RESEARCH AND DEVELOPMENT PERTAINING TO STEEL WIRE ROPE NET SYSTEMS FOR THE PREVENTION OF SNOW AVALANCHES[1]

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Avalanches are most effectively prevented using support structures installed at the avalanche starting zone. All types of support structures were introduced and tested in the 1950's in Switzerland. Damage that occurred during that period to support structures using steel wire rope nets and corrective measures taken, resulted in a proven design. Emphasis is placed on the advantages of steel wire rope net systems.

INTRODUCTION

Snow avalanches are a natural occurrence and when in uninhabited areas, they are out of human control. Once man enters the scene, such phenomena become a hazard and those areas where they are apt to occur can be considered danger zones. Today's expansion into previously untouched areas with our roads, housing, utility structures, recreational facilities, etc., have increased the danger zones and the risk to life and property. This, in turn, increases our need for protective measures. The types of protection which can be taken to prevent a disaster from occurring are as follows:

- Avoid any potential danger zone.
- Areas of a slope where the forest has been destroyed by snow avalanches should ideally be replanted with new trees which, in time, will act as natural barriers against avalanches.
- Triggering avalanches by use of explosives.
- Installing permanent avalanche defensive systems.

TYPES OF DEFENSIVE SYSTEMS

The following is a description of permanent preventive installations which in some instances and when properly combined, can complement each other:

A) Drift Fences - Manufactured of light structures such as fences and panels and influence the wind and position of snow. Intended to reduce the number of slab avalanches and prevent the formation of cornices.

B) Diversion Structures - Expensive massive structures such as dams, stone and concrete walls and structures intended to divert or split a moving avalanche. These structures must be designed to withstand large forces produced by moving snow masses.

C) Containing and Retarding Structures - Structures such as mounds and brakers intended to shorten the avalanche path by reducing the momentum of the moving snow mass, or catching walls or dams intended to retain the moving snow. These systems will have to accommodate large forces and must be designed accordingly.

D) Support Structures - The purpose of supporting structures such as those made from timber, heavy steel, concrete members and steel wire rope nets, etc. are to prevent slab avalanches from starting in an area under protection, as well as stopping loose snowslides within a short distance. Avalanches traveling at full speed have too much power to be stopped or controlled by supporting structures. Also, these types of support structures using a wire rope net system are not suitable to contain wet and loose snow. The supporting structures must be designed to accommodate dynamic forces from avalanches that may start between the rows of the supporting structures.

FACTORS THAT CAUSE AN AVALANCHE

In order to understand the effectiveness of avalanche defensive system as a measure against the protection and/or prevention of avalanches, it is appropriate to discuss those points which are causing various types of avalanches.

1. Slab Avalanches: Two types of motion take place in the snow cover accumulated on a slope. One

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is between individual snow particles or layers and is called the creeping motion. The other is called gliding motion and takes place at the ground snow interface when the entire pack moves down slope. Creeping and gliding motion are variable and subject to conditions such as: slope angle, snow depth, roughness of the terrain and the quality of the snow cover.

Slab avalanches usually occur if the shear strength of the snow cover near the ground is exceeded or if an extremely weak layer in the snow cover is overstressed. The avalanche can be triggered by wind pressure, extreme snow accumulation or by skiers, etc.

The rupture zone or starting zone for slab avalanches exists primarily where the slope steepens downward, in areas where deep snow accumulates, in transition zones of the terrain and where the snow depth increases from the top to the bottom of a slope.

2. Loose Snow Avalanches: This type of avalanche take place in light, fluffy snow where there are very few, if any, internal stresses. Normally, only a small impulse such as a falling stone or a snow clod is required to trigger loose an avalanche. The motion is caused by the initial disturbance and is enough to put more snow into motion. The fracture line increases in length and becomes pear shaped.

SUPPORT STRUCTURES WITH STEEL WIRE ROPE NETS

At this point in time, our attention is focused only on the importance of supporting structures using a steel wire rope net system (Fig. 1).

