THE AVALANCHE MONITORING SYSTEM OF MOUNT PIZZAC

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ABSTRACT

The monitoring system of Mount Pizzac has been created in order to study the avalanche dynamics and the effect of its impact on the structures.
In its extreme dimensions the monitored avalanche gets off at 2200 meters and stops at 1745 meters, thus following a trajectory of 836 meters with an average gradient of 31°.
The necessary structures for monitoring have been installed in the track of the gully between the above limit of the flowing zone and the central track of the accumulation zone, for a whole length of 418 meters. They allow to observe the development of the event, thus recording continuously: pressures, speed and geometric variations of the body of the avalanche.
In particular six steel poles, each one fitted out with n. 8 pressure measuring devices (each one with an area of 7850 mm²) allow to determine the profile of the pressures continually with a resolution of 50 cm up to a maximum height of 5 m. Moreover, five of the six poles placed along the flowing zone of the avalanche are fitted out with measuring devices able to check the flow height, allowing the recreation both in time and space. A small-sized wedge-shaped obstacle (area 1 m²) allows to estimate the influence of the form and area over the power of the avalanche impact.
Furthermore, knowing the time when the avalanche flow passes by means of sections placed at known distances, it is possible to determine the average speed of the front in 14 tracks of the flow line.
The monitoring system has three cameras which permit to record the event automatically.
15 events have been recorded since 1993, when the monitoring system was first installed. The avalanches which occured most frequently were wet snow flowing avalanches in springtime and dry snow flowing avalanches in wintertime, with average volumes of 2000 m³. Particularly for average speeds of the avalanche front ranging from 2.5 to 23 m/s, the pressures have recorded variable readings going from 5 to 175 kPa.

INTRODUCTION

The monitoring system of the dynamic parameters of Mount Pizzac has been created by the Experimental Centre for Avalanches and Hydrogeologic Defence in Arabba (CSVDI) which carries out studies and researches aiming at protecting the mountain environment and at defending from natural dangers, this within the Veneto Region.
The system has been installed in order to acquire real data about speed, pressures and flow height of an avalanche representative of the specific territorial context. These data are necessary for the calibration and the validation of calculation models which are indispensable for the drafting of maps and plans of the avalanche danger, for the right planning of works of artificial triggering and the design of passive defence works.

ILLUSTRATION OF THE MONITORED SITE

The avalanche site of Mount Pizzac is located on the western site of the homonymous mount, near Arabba in the province of Belluno.
The reasons for the choice of this site are the following:
- it is near the headquarters of CSVDI and therefore allows a continuous control and a quick access;
- it is subordinated to a system of artificial triggering (CA.T.EX.), by means of which avalanches are induced, also with low new snow supplies.

Morphologically the site is characterized by a funnel-shaped side in the upper area, by a tight channel in the central area and by the confluence of two ski runs in the lower area. Altogether it develops from 2200 to 1745 m a.s.l for a length of 836 meters and an average gradient of

31°.
The avalanches occurring here are of two types:
- dry or slightly moist snow avalanches during the central period of the winter season (average mass of the snow = 160 Kg/m^3), mixed-motion avalanche, with average speeds ranging from 23 to 6 m/s and maximum pressures of 175 kPa. They are mostly avalanches by loose snow or surface soft slabs and they stop eiher in the final track of the channel or along the ski runs below.
-wet-snow avalanches at the end of the winter season, (average mass of the snow = 294 Kg/m^3), flowing avalanches, with average speeds ranging from 11 to 1.5 m/s and maximum pressures of 130 kPa. They are natural loose snow avalanches of moderate dimensions, and they usually stop along the gully but rarely get to the ski runs below.
Until now 15 events have been recorded, of which 6 were significant. 1 occurred during the winter season 93-94; 1 in the winter season 94-95; 1 in the winter season 95-96; 1 one in the winter season 96-97; and 2 during the winter season 97-98.

CONFIGURATION OF THE SYSTEM

The system covers a track of 418 m of the avalanche site, corresponding to about the length of the gully.
Formerly, in 1993, the site was monitored by means of the following equipment:
- n.5 steel poles, being 5 meters high, the first, the second and fifth being fitted out with n. 8 pressure measuring devices;
- n.8 vibration measuring devices for the measurement of the speed of the avalanche front and n. 3 ultrasound gauges of the flow height, scarfed to a steel rope set at the head of the poles.

