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STUDIO TECNICO DOTT ING MASSIMO RAVIGLIONE
ROCK AND SNOW ENGINEERING

MOUNTAINS WORKING

PAPETTI
PIANIFICAZIONE, SVILUPPO E DIFESA DEL TERRITORIO

ACTIVE WORKS IN A STARTING ZONE: MONITORING, MAINTENANCE AND FUNCTIONAL RESTORATION. AN ANALYSIS OF REAL CASES OF INTERVENTION

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Active works in a starting zone are interventions made with more or less complex engineering structures (usually snow nets, snow bridges, rakes, tripod stands, etc.) designed and built to hold back the snow cover in the releasing area by limiting the gravitational phenomena (snowflow) of the snowpack.

Their secondary, but not less important function is to create "breakages" (linear in case of a continuous positioning or punctual in case of an interrupted fragmentary positioning) within the potentially unstable slab so as to reduce the destabilizing forces and, as a consequence, to limit the avalanche trigger.

ACTIVE WORKS IN A STARTING ZONE
snow nets, snow bridges, rakes, tripod stands, etc. …
↓
Primary function
hold back the snow cover in the releasing area by limiting the gravitational phenomena (snowflow) of the snowpack
↓
Secondary function
create "breakages" within the potentially unstable slab

In many cases, not only are the works or the single handiwork exposed to the stresses related to their function of snowpack retention in the starting zone, but they are also subject to "external" stresses which are not consistent with the function for which those active works were conceived, designed and installed.

The on-site installation involves the construction of continuous lines or, in some cases, interrupted lines of snow barrier structures able both to counteract the snow creep phenomena and to interrupt the slab continuity.
The on-site placement, both in terms of distance between the lines and in terms of coverage of the potential detachment area, must consider in detail the morphology of the slope (in particular: the slope angle Ψ, the coefficient of friction φ snow-ground, the height HK of the protection works and the glide factor N) as well as the potential issues, not directly linked to the natural accumulation of the snowpack (e.g. snow brought by the wind) which can generate additional stresses on the protection structure.

ACTIVE WORKS IN A STARTING ZONE
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Stresses related to their function of snowpack retention in the starting zone
Snow Creep
↓
"External" stresses which are not consistent with the function for which those active works were conceived, designed and installed
Overload from windblown snow
Avalanche beetween the lines
Rock fall
Landslides and debris flow

SNOW CREEP
The solicitation of gliding in the line of slope generally depends on the slope angle [Ψ], the snowpack density [ρ], the height of the snow cover [H], the exposure and the roughness of the contact plan between the snowpack [N] and the ground.
The Swiss and French directives regulate the input loads to be applied to the calculation of the structures in terms of action related to snow gliding and express this stress through the following relations.

UFAMWSL SNV
Defence structures in avalanche starting zones

$$S'_N = \rho \cdot g \cdot \frac{H^2}{2} \cdot K \cdot N \cdot f_c$$

where:

- S'_N → component of snow pressure in the line of slope [kN/m]
- ρ → general average density of snow [t/m^3]
- g → gravitational acceleration [m/s^2]
- H → general snow height [m]
- K → creep factor [-]
- N → glide factor [-]
- f_c → height factor [-]

AFNOR NF P 95-304
Equipements de protection contre les avalanches – Filet paravalanches

Table 1 summarizes the variation of the load Fn orthogonal to the protection work. The extreme values vary from 9.90 kN/m to 75.2 kN/m as a function of the glide factor N [-] and the height of the snowpack H_n [m].

Tab. 1: total pressure (art. 6.8 of NF P 95-30)

N	2 m	3 m	4 m	5 m
2,0	9,9	[illegible]	39,6	61,8
2,5	12,0	27,1	48,2	75,2

OVERLOAD FROM WINDBLOWN SNOW
The action of wind transport from the windward side to the leeward side generally determines the creation of slabs along the leeward side. This phenomenon can create two main problems for active protection works: the first relating to the potential burial of the work and the second concerning the increase of the load on the work. According to the empirical relation proposed by Föhn (1980), the value of wind accumulation is:

$$H_{sd(1gg)} = k \cdot V^3 \text{ for } V \leq 20 \text{ m/s}$$

where:

- $H_{sd(1gg)}$ → accumulation of snow brought by the wind in 24 hours [m/d]
- k → empirical coefficient equal to 0,00008 [$s^3d^{-1}m^{-2}$]
- V → daily average values of wind speed [m/s]

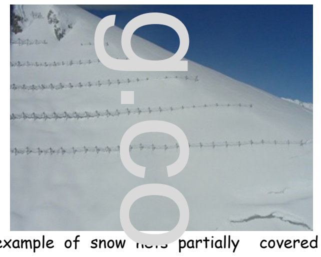

Fig. 1: example of snow nets partially covered by wind accumulation

In the literature, the extreme values of wind loads for a 24-hour wind action can reach the values shown in Table 2.