Supporting structures with steel wire rope nets in Europe have been used for many years. Since 1951 our company has completed approximately 15.5 miles of Avalanche Wire Rope Net Systems. They are being installed mainly in Europe, and amount to about 265 installations.

It should be mentioned that the steel wire rope net system does have its limitations and that no system can be installed that assures complete protection in all situations. However, with proper design and construction as well as an awareness of the surrounding conditions, a large portion of the danger zone can be avoided or substantially reduced.

HISTORY

Years ago, one of our employees made a most interesting observation while looking at a steel wire that was strung across the roof of a house. He realized that a single wire was actually preventing a substantial mass of snow from sliding down the roof. The creeping snow mass, to the contrary, was not cut by the wire but was compacting and

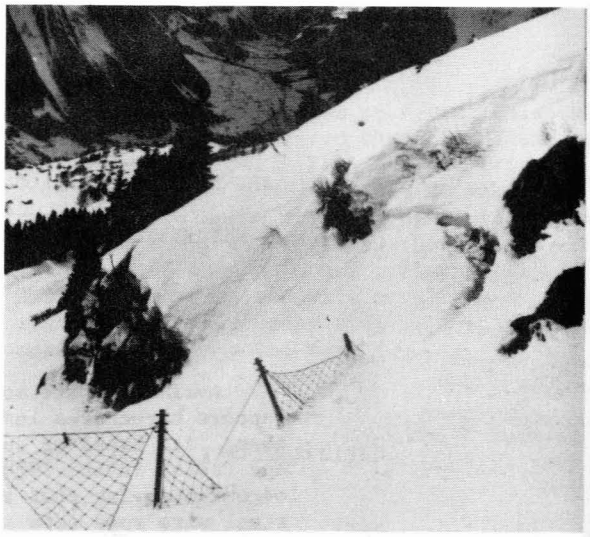


Figure 1.--Support Structure with wire rope nets installed at the avalanche starting zone.

hardening the snow while acting as a barrier. This observation led to the belief that a steel wire rope net system could be used as a snow retaining fence, allowing the containment of large sections of snow until they could compact and harden to bear their own weight.

Soon, the first steel wire rope avalanche prevention system was designed and installed in the field (fig. 2).

Since 1951, all types of designs of safety systems using steel wire rope nets were introduced and tested in Switzerland.

Repairs and alterations in the field were sometimes necessary and in some instances, support structures of various designs, made not only with wire rope net systems, but by heavy steel members, wood or concrete beams were totally destroyed during the snow season (fig. 3).

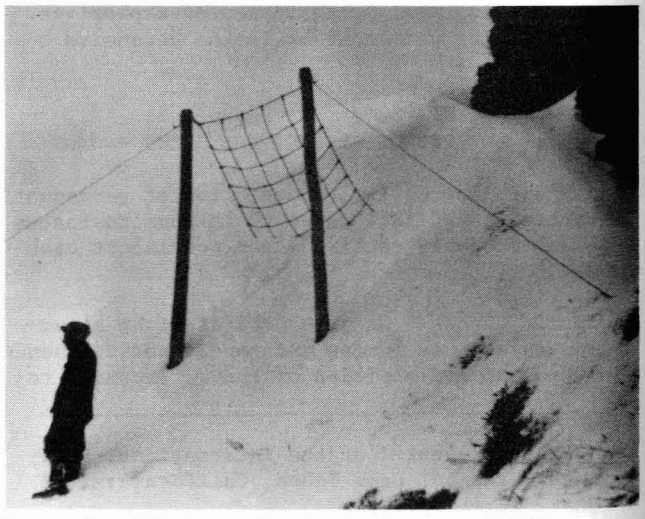


Figure 2.--First Avalanche Prevention System made from wooden poles, using a rectagular wire rope net.