In 1995, a first supplement was carried out. It consisted in installing a sixth pole and n. 8 pressure measuring devices on each pole not provided with the latter.
In 1997 the system was strengthened further through the addition of a wedge-shaped pressure measuring device set on the third pole, of measuring devices of the flow height set on the borders of the remaining 5 poles and of a video recording and check system by means of 3 cameras of which two were panoramic and were set on the opposite side and 1 was thematic and placed on the top of the pole fitted out with the wedge-shaped measuring device.

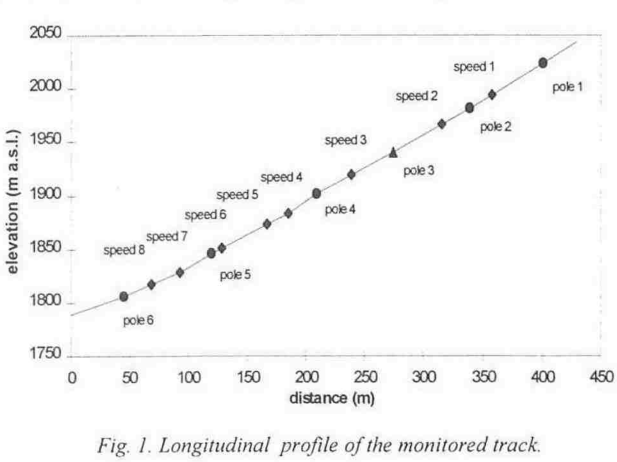

Fig. 1. Longitudinal profile of the monitored track.

Therefore, the present system is shaped as follows:

Infrastructure

The monitoring system is made up of an infrastructure formed by six steel poles, set perpendicularly to the ground along the gliding track of the avalanche. At the head of the poles a steel rope is stretched.
Eight pressure measuring devices are set on each pole for a total amount of 48 measuring devices. On the connecting rope n. 8 measuring devices are scarfed, in order to survey the passage of the avalanche front and therefore to determine the speed of the latter (fig. 1).
Five of the six monitored poles are fitted out with measuring devices able to survey the height of the avalanche, thus allowing the construction of its geometric profile.
The third pole starting from the top has been fitted out with a wedge-shaped physical model.

Cameras

Two cameras capable of recording the event and surveying the conditions of the whole site before, at the moment and after the event, have been intalled on the side opposite the avalanche site.
One of the two cameras has an electric zoom and a motorized traverse, the second has a fixed focus.

Speed sensors

The speed of the avalanche front is obtained by fixing the passage of the snow mass in points of survey set at known distances and this does not allow the definition of the instantaneous speed but the average speed in the track included between two consecutive sensors.
Eight speed sensors hanging from the aerial rope are set to the six points corresponding to the monitored poles.
These sensors are made up of an aluminium pole hanging from the rope to which a movement transducer of the vibration kind has been fixed.

Pressure measuring devices

The dynamic pressure performed by the snow mass is checked by sensors which have beeen installed on the front part of each pole.
On each pole, set perpendicularly to the ground, eight sensors at an approximative distance of 0.60 m have been installed, for an overall number of 48 pressure measuring devices.
The measuring devices are mechanical with a resistive transducer.
The dimension of the front surface of contact, for each sensor is 78.5 cm^2, corresponding to a diametre of 0.10 m; the reaction springs foresee the final stroke at about 200 kg corresponding to a maximum value of pressure equal to 250 kPa.
The system of acquisition allows a frequency of sampling of about 160 Hz for each sensor, for an overall recording

time equal to 5 minutes.

Flow height measuring devices

On the borders of five of the six equipped poles, mechanic measuring devices have been put. These are able to check the flow height through contact with the moving snow mass.

They are constituted of a series of microswitches set at intervals of 5 cm along the pole axle.

In correspondence to the third of the six monitored poles, without such sensor because it is fitted with a wedge-shaped physical model, one can go back to the flow height in relation to the number of pressure cells affected by the phenomenon. In this case the margin of error can get to 0.6 m, corresponding to the distance between two cells.

The acquisition system allows a frequency of sampling of about 160 Hz and 4000 Hz respectively for an overall recording time equal to 5 minutes.

Model of small-sized wedge fitted out with a camera

A small-sized physical model, wedge-shaped, has been fixed at the third monitored pole and permits to study the dynamic pressure of the avalanche on a surface with a predetermined form.

The collision surface perpendicular to the direction of the flow is equal to 1 m^2, the angle of incidence is 60°.

The acquisition system allows a double frequency of sampling of about 160 Hz and 4000 Hz respectively for an overall recording time equal to 5 minutes.

A camera with fixed focus, set at the extremity of the pole with the framing perpendicular to the avalanche flow allows to observe the disposition of the flow lines around the obstacle during the event and the disposition of the deposit.

