Artificial Avalanche Release above Settlements

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ABSTRACT: In the Swiss Alps avalanche control with triggering by explosives is widely used in ski areas and also along traffic routes. New methods for artificial avalanche release have been developed during the last years. Autonomous devices allow remote triggering of avalanches independently of visibility and with a good detonation effect. In Switzerland the standard methods for protecting settlements are snow supporting structures and earth dams. Some endangered settlements or group of houses still have no protection with structural defence measures due to high costs. At some of these locations, artificial avalanche release has been applied successfully since the 1950s. Local avalanche control services are interested in improving the safety measures. Therefore the application of artificial avalanche release for the protection of settlements is also discussed for new locations. In general, artificial release above settlements should be applied with extreme caution and should remain an exception. The main risk of artificial release above settlements is triggering a too large avalanche causing damage. For such applications the avalanche situation must be studied in detail. Important points are the evaluation of the terrain features in regard to the effectiveness of artificial avalanche release, the potential for triggering secondary avalanches and the existing damage potential. We developed a technical guideline which defines the most relevant factors for evaluating the safety aspects.

KEYWORDS: Snow avalanche, avalanche protection, avalanche control by explosives, temporary protection measures.

1 INTRODUCTION

The integral risk management includes land-use planning (hazard mapping), structural (permanent) and temporary protection measures (SLF 2000). Preventive road closures, closures and evacuation (also curfew, persons can stay in their houses) in inhabited areas and artificial avalanche release are examples of temporary measures. In the Swiss Alps, avalanche control by explosives is widely used in ski areas and also along traffic routes. In these cases, artificial release usually does not endanger persons since the endangered areas can easily be closed. Sometimes, damage to infrastructure (e.g. pylon of a chair lift) can not be avoided.

The standard methods for protecting settlements are snow supporting structures and earth dams (Margreth, 2009). Some endangered settlements or group of houses still have no sufficient protection with structural defence measures mainly because of too high construction costs. To guarantee an acceptable safety level at these locations, local avalanche control services evaluate the hazard and arrange temporary measures such as evacuations. At some of these locations additionally also artificial avalanche release is used – occasionally since the 1950s.

The extraordinary avalanche winter 1998/99 clearly demonstrated the importance of temporary avalanche protection measures. Many accidents in the Swiss alps were prevented with the evacuation of endangered settlements, road closures or artificial release of avalanches (SLF, 2000; Wilhelm et al., 2001). At some locations avalanche control was successful due to frequent use of explosives (Fig. 1, 2). It proved to be important to attempt artificial release also during bad weather conditions even when it was not possible to evaluate its results. Therefore often mortars were used, which have the disadvantage that the detonation effect is rather small (detonation within snow cover) and that for safety reasons the targets often are well below the ridge which is quite far away from the optimal detonation point. Usually helicopter bombing (dropping charges) was done as soon as the weather conditions were good enough. At most locations a combination of mortar fire and helicopter bombing was applied. Also with frequently avalanche control, bigger avalanches were triggered with a size corresponding to a return period of about 10 years. Two very large avalanches caused damages in Leukerbad (Fig. 3) and at the Lukmanier Pass (power line). In both cases due to a too long period without attempts, a big powder snow avalanche was triggered. Also secondary releases occurred (e.g. in the release area Laschadura, Fig. 4).

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Fig. 1: Klosters Tallawine: Large, steep (≥35°) release area; artificial release since 1967, 5 mortar targets, also helicopter bombing (since 2007 catching dam in runout zone).

Fig. 2: Walenstadt: Large powder snow avalanche, Feb. 2003 (triggered by mortar fire).

Fig. 3: Leukerbad: The roof of a well constructed house was damaged as result of a helicopter bombing operation, Feb. 1999.

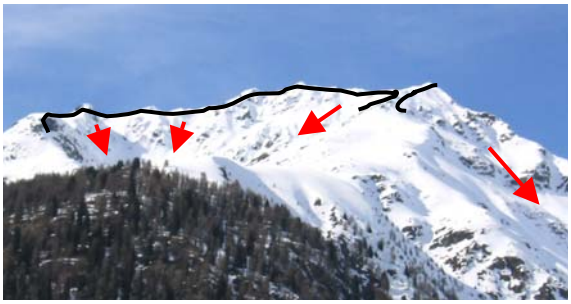

Fig. 4: Zernez: Primary avalanche path Barcli (1) and secondary area Laschadura (2), flat ridge between.