Tab. 2: wind loads during 24 hours

V [m/s]	Hs [cm/d]
5 - 10	5 - 10
10 - 15	10 - 35
15 - 20	35 - 75
20 - 25	75 - 200
> 25	> 200

AVALANCHE BEETWEEN THE LINES
Special snowmaking conditions linked to high diurnal temperature increases and low nightly refreezing create favorable conditions for the humidification of the snowpack up to the basal layer and an increase in density.
These conditions, which generally occur earlier in the season or in the spring, allow the triggering of creeping phenomena and the formation of ground avalanches of humid and wet snow.

Fig. 2: example of ground avalanche between the lines

ROCK FALL
In many starting zones, rocky outcrops generate phenomena of collapse with rockfall events particularly in periods with higher temperature gradient between day and night.

Fig. 3: example of the impact of rock blocks on snow nets

LANDSLIDES AND DEBRIS FLOW
In starting zones with modest coverage debris (for example land class 4 type smooth scree mixed with earth), localized landslides or small debris flow are frequently seen especially in periods when snowpack is absent.

The stresses, in relation to the deformability of the structures, can cause alterations in the geometry or damage to the snow nets that may compromise their performance or functionality.
The stress due to snow creep generates standard load conditions both in rigid and in flexible snow barriers structures while the stresses caused by both distributed dynamic loads and concentrated dynamic loads can cause greater problems on rigid structures and semi-rigid structures, whereas the deformability of flexible structures allows greater stress distribution.

ACTIVE WORKS IN A STARTING ZONE
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"EXTERNAL" STRESSES
↓
Problems at the foundation structures
Problems at the structure

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MountainS WorkinG

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PROBLEMS AT THE FOUNDATION STRUCTURES

The problems at the foundation of active works are mainly caused by asymmetric load (e.g. wind overload) or punctual dynamic stresses (e.g. rockfall) or distributed loads (e.g. small avalanches between the lines, landslides or debris flows).

Fig. 4: example of a complete pulling out of an uphill anchor in a snow net

Fig. 5: example of a complete pulling out of an downhill anchor in a snow net

Fig. 6: example of the failure of the foundation plinth on the support of a snow bridge

Fig. 7: example of downhill rotation and translation of the post foundation of snow nets

PROBLEMS AT THE STRUCTURE

The issues to the structure of active works are primarily caused by the following conditions: punctual dynamic load conditions (e.g. rockfall) or distributed dynamic load conditions (e.g. small avalanches between the lines, landslides or debris flows).

Fig. 8: example of damage in the structure of snow nets

Fig. 9: example of damages in the crossbeams in the structure of snow bridges

With reference to the assessment of the physical condition of supporting structures shown in the Swiss directive, in Table 3 we summarize the degrees of maintenance according to the need for intervention, the time of the problem onset and the consequences which could be triggered for inaction.

Tab. 3: condition class

Urgency	Loss of security	Onset of the damage	Consequently the damage
Condition class 1 «good»			
none	low	> 5 years	none
Condition class 2 «damage»			
1-3 years	medium	1-5 years	none
Condition class 3 «poor»			
very	high	< 1 year	extreme impairment

INCREASE OF THE CLASS CONDITION
↓
increase of the urgency maintenance
increase of the loss of security
decrease of the time for the onset of the damage
increase of the consequently the damage

At the same time, as the degree increases, the time period for the occurrence of possible damage decreases, as schematically shown in Table 4.

Tab. 4: possible damage

Condition class	Main type of damage
Condition class 1 «good»	• deformed crossbeams • erosion of foundation block < 10-20 cm • collection of debris on grate thickness < 50 cm • uniform surface corrosion
Condition class 2 «damage»	• slightly deformed supports • displaced cable clips • micropile anchors pushed into the ground • exposed anchors > 20-40 cm (still intact)
Condition class 3 «poor»	• buckled supports • heavily deformed or broken girder • broken or pulled out anchors • buckled micropiles • broken wire ropes

INCREASE OF THE CLASS CONDITION
↓
increase of damage
increase of maintenance

Table 5 shows, according to the degree of maintenance, the type of intervention and the time of achievement.

Tab. 5: sequence of maintenance

Condition class	Types of interventions
Condition class 1 «good»	inspection and checking after every major event or every 3-5 years
Condition class 2 «damage»	repair within 1-3 years
Condition class 3 «poor»	immediate repairs or replacement before the winter

INCREASE OF THE CLASS CONDITION
↓
increase of maintenance
decrease of the time for the maintenance

Conclusion … The maintenance of active works in the release area, regardless of the type of work, involves specific issues connected with constructions sites and logistics, due to the particular location of the works.
To this purpose, a preliminary monitoring is a fundamental step to assess the time of intervention and to define maintenance and repair activities.
In parallel to maintenance, a number of preliminary activities will have to be considered in order to improve the areas of intervention so as to face potential critical environmental issues (such as rock falls, landslides, etc. …).

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