USE OF SNOW FENCES TO REDUCE AVALANCHE HAZARDS

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Introduction

In Norway, roads and buildings are, in some cases, protected from avalanches by the erection of snow fences on the windward side of avalanche areas. These fences are used as protective measures either independently or combined with supporting structures in the starting zone. In the latter case, their function is to reduce the quantities of snow in the avalanche areas so that supporting structures can be dimensioned to withstand a lower load than if fences were not erected.

This method is especially feasible in Norway because of our particular topographical conditions. In many cases, above the avalanche areas there are plateaus extending for several kilometers with ample space to position snow fences to accumulate snow without risk of avalanches.

We have achieved very good results with these snow fences. They have substantially reduced the amount of snow in the starting zone, and there has been a marked decrease in the frequency of avalanches. Although snow fences are quite effective, it must be noted that, before they are erected, a thorough analysis must be made of the amount of snowfall, the prevailing winds, and the topography, in order to determine whether fences are a suitable protective measure.

Analysis of Wind Data

Only the quantities of snow transported near the ground can be collected by snow fences. It can be anticipated that significant ground transport will occur when wind speeds exceed approximately 10 m/s. In most of the Norwegian avalanche areas, speeds over 10 m/s will occur on 15-20 days of each winter month.

Before design and installation of snow fences, it is essential to record wind speed and direction. Large-scale wind patterns (1-10 km) can be determined from long-term meteorological records. Smaller-scale winds can be determined from local anemometers, windvanes, and by examining snow depths around mounds, rock, depressions, etc. Very often, large- and small-scale wind patterns do not coincide.

From anemometer and windvane data, it is possible to plot wind roses (frequency of winds at each direction) for

speeds in excess of the drift criterion, 10 m/s. It should be understood that a wind rose that takes into account only high-speed winds will probably not resemble the wind rose based on all wind speeds (low and high).

The wind rose provides basic information on snow fence orientation and capacity. For example, if the dominant direction is from the west, and there is a strong secondary contribution from the east, then the snow fence should be designed with enough capacity so that the secondary direction does not fill in the fence.

Evaluating the Topography

Next it is necessary to evaluate the extent to which the ground is suitable for snow fences. We know that the windborne snow is concentrated in a 100 m-wide belt from the top of the starting zone, and that fences are effective only against this snow. Ground suitable for snow fences should therefore have a concentrated starting zone, and the difference in height between the fences and the starting zone should not exceed 100 m (Fig. 1).

On the plateau where the fences are to be erected, the ground should be relatively flat since, on gradients of approximately 10°, the creeping of snow results in considerable forces that may easily cause wooden snow fences to collapse in the spring. Particular attention must be given to areas with depressions running parallel with the drift-forming wind. Much snow collects in these depressions and snow fences will become ineffective early in the winter.

In 1970, a total of 1000 m of snow fences were erected on a plateau, windward with respect to starting zones that affect a highway. The first avalanche after they were erected occurred in 1976, a small slab avalanche, 20 m wide. An inspection carried out in the spring revealed a depression running out parallel with the drift-forming wind, towards the starting zone. So much snow had collected around the fences in this depression that they became ineffective early in the winter. Therefore, it is necessary to use high and strong snow fences when fencing such depressions.

Design of Snow Fences

Both field and model experiments have been made for snow fence design. With reference to Fig. 2, it is customary to define a fence density and a total density. Based on the model experiments carried out by the River and Harbour Laboratory in Trondheim, we concluded that the total density should be approximately 40-45%. On flat ground, we prescribe a <u>fence</u> <u>density</u> of 50% and a ground clearance of 20% of the snow fence height. Across areas of heavy snow it is desirable to increase the ground clearance and correspondingly increase the <u>fence density</u>, otherwise the snow creeping forces will destroy the horizontals nearest the ground.

We have also experimented with different materials for the snow fences. Considering economics, wooden fences appear adequate. They collect the snow well besides being able to withstand the snow creeping forces.

Experience indicates that there is little purpose in using fences taller than 4.5-5 m. The cost of taller fences would be disproportionately high, and it would be better to use more rows of snow fences rather than one tall fence. However, it may be necessary to use taller snow fences across depressions in the ground.

Evaluating Number of Rows of Snow Fences

More than one row of snow fences will be needed in most avalanche areas. When the wind forces in the area are known, quantities of drifting snow can be taken from a formula derived by Dyunin (1966).

$$\psi = 0.34 (V-3)^3$$

 ψ = total drifting snow quantity in g/m.s and

V is wind velocity 0.2 m above the snow surface.

In Norwegian coastal mountains, the snow fences should be dimensioned for a collecting capacity of approximately 500-1000 m^3 per meter of fence length.

On flat ground, a snow fence will have a collecting capacity of about 12 H², where H is the fence height. On hilly ground, the capacity depends upon the gradient and whether fences can be erected on lengthwise ridges. When good positions are found, two rows of fences will suffice in most cases, but on rising ground or where depressions run along the direction of wind, up to five rows may be needed. The distance from the avalanche area to the first row of fences should be about 15 times the height of the fence, while the distance between rows of fences may be 10 times the fence height (Fig. 1).

Conclusions

Snow fences are an effective measure to protect roads and housing against avalanches in places where the topography and climate are suitable. The main requirements are:

- Drifting snow must constitute a substantial percentage of total quantity of snow in the area.
- 2. On the windward side of the avalanche area, there should be a large plateau.
- 3. The starting zone should be concentrated, and no lower than 100 m from the fence area.
- 4. The fences should be designed with a collecting capacity of 500-1000 m³ per meter of fence length. In regions suitable for snow fences, two rows of fences will suffice, while, in less favourable circumstances, up to five rows may be required.
- The distance from the starting zone to the first row of fences should be 15 × the fence height, and the distance between rows 10 × the fence height.

Reference

Dyunin, A.K. 1967. Fundamentals of the Mechanics of Snow Storms. in H. Oura, editor, <u>Physics of Snow and Ice</u>, Vol. 1, Part 2, Institute of Low Temperature Science, Sapporo, Japan, pp. 1065-1073.

Discussion

- PERLA: Do you favour the use of jet-roofs in Norway?
- NOREM: We do not consider jet-roofs, or any cornice control structure, justified economically. It is still necessary to monitor and control snow in the starting zone beneath the cornice. In many cases, cornices can be used advantageously to stabilize the starting zone.
- WIERINGA: What are your snow depths in areas where you use snow fences?
- NOREM: The rule of thumb on the West Coast of Norway is 3 m. Near the mountain laboratory of the Norwegian Geotechnical Institute (Grasdalen), depths reach 5 m.

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FIGURE 1 USE OF SNOW FENCES TO REDUCE THE AVALANCHE HAZARD

V



Fence density = $\frac{d}{w+d} \cdot 100 \%$ Total density = $\frac{\Sigma d}{H} \cdot 100 \%$

FIGURE 2 DESIGN OF SNOW FENCES