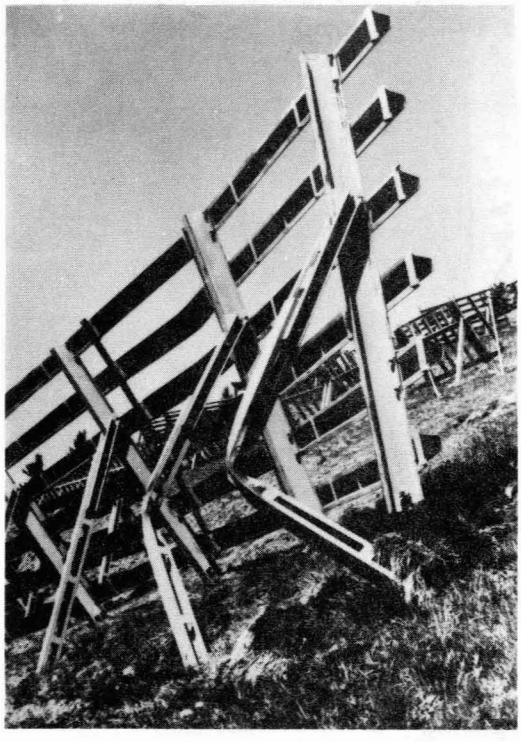


Figure 3.--Damaged Support Structure

In 1951, a patent was applied for by our Company for the snow avalanche prevention system. It should be mentioned that field tests also indicated that the snow avalanche prevention nets can be alternately used for protection against rockfall.

In 1954, Professor Dr. R. Hafeli from the Swiss Federal Institute of Technology was engaged in order to calculate and design a more effective system. Triangular shaped nets supported by flexible posts have proven to be more efficient and economical. As many nets as necessary can be added in order to accommodate any particular length that the system is designed for (fig. 4).

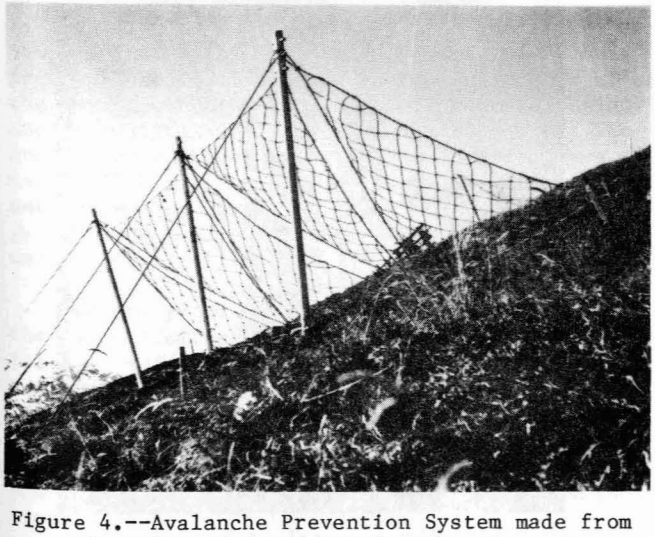


Figure 4.--Avalanche Prevention System made from flexible steel posts and triangular nets.

The nets are securely anchored to the ground and are fastened to the posts. Suspension cables that are designed to carry large forces are secured to the posts and rigidly anchored to the terrain at the Valley side of the slope. Constant forces are then diverted to the anchors of the nets, allowing the post to absorb most loads in its axial direction thereby preventing the post from bending and/or breaking.

Since 1955 and the 10 years that ensued, the Swiss Federal Institute for Snow and Avalanche Research was actively involved in observing avalanche systems and their effectiveness on location. All damage occurred during that period was recorded and the manufacturer was informed accordingly.

Much appreciation must be given to the Swiss Federal Institute for Snow and Avalanche Research for their efforts and willingness in sharing their findings with the industry. Without their help it would have been impossible to constantly upgrade our product and achieve a design which has proven itself in actuality.

MEASURES TAKEN IN ORDER TO IMPROVE THE STEEL WIRE ROPE NET SYSTEMS

The intention is to outline all failures and improvement made during the development stages of such safety net systems using a heavy wire rope net system.

