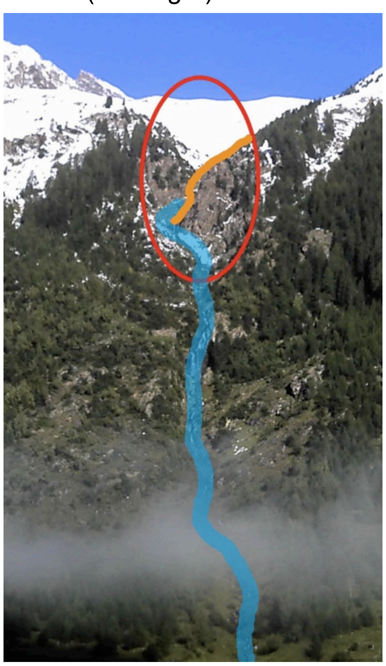

Figure 6: View from the avalanche radar to the Großtal avalanche. The red circle marks the area monitored by the radar. The blue line marks the avalanche channel and the orange line marks a rocky ridge, which is screening part of the channel from the avalanche radar.

Small avalanches triggered by the avalanche towers outside the monitoring area are detected as soon as they reach the channel. This radar configuration gives on the one hand information about smaller avalanche activity in the starting zone and additionally details how far the avalanches flew down the channel. Unfortunately the channel has a S-shape in the lower monitored area, which means that a small part of the channel is in a shadow zone produced by the rocky ridge from the right (marked orange in Fig. 6). In this shadow zone the radar cannot monitor any data, meaning it is “blind” on a small part of the avalanche track.

4.3 Hoher Zug avalanche

On the opposite side, southerly, is the release area of the Hoher Zug avalanche (Fig. 1). Figure 7 gives an overview of the two main starting zones (1.5 ha and 3.5 ha), confluencing to a single channel further down the mountain.

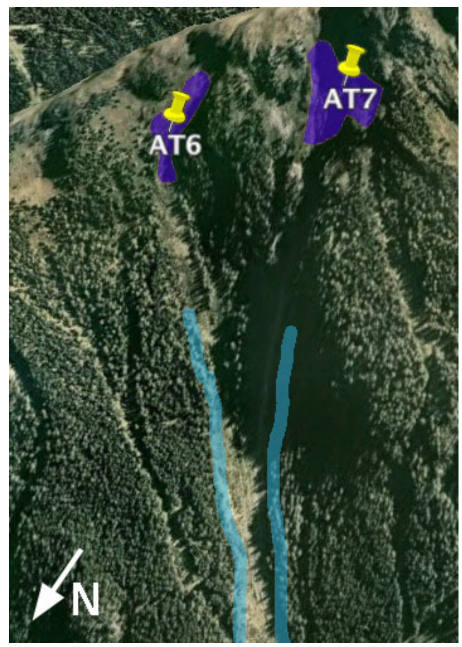

Figure 7: Overview of the two Wyssen avalanche tower (AT) installations at Hoher Zug starting area with effective range indicated in different colors. The channeled avalanche track is marked blue (Picture: Google Earth).

The position of the avalanche towers and the effective range are marked. The two starting zones are open slopes with a slight concave shape, which favour the full development of the effective range of the avalanche towers. As already mentioned above, besides thorough analysis of terrain and snowpack, the position of the towers has also been chosen according to experiences made from helicopter bombing in previous years.

5 EXPERIENCES FROM THE FIRST WINTER

The winter 2011/2012 was characterized by remarkably high snowfalls in Austria, and therefore an evaluation of the installed systems was possible. The Wyssen avalanche towers are by now over 10 years on the market and well known as reliable and efficient avalanche release systems. Also within this pilot project for road protection, the towers were operating dependable, without any problems. Key subject was a well-planned and officially approved concept of operations, including i) definition of minimum and maximum snow heights for artificial release, ii) involved agencies (e.g. avalanche control team, police, community, etc. iii) exposed areas and necessary roadblocks, evacuations etc. and iv) residual risk of the measures.

More attention was focused to the avalanche radar, as this was a new device. At the beginning a few false alarms were sent and we realized that it is necessary to calibrate the automatic detection parameters to the environmental conditions. False alarms were caused by strong winds, producing vortices of snow particles in the starting area of the Grosstal avalanche. The challenge was to define the automatic alarm parameters in a way that they are not triggered by these snow vortices, but that already small, artificially released avalanches are detected. After one month and a few false alarms the radar system was adjusted and worked reliable during the rest of the winter.