N°	C.	Data	Tipo	Speed (1)		Pressure	Pmax	Speed
				sen s.	pole	sen.	kPa	m(s)
1	1	08-01-94	Dry / loose	8	3	16	174.6	23.2
2	1	09-03-94	Moist / loose	5	2	2	28.4	6.1
3	1	09-04-94	Moist / loose	1	2	2	8.8	11
4	1	15-04-94	Moist / loose	3	2	2	12.8	5.6
5	1	17-04-94	Moist / loose	1	2	2	6.9	3.9
6	1	17-04-94	Moist / loose	2	2	3	28.4	6.2
7	1	27-02-95	Dry / slab	7	3	9	66.7	19.2
8	1	09-03-95	Dry / loose	2	2	2	6.9	7.8
9	1	24-03-95	Moist / loose	1	1	1	4.9	1.5
10	1	06-04-95	Moist / loose	2	2	2	31.4	6.3
11	1	21-04-95	Wet / loose	1	1	1	10.8	1.5
12	2	24-03-96	Wet / loose	-	4	10	129.5	12.6
13	2	04-01-97	Moist / loose	8	6	23	82.4	6.2
14	3	05-12-97	Dry / slab	6	6	10	44.1	9.5
15	3	21-12-97	Dry / slab	6	6	34	150.1	20

Tab. 1. Events recorded by the monitoring system. N= progressive, C=configuration. The columns speed (1) and pressure report only the number of activated sensors

RECORDED EVENTS

Table 1 reports some information relative to the events recorded from 1994. Even though the configuration of the system has changed and consequently the type of collected measures, the three fields indicated by number 1, 2, 3 corresponding respectively to the configurations of the seasons 1993÷1994, 1995÷1996 and 1997÷1998 are stressed in the table.

To show the potentiality of the system, the dynamics and the relative data acquired from the avalanche which occurred on the 21.12.97 will be analysed, for it is the most complete to allow an analysis of the characteristics of the system with its present configuration.

EVENT OF THE 21TH OF DECEMBER 1997

The examined event, induced artificially, took place at 8.05 a.m. as surface soft slab avalanche consisting of dry snow and with mixed gliding, as a consequence of new snow supplies (70 cm) during the previous 48 hours.

The avalanche ran through the monitored site entirely, affecting the ski run below for a track of 50 m where it stopped its run leaving a deposit consisting of round-shaped blocks behind.

Pressure values were recorded on each of the six monitored poles for an overall number of 34 sensors, average speed values of the front in the six points corresponding to the poles and in 6 of the 8 points corresponding to the staff sensors; values of the avalanche flow, which furnished the geometric profile both in space and time of the avalanche in each of the 5 prearranged points.

Even in the morning hours, the discrete conditions of visibility at the moment of release permitted the recording of the event as it developed, by means of prearranged cameras. The latter allowed an estimation of the front speed also in the unmonitored zones.

Besides, through a survey after the event, a series of very detailed nivologic information were collected. They have allowed the estimation of the mass balance of the event.

In particular strata profiles in proximity to the release zone and in correspondence to the major deposits along the gliding zone and the accumulation zone were carried out. Along the whole avalanche site a series of transverse sections were considered. In correspondence to these, values of the snow cover height were checked and analyses of stratigraphy of the snow cover able to single out snow masses which had been drifted by wind and deposited by the progressing avalanche.

Avalanche speed

The speed sensors together with the six monitored poles permit to establish the time when the front passes on 12 sections of measurement along the equipped track.

But if the checked data with respect to the six poles turn out to be definite, the precise identification of the passage of the front with respect to the staff sensors requires an interpretation of the signal able to single out pre-recordings due either to vibrations driven into the cable supporting the sensors and stretched longitudinally at the head of the poles, or in turbulent forms which precede the avalanche front.

As regards this event some discontinuities found between these two methods of measurement advise against using the data furnished by the staff senors. But the values relative to the monitored poles together with the speeds deduced from the recording of the event relating to to the starting zone allow to point out the correlation both in space and time displayed in figure 2.

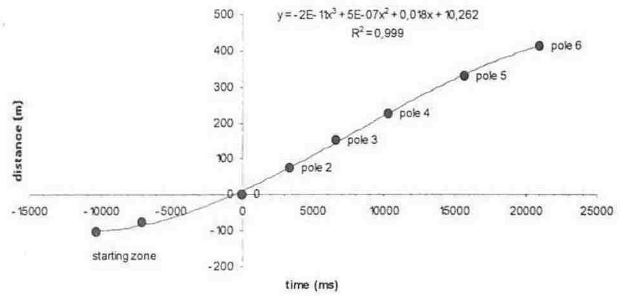

Fig. 2. Spatial and temporal correlation relative to the motion of the avalanche

The negative abscissa reports the trajectory of the avalanche preceding the monitored site. It corresponds mainly with the release area and the first part of the gliding zone. The abscissa, instead, coincides with the monitored part relating to the gliding and the beginning of accumulation (pole 6).

