

PASSIVE SOLUTIONS TO IMPROVE THE PROTECTION OF A MISPLACED CHAIRLIFT ENDANGERED BY MAJOR AVALANCHES

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ABSTRACT: Due to an unexplained shift during its construction project in contrast to the avalanche recommendations, The Arcelle chairlift was impacted several times by major avalanches in recent years. A posteriori protection solution based mainly on braking mounds was then developed which has been naturally and positively tested during the Eleanor storm at the beginning of 2018.

KEYWORDS: chairlift station, braking mounds, posteriori protection.

1. INTRODUCTION

The Arcelle 6 person detachable chairlift is located at Val Cenis, a ski resort in the Maurienne Valley (French Alps) close to the Italian border. This lift was erected in 2007 based on usual avalanche analyses which showed that its upper part (including its station) was located close but aside the huge Arcelle avalanche. Initially, the upper station was foreseen at a safe location on an external lateral bump around 2350m asl... but for unclear reasons, was finally built directly within the limit of the suspended valley below the bump! Whereas the initial project was not suspected to be impacted by avalanches under a 100-years return period, the upper station was effectively buried three times during the first 10 years. This led the ski resort management to look for new solutions being stated that the lift itself could not be relocated and should be considered where it is.

2. ARCELLE SITE AND AVALANCHES

This site potentially gathers snow avalanches from different slopes of a large cirque below Signal du Grand Mont Cenis Peak (3377m asl): the highest steep slopes in a very alpine terrain (see Figure 1) are continued by a 200m-wide U-shaped slightly-steep suspended valley.

In the history (for instance in 1983), events reached the very bottom of the Arc Valley around 1500m asl, i.e. more than 2km farther than the top of the lift: so, its station can face a flow in full development phase.

Hopefully, the main starting zones were parallelly equipped with Gazex® exploder systems but which sometimes do not prevent massive ava-

lanches: indeed, Val Cenis location can be particularly subjected to intense snowfalls especially in case of a massive depression fed on the Genoa Gulf of the Mediterranean Sea and coming back to the Alps along the Italy-France border: snowfalls can easily reach more than 1m in 24 hours and even more. Due to its configuration under fresh snow conditions, the Arcelle cirque is also prone to a complete release by transmission of the main fracture line to contiguous slopes and orientations.

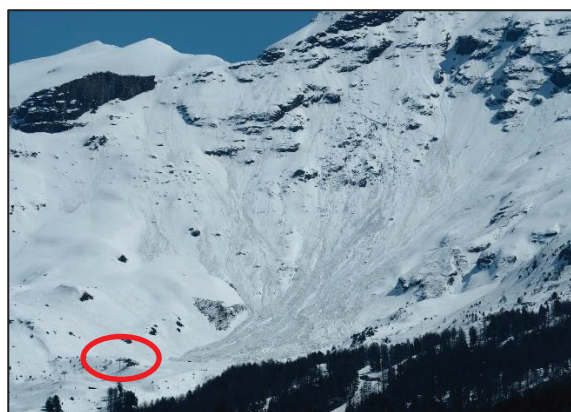


Figure 1: view of the Arcelle chairlift top station (red circle) below Grand Mt Cenis Signal slopes (source: data-avalanche.org)

During the winter 2016-17 and despite a small protective dam just above, the top station was partly filled with snow a first time in November and then almost buried in March (see Figure 2). Each time, it was a mixed avalanche whose dense part filled or buried the station to stop rapidly downhill whereas the powder cloud impacted and slightly damaged the siding of the upper machinery shelter.

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Figure 2: November 2016 (top) and March 2017 (bottom) avalanches

3. PROTECTIVE STRATEGY

These two events pushed the ski resort management to firstly understand why such accidents occurred so regularly and secondly look for additional and original protection measures as just multiplying shooting points would be insufficient. So, a general analysis was restarted which rapidly discovered the location problem: indeed, first project schemes before the construction located this top station on the small hill visible behind on the top picture of Figure 2. Effectively, it would not suffer such an avalanche exposure there.

However, it is now where it is, and it was decided to evaluate possible and most efficient solutions in this situation: efficiency was considered regarding the priority of the capability to effectively improve the protection level and eventually not in an absolute manner but accepting a “certain” industrial risk. For instance, the powder cloud part is “acceptable” provided that the machinery shelter’s external skin is just reinforced (sheet metal instead of plexiglass for instance). So, the analysis focused on the dense flowing parts mostly to prevent prejudicial pressure on the station supporting structure but not modifying the chairlift configuration and limiting filling volumes to easily resume operations after such an event (in some cases, snow clearing was finally the main constraint). Secondly, this solution had to be quick to implement, both administratively and technically and absolutely before the next winter (which was a very good intuition...). Thirdly, it should of

course require the most limited budget all the more this unexpected cost arrived at a period when the ski resort was already facing other important financial commitments.

