Life cycle management for technical avalanche protection systems

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ABSTRACT

Large areas in the alpine regions of Austria are endangered by avalanches. In order to protect settlement areas and traffic ways technical protection works (e.g. snow bridges, deflecting dams) were built in large number where the effects of protection forests are not sufficient for sustainable safety. Avalanche defence works are subject to extraordinary loads and extreme environmental impact which frequently cause damages and reduce the life time of the constructions. Regular inspection and maintenance measures are expensive but also essential in order to preserve the functionality of the protection works. The type of construction of protection measure is substantial for the maintenance costs later on. The approach of life cycle costing thus is suitable in order to plan protection measures economically. The article gives an overview of the most important risks for the stability and usability of technical avalanche protection works and of the most common types of damages. Furthermore it gives an insight into the system well established of life cycle management (maintenance) in Austria and presents the legal and technical standards that are under development.

1. INTRODUCTION

Technical avalanche protection in Austria is foremost equivalent to defence works in the starting zone. Approximately 95 % of the investments for avalanche protection were used for snowpack-stabilizing works within the last 50 years. In the Alps modern avalanche defence works are realized since the 1950ies. This development was triggered by the avalanche disaster of 1954, which caused the death of 109 people only in the district of Bludenz (Vorarlberg).

Fig. 1: Avalanche defence work in the starting zone in the Grappes-Lawine (Vorarlberg).

The first systematic avalanche defense works in Austria were realized for the protection of the Arlberg railway at the turn of the 19th to 20th century. In the 1950ies the Swiss Institute for

Snow- and Avalanche Research (Davos) issued the first technical guideline for defence works in the starting zone. Based on this standard the Austrian Service for Torrent and Avalanche Control developed an own system of technical avalanche protection supported by the practical experiences of engineering. Only in the province of Vorarlberg since that time about 100 km of defence works were built according to the principles of this system. Today technical avalanche protection is a task of paramount importance for the safety in the Alpine valleys and guarantees the sustainability of the basic functions of living (live, traffic, health, work, supply, mobility).

After their completion avalanche protection works are subject to extreme environmental conditions and loads, consequently the ageing and wear rate is high and the life time of the constructions is limited. Extraordinary snow pack and the impact of avalanches which were not taken into account in the planning process may as well cause severe damages. While defence works in the starting zone are particularly endangered by dynamic loads, the risk by avalanche impact for the stability of retarding or deflection defence works (e.g. dams or concrete barriers) is low. In order to reach the "optimal" life time avalanche defence works have to be maintained regularly. The maintenance of a building is the „combination of all technical and administrative measures and management tasks during the life time in order to preserve or restore the effectiveness of the construction so that the demanded function durably exists." (Schröder, 2005). In the course of planning the durability of the protection works is improved by the selection of a construction (design) adapted to the function of the building, the use of resistible building material and the dimensioning including a safety surcharge. The standards of quality for avalanche defence works in the starting zone are as a rule lower than in general civil engineering. The tolerance for ageing and wear is generally higher as the protection works may still fulfil their function even after extreme events. This tolerance is compensated by a careful assumption of loads.

Due to the constantly raising demands for safety concerning natural hazards and the large stock of avalanche defence works in Austria it seems to be urgent to develop a general technical standard at the state of the art for this branch taking also into account the supervision and maintenance of the constructions.

2. RISKS FOR STABILITY AND USABILITY, TYPES OF DAMAGES FOR TECHNICAL AVALANCHE PROTECTION WORKS

A „damage" is an alteration of a building, of its foundation or surroundings caused by external or internal influences, that lead to a reduction of the stability, usability or durability of the supporting construction. Damage occurs if a certain limit value of the "stock of wear and tear" (according to DIN 31051) is not reached any more and a critical state or the usability arises. Regular maintenance counteracts this critical state and extends the life time of the defence work. A defence work may fail when the limit value of stability, usability or durability is exceeded. This failure or destruction can be preceded by damages in the construction but also be suddenly caused by overload. In general the failure of a building is assumed if a defined limit state is exceeded. This limit state is reached if the building (including its foundation and subsoil) or parts of it do not meet the requirements of design any more. As a rule local failure of single snow bridges does not inevitably lead to a failure or the whole protection system, nevertheless an expansion of this damage may cause a serial failure. In this case avalanche release is also possible from protection areas in the starting zone. The

most important risks (cause for damages) for the stability of defence works in the starting zone are presented in table 1.

Causes for damage	Impact on the defence work	Average costs for repair since 1996 for one snow bridge [€/year]
a) Overload caused by snow pressure	Deformation and breaking of components of the snow bridges	1.000 €
b) Overload caused by avalanches	Deformation and breaking of components of the snow bridges	8.000 €
c) Insufficient slope stability	Slip of the foundation	13.500 €
d) Rock fall	Damage or destruction of parts (components) of the snow bridge.	3.500 €
e) Unsatisfactory building quality	Destruction of anchorage or slip of foundation	2.500 €
f) corrosion	Loss of stability by wear.	0 €

Tab. 1: Causes of damages for avalanche defence works in the starting zone and average costs of repair.