Axial forces exceeding 20 tons and additional horizontal forces will, in some cases, tend to bend and/or break the weakly designed steel posts (fig. 5). As a result of these accidents, the posts were constantly upgraded and in one instance, the existing posts were filled with concrete in order to strengthen same. Unfortunately, very little improvement could be noticed by doing so.

Also, uneven fastening of the nets to the round steel bars, located on top of the steel post will result in an additional unwanted bending moment and in some cases, will either bend or break the post.

Large horizontal forces which are a direct result of the constantly creeping snowmasses were sometimes underestimated and therefore resulted in further damage to the system. In some instances such damage only became visible in the snow-free season.

In order to arrive at a more accurate calculation for these systems, a column of saw dust was inserted into the snow blanket directly behind the snow fences, allowing visual observation of the actual movements of the snowmasses (fig. 6).

Another weak point of the earlier system pertains to the anchors of the snow nets. The use of solid steel, ring type anchors was unsuitable because

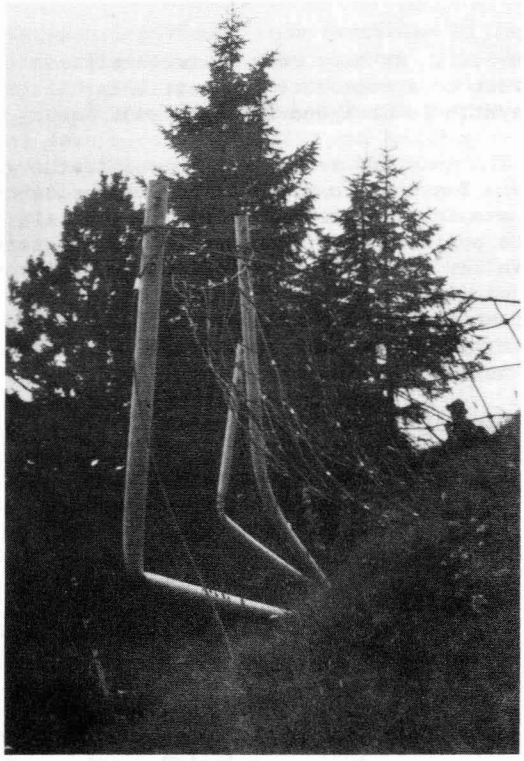


Figure 5.--Bent steel posts, as a result of extreme snow forces.

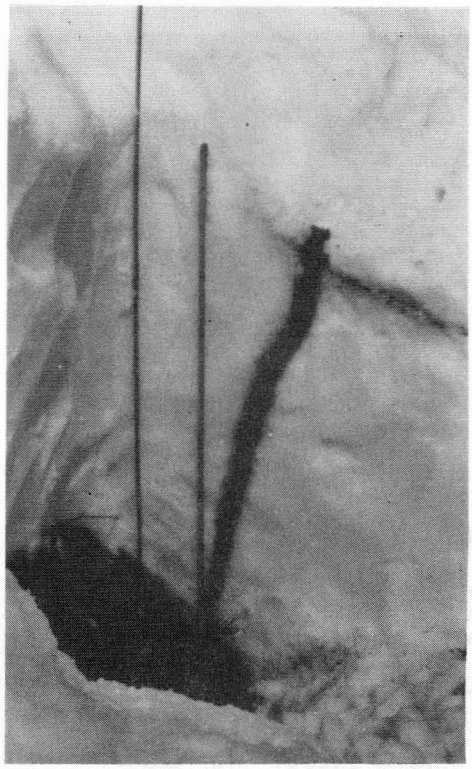


Figure 6.--Saw dust column located in the snow blanket.

they easily bent and broke and sometimes cracked the surrounding foundation material thereby weakening the system.

The ring type anchors were then replaced with solid steel U-type anchors. Again, the same problems occurred as with the ring type anchors.

Eventually, both the solid steel ring type and the U-type anchors were replaced with the more flexible wire rope anchors.