4. PROTECTION DESIGN AND ASSESSMENT

Rapidly, solutions focused on passive structures like dams or braking mounds seemed to fulfill most parameters. After defining a reference scenario consistent with the last know major avalanches (and assuming that the existing artificial release network would finally filter more important events), RAMMS was used to model it (see Figure 3 top) and obtain reliable values of speed and flow height at the top station location. Depending on this hypotheses, results showed very good agreement both with the 1983 historical event and 2017 avalanche runouts to better understand the behavior of the overall Arcelle avalanche system.

Then the Jóhannesson et al. (2009) process was applied to preliminary evaluate a possible deflective dam: it concluded that a very massive structure of several tens of thousands cubic meters would be required. If good materials were directly available on site, such earthworks seemed difficult to be accepted both administratively, environmentally ... and financially in addition to possible stability challenges.

So, and with positive feedback in equivalent situations (Yount et al. 2016), it was preferred to look for a mixed network, reinforcing the small existing dam as an extreme protection and combining it with braking mounds uphill. Consequently, the question was to establish the geometry of individual mounds and their number and distribution in the field.

Additional aspects were also considered: as the top station is located laterally of the main flow stream, mounds distribution was intended to promote the braking and storing of the first wave in its direction to constitute a new massive obstacle and to deflect the following flow of the avalanche. At the same time, spaces in-between mounds had to let grooming machines go in after the avalanche either to clear snow or better to reshape the deposit so that mounds could become the supporting infrastructure of a snow dam as positively experienced by Segor et al. (2010).

Finally, different configurations were tested numerically: even if the RAMMS model is not directly adapted to properly consider such topographic particularities, it is interesting to analyze main trends either based on a modified DEM including foreseen mounds or considering them as no flux cells.

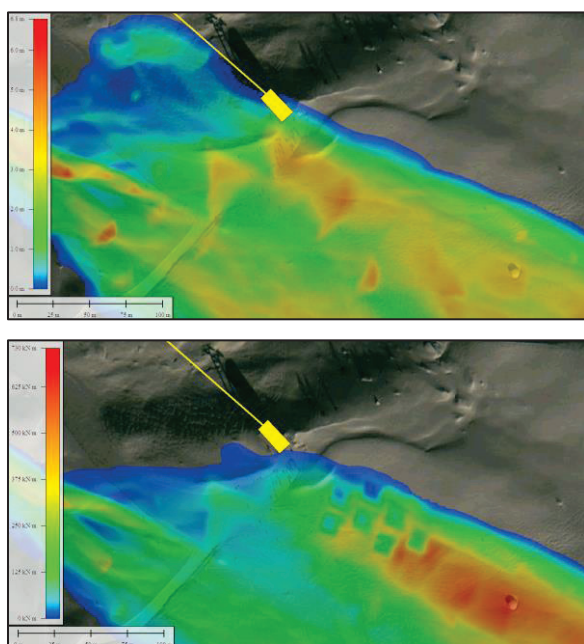


Figure 3: Numerical comparison with Ramms of the reference scenario (top) and introducing braking mounds within the topography.

Finally, a staggered network of six braking pyramids was decided in addition to the enhancement of the small existing dam just above the chairlift. The three most exposed mounds directly facing the avalanche were designed sharply and reinforced adequately based on the state of the art of passive avalanche protections (Rudolf-Miklau et al. 2015).



Figure 4: View of the "pyramids" and dam network at the end of 2017

These protections are around 6 meters high and were optimally preferred to a unique (at least) 20-meters high dam. They were built during fall 2017 in a few weeks (see Figure 4).

5. CONCLUSION: AND THEN CAME EL-EANOR...

Directly during the next winter, the system was tested "thanks" to the Eleanor storm followed by a very intense east front bringing almost two meters of fresh snow: a major avalanche occurred

but only a limited layer of snow entered under the station: in comparison to previous burying events, the corresponding volume was relatively smaller even though the event was larger (another chairlift situated downhill was deeply damaged during this period where it never experienced any known avalanche before). Within the assumed industrial risk, the upper part of the building was also impacted by the powder cloud and some sheet walls were damaged. But, the network globally played its role very well even showing the expected deflecting effect. Regarding conditions at that time, it might have clearly saved the infrastructure confirming an optimal cost-benefits ratio.



Figure 5: Top station just after the avalanche and lateral braking mounds

REFERENCES

- Jóhannesson, T., P. Gauer, P. Issler and K. Lied (eds) 2009: The design of avalanche protection dams, Recent practical & theoretical developments, European Commission, 212 pp.
- Yount, J., B. Gorsage, R. Newcomb, L. Elder, K. Elder, G. Richards, 2016: Passive avalanche defense mounds in the ebul of the woods avalanche path, Wyoming, Proceedings, International Snow Science Workshop, Breckenridge, Colorado, 548-555
- Segor, V., P. Dellavedova, E. Borney, A. Debernardi and S. Roveyaz, 2010: A quick winter solution for hazard mitigation in the deposition area – application in the Aosta Valley – NW Italian Alps, Proceedings, International Snow Science Workshop, Squaw Valley
- Rudolf-Miklau, F., S. Sauermoser and A. Mears (eds.) 2015: The Technical Avalanche Protection Handbook, Ernst and Sohn, Berlin, 430 pp.