Fig. 2: Damages (failure) of snow bridges (protection work in the staring zone) due to overload caused by snow pressure (left), overload due to avalanches (middle) and insufficient slope stability (right).

Damages due to overload primarily occur in the lee triggered by accumulation caused by snow drift. Mainly the upper most beams are deformed. Due to this deformation the beam looses its power of resistance and may fail. Damages caused by avalanches occur in areas where unprotected parts in the starting zone still exist. The costs for repair may be especially high in areas where slope movements occur due to insufficient slope stability. Especially shallow seated movements turn out to be problematic as the foundation slips away while deep reaching anchorage stays stable. Rock fall may fill up storage room of snow bridges and cause overload of the supporting construction. Extreme rock fall events may trigger the failure and destruction of avalanche defence works. Unsatisfactory building quality is often due to insufficient length and stability of anchorage. If the foundation of the supporting pole is carried out too shallow it easily may slip away.

Fig. 2: Damages (failure) of snow bridges (protection work in the staring zone) due to rock fall (left), slip of foundation (middle) or destruction of anchorage (right).

Fig. 2: Damages (failure) of wooden snow bridges (protection work in the staring zone) due to break of the supporting construction (left); destruction of concrete retarding barriers due to extreme avalanche pressure (right).

3. LIFE CYCLE MANAGEMENT (MAINTENANCE) SYSTEM IN AVALANCHE PROTECTION

3.1 Life cycle management in avalanche protection

The prerequisite for a sustainable preservation of the protection function of technical avalanche control measures requires a long-term planning of financial resources for maintenance. In competition with other investment tasks of public households it is necessary to take into consideration a partial or total renunciation of supervision and maintenance measures. This scenario will most probably lead to a significant reduction of durability and an early decline of the security level as well as an increase of damage potential. These effects have to be visualized in the hazard maps.

In addition to the economic aspects of maintenance management also legal, organisational and technical standards are required for the fulfilment of this important task. The supervision of avalanche protection works involves a wide range of public and private institutions (municipalities, beneficiaries, authorities, land owner), for this reason a lot of interfaces exist which require intensive coordination. The maintenance of avalanche protection works is a

legal obligation of the bailee, the coordination of supervision and maintenance measures is due to the Forest Act a task of Austrian Service for Torrent and Avalanche Control.

The following instruments are basic requirements for an integral maintenance management system:

- Legal regulation of supervision of protection measures
- Cadastre of protection works (data base)
- Organisational model for the recurring supervision and inspection of protection works (monitoring)
- Specification of the optimal maintenance strategy

3.2 Legal basis for maintenance

The legal basis for the financing of avalanche protection works in Austria is the Hydraulic Engineering Assistance Act, subsidies come from the federal Disaster Relief Fund. Thereby municipalities have easy access to the necessary financial resources for maintenance measures. Technical avalanche protection measures are by legal definition "water protection works" according to Art 41 Water Act and require a permission by the authorities, which includes the obligation of maintenance. Nevertheless protection works are due to Art 297 Civil Code part of the real estate and thus property of the land owner. For this reason in most cases the obligation of maintenance is separated from ownership apart from the case that the land owner is identical with the protected person. According to the legal regulations maintenance includes the task of the current supervision, the servicing, the regular inspection by an expert and the repair of damages. Due to Art 102 Forest Act the inspection of the biological and forestry measures is task of the Austrian Service for Torrent and Avalanche control as well as the supervision of the avalanche catchment areas. However a public obligation for maintenance of protection measures is not derivable from the legal regulations.

3.3 Maintenance service

Avalanche protection works are most often planned in combination with reafforestation. Afforestation measure in high altitude areas require regular care for decades, consequently the supervision of technical measures can be realized without additional costs. During winters rich in snow the supervision of avalanche protection works is carried out by aerial observation (helicopter). Great parts of the damages can already be detected from the air. The regular inspection of technical protection measures guarantees the execution of urgent maintenance measures in time.

3.4 Financing of maintenance measures

Avalanche protection projects require long time for realization, thus damages that occur during the first decades can be repaired by means of the project funds. Minor repair measures (limit: € 15.000,--) are regularly financed in the framework of the so called "maintenance service" of the Austrian Service for Torrent and Avalanche Control. These funds are available unbureaucratically and do not require a specific approval by the authorities in charge. In case of severe damages it is necessary to apply for the financing of a separate maintenance project, which is supported by public subsidies and contributions of the beneficiaries.

3.5 Standardization of monitoring and maintenance in the ONR 24807

In order to achieve constant quality of monitoring and maintenance of avalanche defence works, an Austrian Standard Rule (ONR 24807) is under development. The monitoring concept, based on the Austrian standard mentioned above, is divided in two parts, the inspection and the measurement or intervention part (Fig.3). The main target of the inspection part (fist part) is to assess the condition in a comprehensive manner. The aim of the inspection is to classify the structure in one of three condition levels. Level 1 - buildings are new or as good as new, level 3 - building are completely destroyed.