Profile of the avalanche

The five geometric profiles of the avalanche which were surveyed along the gliding zone point out a progressive temporal dilation of the event. The latter correlates well with the progressive decrease of the speed which the avalanche had when it ran down towards the valley (Fig 3).

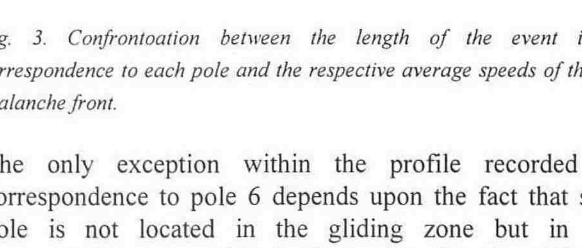

Fig. 3. Confrontoation between the length of the event in correspondence to each pole and the respective average speeds of the avalanche front.

The only exception within the profile recorded in correspondence to pole 6 depends upon the fact that said pole is not located in the gliding zone but in the accumulation zone. This is the reason for the different behaviour.

In fig.4 two of the five profiles relative to respectively pole 1 and 2 are reported as examples.

The analysis of one profile type admits to determine both the preexistent snow height and the snow height after the event and therefore allows to establish the quantity of wind-drifted snow amounts and deposited in correspondence to the monitored pole.

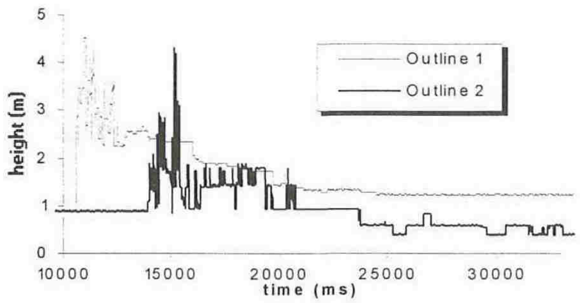

Fig. 4. Avalanche profiles recorded in correspondence to pole 1 and 2

It allows, moreover, to determine the maximum height reached by the avalanche, which generally coincides with its front, and the duration of the event.

In particular, in profile 1, the avalanche front turns out to be easily identifiable; it is characterized by maximum height values (4.5 m maximum height reached by the avalanche along the whole trajectory) and by big oscillations probably caused by the impact of blocks with a high density which were carried on the surface to which a constantly decreasing trend follows, corresponding to the body of the avalanche for an overall length of 15 s.

The analysis of profile n° 1 emphasizes the presence of a preexistent snow cover about 90 cm high on which the avalanche seems to have glided without causing its erosion, leaving a snow deposit behind after its passage. The latter has made the snow cover rise at a height of about 1.3 m.

The second monitored pole, to which corresponds profile 2, has been located in a decentralized way with respect to the bottom of the gliding channel of the avalanche. This gets also the profile to refer to a more external section with respect to the centre of the avalanche and the trend of the former to be no longer decreasing uniformly but to present some discontinuities which make the clear identifying in the passage between the front and the body of the avalanche difficult.

Pressure values

The graphics of figure 5 which define the output typology of the measures relative to the sensors of pole 1 situated at 2024 m a.s.l. consent to an interesting analysis of the avalanche dynamics in a determined section.

The numeration of the sensors is increasing from the bottom to the top and that is why sensor 1 turns out to be the nearest to the ground.

In all diagrams the profile of the avalanche (thin line) was reported, the pressure value recorded by a specific sensor (thick line) and the straight line of reference which indicates the height inside the avalanche body to which the pressure value refers to.

This disposition of graphics easily allows to associate the pressure value with the avalanche area to which it refers.

The sensors checking the avalanche profile are more sensitive than pressure measuring devices; though having a signal of passage from the sensors of the flow height, this gets the pressure measuring devices to record no values, even though dipped into the snow mass.

In most cases of signals recorded by pressure sensors it is possible to see some typical trends with regard to sensors located at the inside of the preexistent snowpack, which do not suffer or only partly feel the load of the avalanche (sensor 1). Some trends are also to be seen in the sensors knocked down by the central mass of the avalanche, which survey average constant and high pressures (sensors 2 and 3) and in more superficial sensors which present a strongly irregular trend with fast fluctuations of pressure (sensors 4,5 and 6).