The posts under stress will transform axial forces up to 20 tons thru its flexible cross joint to the foundation plate. Additional horizontal forces which cannot be avoided, resulted in jolting of the post tube. Later the tubes were reinforced with a steel collar with hopes that the matter had been eliminated.

Even though every precaution was taken to solve this particular problem, the flexible cross joint was damaged over and over again. Due to its design, the joint was unable to withstand the enormous forces that were applied to the system.

Immediate action was in order and a special test device was installed in an independent laboratory where the cross joint could be tested and calculated to its maximum breaking strength (fig. 7).

The test results clearly indicated that the cross joint was not suitable to sustain the required forces applied in actuality in the field and therefore could not be used for any further installations.

Also in 1968, the Swiss Federal Institute for Snow and Avalanche Research introduced their new guidelines pertaining to avalanche prevention systems. It was requested that larger forces be used and that the safety factor be increased when calculating new systems.

Test results using a ball and socket type joint for the flexible post were most favorable.

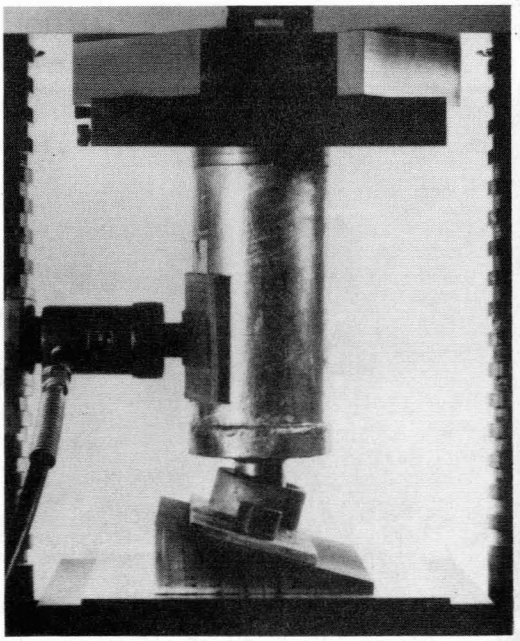


Figure 7.--Test Device

These tests have shown that only after applying an axial force of 71 tons and a horizontal force of 4.5 tons, will damage occur. According to the test, the first deformation will occur by a force of 55 tons, assuring a safety factor of 2.6 for the foundation. (A safety factor of 2 is required in the guidelines).

Presently all posts are being designed and equipped with ball and socket type joints and no further damage has been recorded while using this design.

In some installations, the net outer ropes would break due to the enormous forces applied to the system.

All of these problems have long been corrected and no further damage has been reported from the field.

Finally, the last point which should be discussed pertains to the foundations for these systems. Even though excellent foundation design data and drawings are supplied by the manufacturer, in some cases the actual foundation work has not been properly executed. Therefore, on occasion, anchors and post foundations have been ripped out of the ground during the snow season (fig. 8). It is essential that qualified field personnel be used when installing such systems in order to assure absolute safety.

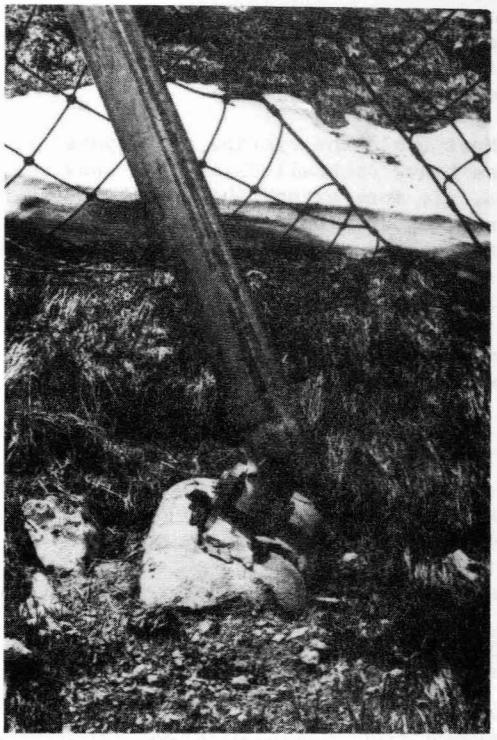


Figure 8.--Ripped out post foundation

Setting of anchors into solid rock is a simple task. Although it must be said that in lesser suitable terrain than bed rock, anchoring of the net system can create some problems. For this reason in 1980, an explosive wire rope anchor was developed and tested in our laboratories which had a theoretical breaking strength of up to 70 tons (fig. 9).