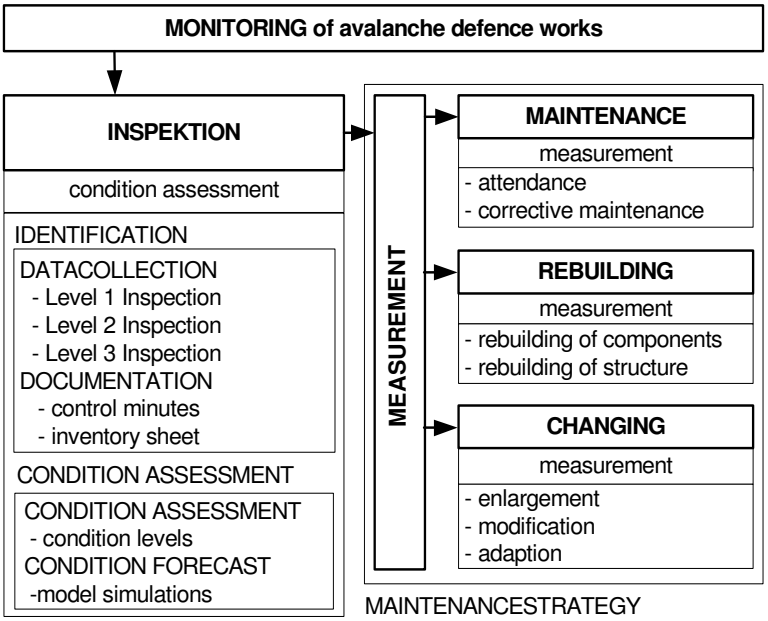

Figure 3: Configuration of the maintenance concept for avalanche defence works

The measurement part (second part) contents precise structural and organisational procedures. Depending on the condition levels in the ONR 24807 minimum standards for structural measurements und periods for their realization are defined. These minimum standards are stricter for "key structures". The measurements can be divided into the maintenance, the rebuilding and the changing of a structure.

A permanent technical protection system against avalanches contents a lot of single structures (snow bridges, avalanche retarding structures) which are in permanent interaction. Taking into account this interaction, the whole system contains structures which higher and lower negative effects on the safety of the whole protection system and the protected areas, if they fail. Depending on the weightiness of these negative effects the structures can be divided into "standard" and "key structures". This classification (referring to *Austrian Standard Rule EN 1990*) of protection measures has to be defined at the beginning of every monitoring process.

In order to assess the safety of a structure, data about the past, the actual and the expected prospective condition are needed. Thus a fundamental task for the condition assessment is the periodic inspection of these structures. To consider economic limits three control levels have been developed. In level 1 (L1) all structures will be periodically inspected e.g. by lumbermen during the annual inspection. If a damage on a structure is identified a competent expert will do a level 2 inspection (L2). If there is no chance of assessing the structures actual condition a level 3 inspection (L3) will be held. Level 1 and 2 are done with visual inspection methods. For a level 3 inspection more complex engineering methods are used.

Types of Inspection	L1	L2	SL2	L3
	Level 1 Inspection	**Level 2 Inspection**	**Special Level 2 Inspection**	**Level 3 Inspection**
Periods	Key structure: annually Standard structure: at least every 5 years	all structures: before end of guarantee Key structure: every 5 years	Key structure: after extreme events	all structures: in vase of need
Methods	visual	visual		advanced methods
Executed by	Lumbermen	Experts		Experts (interdisciplinary)
Result	Level 1 minutes	Level 2 minutes		Level 3 minutes

Tab. 3: Types of inspection according to ONR 24807.

3.6 Sustainable planning and maintenance strategy of avalanche protection measures based on a Life Cycle Costing (LCC) approach

The concept of life cycle costing (LCC) integrates all costs (planning, building, maintenance, and removal) which occur during the life time of a protection measure. The goal is to optimize costs for the whole life cycle of the single protection work as well the whole protection system. A farsighted maintenance of protection measures requires as a rule a combination of preventive (e.g. condition monitoring) and corrective measures (e.g. repair). Concerning the controllability of life cycle costs it turns out that the best chances exist in the planning and construction phase: Maintenance cost can be optimized by means of design, selection of the type of measure, durability of selected building material und serviceability of the construction. During the operation phase regular supervision and recurring inspection of the protection measures is a guarantee for sustainable usability.

4. CONCLUSIONS

Technical avalanche protection works are subject to extreme environmental condition and forces (snow pack, avalanches, rock fall, instable slopes, corrosion), which may cause severe damages and lead to a failure of the construction. Regular supervision and recurring inspection (condition monitoring) help to detect damages in an early state. Sustainable maintenance of avalanche protection works requires convertible legal regulations and operational tools at the state of the art, the technical standards and procedures for this task will be set up in the new Austrian Standard Rule ON 24807 (edition expected: 2008). Maintenance measures, obligation of the bailee are carried out within the framework of the Austrian Service for Torrent and Avalanche Control, the financing supported by public subsidies from the Federal Disaster Relief Fund. An economical use of these funds requires a maintenance strategy based on the principles of life cycle costing (LCC). It is the goal of sustainable maintenance to preserve a sustainable function of avalanche protection measures.

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