Remotely controlled avalanche release systems such as Gazex, avalanche tower or avalanche guard (Fig. 5) allow the frequent use of explosives independently of weather conditions and guarantee a good detonation effect at the chosen location in the release area. These autonomous systems represent a major development and are one of the reasons why the artificial release above settlements attracted a lot of interest recently. Local avalanche control services are interested to improve the safety measures. Therefore the desire is increasing to apply the artificial release more frequently also above settlements. Consequently, the need emerged to provide recommendations on how to proceed when evaluating the applicability of artificial release above settlements.

Fig. 5: Remote systems Gazex, Inauen-Schätti avalanche guard, Wyssen tower (from left to right).

2 PRINCIPLES

In general, artificial release above settlements should be applied with extreme caution and should remain an exception. The main risk of artificial release above settlements is triggering a too large avalanche causing damage. The strategy is to trigger frequently small avalanches in order to avoid a large destructive avalanche. The closure and control of the endangered area in the runout zone during the control operation can be difficult and needs a particular effort.

Using artificial avalanche release above settlements recommends (1) a detailed evaluation of the safety aspects and (2) a well organized local avalanche control service with established working procedures based on a safety concept. If the installation of a detonation method is subsidized by Swiss government, a report regarding the safety aspects is necessary.

3 APPLICABILITY OF ARTIFICIAL AVALANCHE RELEASE ABOVE SETTLEMENTS

The applicability of artificial release has to contain the evaluation of (1) the terrain in regard to the effectiveness of artificial avalanche release (incl. the potential of triggering secondary avalanches) and (2) the existing damage poten-

tial (Tab. 1). In addition, the following points must be considered: (3) possible detonation methods, (4) required safety measures (temporary closure of endangered areas) and (5) the weather and snow data available for the avalanche hazard evaluation (e.g. automatic weather station).

Tab. 1: Factors to be considered for the evaluation of the applicability of artificial avalanche release above settlements (most important factors italically represented)

Criteria		Positive (favourable)	Negative (unfavourable)
1. Terrain			
Per part of release area	*1.1 Part of release area >35° (higher release probability)*	> Approx. 30% of the area (total area: …..ha > 35°: …..ha)	< 30% of the area (total area: …..ha > 35°: …..ha)
	1.2 Topography, altitude, aspect concerning the avalanche release probability	Depression, plane, evenly bent, north aspect, > 2200 m [1]	Small-scale strong structured, change of inclination, convex, south aspect, < 2200 m [1]
Total release area	*1.3 Release area (concerning potential avalanche size)*	≤ Approx. 10 - 20 ha [1] (total: …..ha)	> Approx. 20 ha [1] (total: …..ha)
	1.4 Topography regarding maximum avalanche size	Well separated release areas	No separated release areas
Track	*1.5 Predictability of the flow direction*	Defined, e.g. gully	Undefined, several flow directions possible
	1.6 Inclination regarding braking	< 20° [1]	> 20° [1]
Runout zone	1.7 Inclination regarding runout distance / altitude	< 10° [1] or uphill < 1000 m [1]	> 10° [1] > 1000 m [1]
Secondary release areas	*1.8 Existence of secondary release areas*	No	Yes, number of areas
	1.9 Separation between primary and secondary area regarding inadvertent release (per area)	Steep slopes on both sides (prim./sec. area), well separated	Other topography e.g. flat ridge between prim./sec. area
	1.10 Preventive measures in secondary area (per area)	Supporting structures or artificial release	Not existing
	1.11 Avalanche record (per area)	No coincidental release known	coincidental release known
2. Damage potential (natural avalanche return period without artificially triggered avalanches)			
Avalanche path and secondary areas	*2.1 Damage potential of a 10yrs. avalanche*	Zero to low (e.g. range land; forest damage hardly possible)	Medium or higher (few inhabited, unprotected houses; barns, uninhabited houses, power lines), important forest (with protection capacity)
	2.2 Avalanche return period (T) to reach settlement area (most exposed buildings)	T > 20y	T < 20y
	2.3 Damage potential until and including most exposed buildings	Low to medium (few inhabited houses, barns)	High to very high (settlement, infrastructure and industry)
	2.4 Damage potential of a 100yrs. avalanche	Low to medium (few inhabited houses, barns)	High to very high (settlement, infrastructure and industry)
	2.5 Preventive measures (direct protection of buildings, dams) on track / runout of a 100y avalanche	Existing	Not existing

