ABSTRACT: This paper deals with the prevention activity and the assessment methods of the local avalanche risk linked to issues of civil protection aiming at assessing the mountain road practicability in the Province of Biella - Piemonte - Italy. The assessment of avalanche danger and related risks is mainly based on the observation of the evolution of weather, snow and avalanche conditions. In many cases, the assessment on a regional scale (defined as the dangers linked to a mountain area, in our case the Southern Pennine Alps), even if based on direct observations, does not completely match the actual local situation. In fact, the assessment on a regional scale cannot often define the "specific details" that can be hidden in a "small area".

With this report, we want to show, as experts in snow science working for the Commission for Avalanches in the Province of Biella and for the Local Commission for Avalanches in the Mountain Community Valle del Cervo "La Bursch" how direct and ongoing observation on site of a specific mountain area, together with the application of well established methods of snowpack assessment allow the detailed analysis of critical issues and the evaluation, in real time, of future potential problems. The problems that we are going to analyse refer to the evaluation and prediction of changes in the stability of the snowpack along the slopes facing mainly south as well as how temperature changes (thermal stress up to $\Delta T \approx 10 - 15^\circ C$ in 24 - 36 hours), due to higher solar radiation, may influence the increase or decrease of the snowpack stability in relation to different snow thickness on the ground.

1. INTRODUCTION

This paper details the work I do as an expert in snow science for the Local Commission for Avalanches in the Mountain Community of Valle del Cervo "La Bursch" and for the Organo Tecnico Provinciale concerning the management of avalanche phenomena on the territory of the Province of Biella. The activity performed from winter 2005 - 2006 until today has concerned the monitoring and analysis of the evolution of weather conditions in the mountain range of the Southern Pennine Alps as well as of the snow characteristics in relevant areas of mountain roads in the Province of Biella. The evaluation and monitoring of weather and snow characteristics allow us to continuously assess both the evolution of cyclonic or anticyclonic conditions and the possible changes that such weather conditions can determine on the snowpack on the ground. Overall, my activity allows the provincial technical bodies of Civil Protection to decide, through the issue of a bulletin of local avalanche danger, to close to traffic all the roads subject to potential avalanche danger.
2. STUDY AREA

The study area covers the mountain range south of the Western Alps, in particular a mountain area called the Southern Pennine Alps. The area extends from west to east starting from longitude E 7° 90' up to E 8° 17' for a development of about 30 km / 18.6 miles, and from south to north from latitude N 45° 60' up to N 45° 75' for a development of about 12 km / 7.5 miles. Altimetrically, the mountain range in the study includes mountains between 1500 m / 4920 feet above sea level and 2600 m / 8528 feet. The total area covered is of about 360 km² / 139.5 square miles (Figure 1).

Figure 1 - Overview of the Southern portion of the Pennine Alps located in the area of the Province of Biella

The area affected by the mountain roads in the Province of Biella, which requires in-depth assessments in relation to avalanche danger and problems of Civil Protection, covers the road stretch between the Oropa sanctuary in the town of Biella and the town of Trivero. The total length of the road is about 33 km / 20.5 miles, altimetrically it reaches the maximum altitude of 1500 m / 4920 feet starting from the minimum altitude of 800 m / 2624 feet.

3. AVALANCHE CHARACTERISTICS OF STUDY AREA

The avalanche starting zones affecting provincial roads are divided into two major groups that are associated with different management problems depending on local snow-weather conditions. The factor common to both groups is essentially the exposition, being oriented primarily toward the southern quadrant SE-S-SW, whereas for the remaining main features, the two groups can be classified as follows:

**Type A Starting Zones:** characterized by bowl shaped detachment zones with medium - high inclinations (ψ = 35° - 45°) with classes of ground type 2 and 3 represented by coarse scree (N_{CH} ≈ 1.3 to 1.8 or N_{FR} ≈ 2.6) and short grass interspersed with low bushes, (N_{CH} ² ≈ 1.8 to 2.4 or N_{FR} ³ ≈ 2.6) with sliding zones in couloirs, exceeding 1000 m / 3280 Feet. In general, the difference in height between the road and the starting zone does not exceed 500 to 700 m / 1640 to 2296 feet.