The immediate notification (yes/no) of avalanche release via text message and the visualization of the radar data using the corresponding PC software, proved to be a valuable tool for the avalanche control team. In addition, the notification about spontaneous avalanche activity facilitated realistic risk assessment and decision-making weather measures have to be taken or not.

Through detailed post processing of the radar data it is possible to gather a velocity profile of the avalanche along the monitored part of the track. Figure 8 shows the velocity plot (red line) of an avalanche monitored on 15.02.2012 at 7pm in comparison to velocity data gathered from the 2D avalanche simulation model Samos AT (green line). At a horizontal distance of 800 m no radar data is available because a ridge of the mountain is producing a shadow zone, as already explained above in chapter 4 (see also Fig. 6).

The monitored velocity data correlated quite well with the data from the simulation. A few peaks of high velocities are not represented in the simulated data. These preliminary results hint that the avalanche radar could provide useful data for the calibration of avalanche simulation models. Further analysis of the collected data are planned to verify these results.

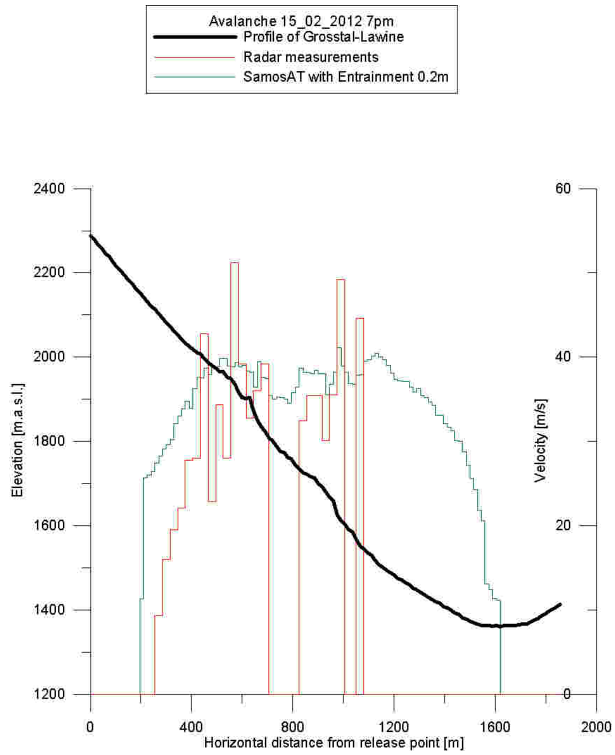

Figure 8: Velocity plot of the radar data (red line), velocity data from Samos AT simulation (green line) and cross section of the Grosstal avalanche path (black line).

6 CONCLUSIONS

The experiences gathered after the first winter showed that the combination of artificial avalanche release using Wyssen avalanche towers and avalanche detection using radar technology could significantly minimize the avalanche risk on the Paznauntal road (B188). This section of the road has not been closed for a single day in the last winter, although snow heights were above average.

The avalanche radar could detect artificial and spontaneous avalanche activity and set an alarm signal. After a few false alarms at the beginning we realized that it is necessary to monitor a few events to calibrate the automatic detection parameters to the environmental conditions of the observed area. However, the avalanche radar showed great potential, providing key information for people being in charge of avalanche control work.

7 REFERENCES

Gauer, P., Kern, M., Kristensen, K., Lied, K., Rammer, L. and Schreiber, H. (2007): On pulsed Doppler radar measurements of avalanches and their implication to avalanche dynamics, Cold Regions Science and Technology, 50, 55–71

Gubler, H. (1977): Artificial release of avalanches by explosives. J. of. Glaciol. Vol 19, Nr. 81, 419 - 429.

Gubler H. and Wyssen S. (2002): Artificial release of avalanches using the remote controlled Wyssen Avalanche Tower, Proceedings: International Snow Science Workshop, Penticton, British Columbia.

McClung, D. and Schaerer, P. (2006): The Avalanche Handbook, The Mountaineers Books

Rammer, L., Kern, M., Gruber, U. and Tiefenbacher, F. (2007): Comparison of avalanche-velocity measurements by means of pulsed Doppler radar, continuous wave radar and optical methods, Cold Regions Science and Technology, 50, 35–54

Rudolf-Miklau F. and Sauermoser S. (2011): Handbuch technischer Lawinenschutz, 1. Auflage, published by Ernst&Sohn GmbH&Co.Kg.