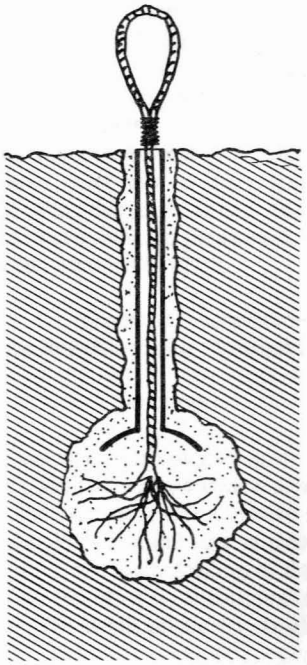


Figure 9.--Explosive Anchor

CONCLUSION

The failures that have been mentioned which pertain to wire rope avalanche prevention systems, might create some doubt in one's mind with regards to liability of such safety systems and the necessity of installing wire rope net systems at all. It should be realized that in the infant stages of the developement of such systems, no calculations and/or design guidelines were in existence. The enormous forces generated by the snowmass were unknown and had to be assumed when designing safety net systems. Only later and with experience gained over the years were some accurate design parameters established.

We are proud to report that since 1968 when the new guidelines of The Swiss Federal Institute for Snow and Avalanche Research were issued, no serious problems were reported regarding our system. But, even so, each system is designed on an individual basis, which takes into consideration a detailed study of the potential danger zones and the surrounding conditions. Certain limitations must be taken into account.

Normally the breakaway area of a given avalanche occurs at the same place on the mountain and is quite predictable. But as always when dealing with Mother Nature, the unforeseen can occur. An avalanche may miss the net system or even damage same, insofar as the maximum snow height which the system has been designed for has been exceeded.

Most avalanche systems are exposed to more or less heavy rockfall during the snowfree season. To some extent this has been taken into account when developing the layout. It should be noted that numerous impact tests have been performed in our factory, showing that blocks the size of 1 cubic yard and weighing 2000 lbs., falling from a height of 98 feet and reaching an impact velocity of 54 mph have totally been stopped in the net system without damaging same.

It is important that periodic inspections of the system take place in order to ascertain what repairs are necessary and the nets must be cleared of all rocks which might have accumulated in the snowfree season. The most effective protection against avalanches is the natural forest and therefore, if at all possible, in conjunction with the net system new trees should be planted, assuring a safer environment.

The wire rope nets available from our Company today have long passed the development stage and are of a proven design offering the following advantages:

- Made of lightweight construction and therefore easy to transport and install in difficult terrain.
- Easy to repair onsite due to its standardized design and ready availability of spare components.
- To some extent, protection against rockfall is assured.
- Environmentally pleasing and hardly visible from a distance.
- Corrosion resistant.
- Can be simply dismounted during the snowfree season, if so desired.

Wire rope type snow avalanche prevention systems in Switzerland are required to pass yearly approval by the Swiss Federal Institute for Snow and Avalanche Research in order for funding to be obtained for future installations of such systems by the Swiss government.

We are happy to report that our avalanche safety system has passed these test continually and this speaks for itself. Numerous systems have been installed over the 35 years they have been in existence on a worldwide basis.

LITERATURE CITED

Swiss Federal institute for Snow and Avalanche Research. December 1968. No: 29. Avalanche Control in the Starting Zone. A) Factors that cause Avalanches. B) The Purpose and the Effect of Supporting Structures.