[1] General values, to be adopted depending on situation

Criteria		Positive (favourable)	Negative (unfavourable)
3. Detonation method and detonation points (target locations)			
General	*3.1 Applicability of the method (time of detonation)*	Guaranteed (weather independent)	Visibility required, location not easily accessible
	3.2 Detonation effect	Medium to high (Detonation on (>2kg) or above snow surface)	Small (Detonation in snow cover, < 2kg)
	3.3 Slope inclination at detonation point (per point)	>35°	<35°
	3.4 Number of detonation points in regard to the effective detonation range	Sufficient coverage (main part of release area along most probable fracture line > approx. 60% covered)	Insufficient coverage (main part of release area along most probable fracture line < ca. 60% covered)
Remotely controlled avalanche release systems	3.5 Location of the system regarding to impacts of avalanches, snow pressure and rock fall	No danger or small intensities (protection possible)	Big intensities (protection difficult or impossible)
4. Closure measures / evacuation			
Effort (for little to medium snowfall)	4.1 Closures, curfew	Small effort (few roads, few houses)	Medium or big effort (several roads, settlement with many inhabitants)
	4.2 Evacuation	Not necessary	Necessary
5. Weather data and check of detonation result			
Snow and weather data	5.1 Automatic weather station nearby or information from nearby ski area	Existing	Not existing
Check of detonation result	5.2 Visibility	Observation possible, e.g. from the valley	No observation because of terrain (e.g. helicopter necessary)
	5.3 Technical support	Installation existing or available (e.g. Geophone)	No installation
6. Possibly: experience of a local avalanche control service			
	6.1 Available experience with artificial release in the area	Existing (successfully use of artificial release since several years)	Not existing (no artificial release until now)
	6.2 Documentation (e.g. records of detonations and avalanches). (Benefit of a record: knowledge of frequent release areas and runouts)	Existing	Not existing

4 TECHNICAL GUIDELINE FOR ARTIFICIAL AVALANCHE RELEASE ABOVE SETTLEMENTS

The technical guideline describes the procedure on how to assess the applicability of avalanche triggering at a certain location (Stoffel, Margreth, 2009).

The evaluation report should contain the following elements (concerning the safety aspects):

- Introduction (area of evaluation)
- Basic documents (maps, hazard map, existing reports)
- Analysis of the avalanche situation (terrain, avalanche record, observed secondary releases, experience with triggering if done in the past, conclusion)
- Applicability of artificial avalanche release (see Tab. 1; conclusion with positive and negative factors)
- Possible alternative protection measures
- Safety concept for temporary measures (if in request contained)
- Recommendation.

It is also possible to describe the avalanche situation (terrain of the avalanche path, avalanche record) and to simply fill out Table 1. Additionally, a conclusion should be made with an overview of possible alternative protection measures.

5 CONCLUSIONS

The importance of avalanche control with explosives increased with the newly developed autonomous installations such as Gazex, avalanche tower or guard. These methods allow the frequent delivery of explosives under almost any weather conditions and guarantee a good detonation effect at the chosen locations in release areas.

In general, artificial release above settlements should be applied with extreme caution and should remain an exception. Using artificial avalanche release above settlements recommends (1) a detailed evaluation of the safety aspects and (2) a well organized local avalanche control service with established working procedures based on a safety concept. If the installation of a detonation method is subsidized by the Swiss government, a report regarding all safety aspects is demanded.

Table 1 describes the most important factors which must be considered regarding the applicability of artificial avalanche release and the safety aspects. The evaluation of all these factors indicates if the artificial release is suited or not. The decision, if artificial avalanche release above settlements is possible or not, is often not easy. For the decision also the cost-benefit ratio, the overall situation (e.g. along a road section) and the general acceptance have to be taken into account. Also permanent measures or a combination of temporary and permanent measures (e.g. artificial release and an avalanche dam) should be considered.

It is recommended to attempt triggering after already small amounts of snow accumulation (e.g. during snowfall) to avoid large destructive avalanches. If a too large avalanche must be expected, it is advisable not to trigger.

Open issues that must be investigated in the near future are the remote control of the endangered area and the automatic detection of the triggered avalanches (both specially for bad weather conditions). At present the SLF studies different methods such as acoustic and radar systems for the automatic detection of artificially triggered avalanches.

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