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Depending on the range of slope of the starting zone, in this type A group there is the possibility of significant snow accumulations in correspondence with snowfall lasting longer than 3 days (for example in winter 2008 - 2009 the values accumulated in 3 days of $H_s$ exceeded the values of 4.0 to 5.0 m / 13.12 to 16.40 feet).

**Type B Starting Zones:** characterized by starting zone along slopes with medium inclinations ($\psi = 30^\circ - 35^\circ$), with classes of ground type 3 and 4 represented by short grass interspersed with low bushes, ($N_{CH}$ = 1.8 to 2.4 or $N_{FR}$ = 2.6) smooth, long-bladed, compact grass cover($N_{CH}$ = 2.4 to 3.2 or $N_{FR}$ = 2.6) with sliding zones partially in couloir or along the slope, less than 50 to 100 m / 164 to 328 feet long. In general, the difference in height between the road and the starting zone does not exceed 200 to 300 m / 656 to 984 feet.

Depending on the range of slope of the starting zone, in type B group there is the possibility of significant snow accumulations also in correspondence of snowfall of less than 3 days (for example in winter 2008 - 2009 the values accumulated in 1 - 2 days of $H_s$ exceeded the values of 1.5 – 2.0 m / 4.92 to 6.56 feet).

The effects on the area are similar for both groups, and can be summarized as follows: damage to road infrastructure (power lines, guard rails, rockfall barriers, ...), slope erosion (mostly for those in couloirs), removal of portions of the forest, transportation of solids along the couloirs and / or watersheds.

Generally, the avalanche stops and / or crosses the road causing the temporary interruption of emergency vehicles transit \(^4\).

\(^4\) in conditions of risk > 3 the roads are closed to normal traffic and opened only for emergency vehicle transit.
The ways of avalanche formation in the two types of starting zones differ substantially, both in terms of size and in terms of starting. In fact, for type A starting zones, avalanches generally occur in combination with heavy snowfall which completely cover the natural anchors on the ground (coarse scree), in this case the avalanches are of medium size; while for type B starting zones avalanches are very small avalanches generally with $H_s < 1.0$ m / 3.28 feet) or avalanches of small size (generally with $H_s > 1.5$ m / 6.56 feet). Both types occur after moderate snowfall associated with high thermal rises (typical of slopes placed at medium to low altitudes, less than 2000 m / 6560 feet) and are mainly oriented to the south.

The different morphological characteristics of the starting zones, combined with other causes of starting which characterize types A and B, include a local analysis of the evolution of weather characteristics together with the structural and physical properties of the snowpack. Monitoring and understanding changes in snow-weather characteristics that determine the stability or instability of the snowpack allow a management approach to avalanche danger and the reduction of related risks.

4. METHOD OF ANALYSIS

The analysis and assessment of the main snow-meteo characteristics, associated with the analysis of avalanche activity, allow to locally estimate the potential degree of avalanche danger. For the sites in the study, from winter 2008 - 2009, the methods of assessing the degree of avalanche danger developed by Aineva and Meteo France have considerably improved on a local scale.

The first method evaluates the degree of avalanche danger in relation to the combined analysis of the avalanche activity observed, the activity of experts covering the snowy slopes, the hardness profile obtained from the penetrometer test and the test result of the sliding block (flow chart 1 – Figure 6).

The second method evaluates the degree of avalanche danger in relation to the comparison between the analysis of the characteristics of the avalanche activity (related to the type of overload and the number of potentially dangerous slopes) and the analysis of the characteristics of the natural avalanche activity (in relation to the size and spatial density of events) - flow chart 2 – Figure 7.
The validation of the output data resulting from the AINEVA method and the Meteo France method is performed by direct comparison with the predictions of avalanche danger scale bulletin issued by ARPA Piemonte Region (the Southern Pennine Alps area) and in relation to the weather forecast and to the assumptions about the evolution of the physical conditions and resistance of the snowpack on the ground.