It is interesting to observe that whereas measuring device 3 started to survey a signal at the same time as measuring devices of the flow height did, the measuring device 2 presents a slight delay; this presupposes that at first also this measuring device was at the inside of the snowpack and that the snow which covered it had been undermined by the passing avalanche, although the sign of the measuring device of the flow height indicates the contrary. This can be explained by the fact that minimum power is necessary to open the switches forming the height sensors and probably the superficial stratus of the preexistent snow cover had not sufficient energy.

The maximum pressure values were recorded in correspondence to the sensor nearest to the ground knocked down directly by the moving mass (sensor 2); nevertheless high pressure values were recorded in correspondence to sensor 4, coinciding presumably with the surface of the flowing part of the avalanche and caused by isolated blocks with high density which produced pressures near to 80 kPa.

The physical model located in correspondence to the third pole at a ground height equal to 50 cm, did not furnish interesting data concerning pressures because it had been submerged in the deposit of the preceding avalanche. The recorded values went only just over 1 kPa against 150 kPa recorded in correspondence to the same pole from the measuring device set at 1.7 m from the ground.

CONCLUSIONS

After the period of planning, carrying out and supplement of the system, completed by now, the development of the work will consist both in acquiring the highest number of possible data relative to avalanche events with various characteristics furnished by the system and supplemented with measurements on the ground, and technological development in order to acquire also data concerning the flow density, internal speed profiles and shear stress.

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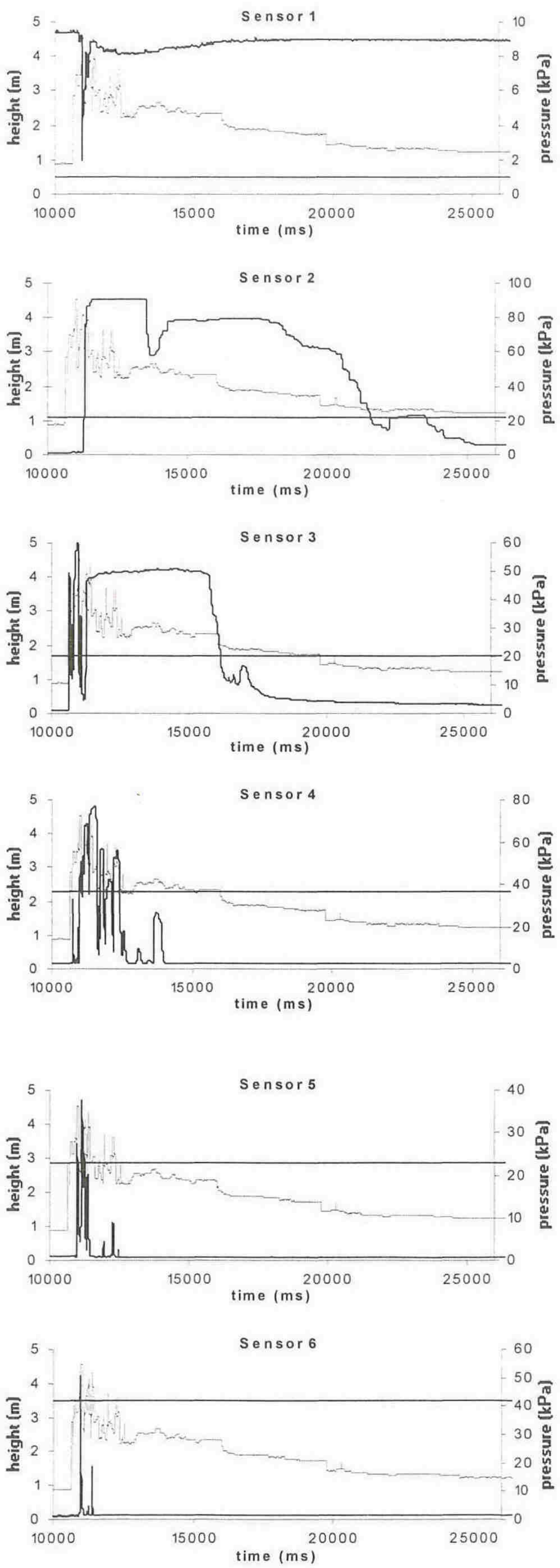

Fig. 5. Pole 1. Avalanche profile (thin line) and pressures done by the latter at different heights (thick line). The straight line indicates the height at which the pressure measuring device is located.

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