Figure 8 below summarizes the method used to assess the danger index on a local scale.


The estimate of the local avalanche danger every bi-week has allowed to reduce, in the last 4 winters, the risks associated with avalanches along the mountain roads in the Province of Biella. In relation to the estimated level of risk, the technical bodies of the Province have kept mountain roads open to traffic in conditions of acceptable residual risk and have prohibited it in conditions of unacceptable residual risk.

“Extreme Winters” associated with avalanche phenomena that characterized the winter seasons of the last 5 years were recorded in 2008 - 2009 with heavy and intense snowfall and in 2010 - 2011 with moderate snowfall associated with high thermal gradients. In relation to the above mentioned “extreme winters”, hereunder is a
summary of both the problems faced when assessing local avalanche danger and the actions taken to mitigate the related risks.

5.1 - Winter season 2008 - 2009
The season was characterized by heavy snowfall (Hs seasonal ≈ 5.00 m / 16.40 feet) and high thermal gradients in late season.

Fig. 9- Hs and snowfall of DH3gg

The main problems faced in the season include:
- the abundant snowfall in the second decade of December: DH3gg 6 approximately 1.16 m / 3.80 feet and a total Hs 7 of approximately 2.50 m / 8.20 feet with a high avalanche activity at all altitudes and at all exposures with a rising in the height of snow cover on three consecutive days of snowfall
- the moderate snowfall of the first decade of March (DH3gg ≈ 0.61 m / 2.0 feet) associated with rising temperatures which resulted in thermal gradients ΔT ≈ 16.3°C in 3 days from T_min = -2.5°C of 04/03 up to T_max = +13.8°C 08/03 with high avalanche activity on southern slopes from altitude of 1400 meters / 426.8 feet with consequent local danger level 4 - High for 8 consecutive days and closure of roads for ≈ 4 days.

5.2 - Winter season 2010 - 2011
The season was characterized by moderate snowfall (Hs seasonal ≈ 3.14 m / 10.30 feet) and high thermal gradients at the end of the season.

Fig. 10 – Min / max seasonal temperatures

Fig. 11- Hs and snowfall of DH3gg

Fig. 12 – Min / max seasonal temperatures

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6 rising in the height of snow cover on three consecutive days of snowfall
7 snow height from the ground, resulting from the data collected by the Arpa control unit in Bielmonte – altitude about 1400 m / 4592 feet
The main problems faced in the season include:

- the weak snowfall during the first decade of March (DH3gg ≈ 0.22 m / 0.72 feet) associated with the presence of widespread wind slabs (soft overlapping hard) and increasing temperatures that resulted in thermal gradients ΔT ≈ 15.7° in 2 days from T_{min} = -0.4° C to 03/03 = +15.3° C to T_{max} of 05/03 with discrete avalanche activity at all exposures starting from an altitude of 1800 m / 547.8 feet with the consequent local danger level 3 - Considerable / 4 - High for 2 consecutive days and no road closure.

- the moderate snowfall during the second decade of March (DH3gg ≈ 0.49 m / 1.61 feet) associated with rising temperatures which resulted in thermal gradients ΔT ≈ 13.2° in 2 days from T_{min} = -0.3° C of 16/03 = +12.9° C to T_{max} of 18/03 with high avalanche activity on southern slopes starting from an altitude of 1600 meters / 487.8 feet with the consequent local danger level 4 – High for 5 consecutive days and road closure for ≈ 2 days.

6. CONCLUSIONS

The reduction of the risk associated with avalanche phenomena, thanks to the application of management techniques aimed at assessing the local dangers, involves an intense and constant monitoring together with data collection and careful and ongoing observation of weather and snow changing conditions acting on the stability or instability of the snowpack.

The local evaluation often helps to appreciate and consider significantly important aspects related to the prevention of potentially dangerous situations that are only marginally described in regional bulletins on a larger scale.

7. THANKS

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9. DEDICATION

This work is dedicated to our dear friends Marco and Anna, forever in our thoughts.