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BY

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OBSERVATIONS DES PRESSIONS DUES A L'IMPACT D'UNE AVALANCHE

SOMMAIRE

On a observé les pressions dues à l'impact produit par des avalanches de neige sèche bien développées. L'auteur décrit l'équipement utilisé et donne un aperçu des résultats préliminaires de deux années d'observations. Il existe une forte variation de pression durant le passage d'une avalanche. La pression maximum, p, observée plusieurs fois au cours d'une avalanche, est $p = \frac{\rho v^2}{2}$, v étant la vitesse apparente du front de l'avalanche et ρ la densité de la neige déposée. On a trouvé une pression moyenne de 0.3 p.

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OBSERVATIONS OF AVALANCHE IMPACT PRESSURES[1]

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ABSTRACT

Observations were made of impact pressures produced by well developed dry snow avalanches. The equipment is described and preliminary results of two years observations are summarized. There is a strong variation of pressure during the passage of an avalanche. The peak pressure, p, observed several times in one avalanche, can be expressed as $p = \rho v^2/2$ with v the apparent speed of the avalanche front and ρ the density of the deposited avalanche snow. The average pressure was found to be 0.3 p.

Introduction

Impact pressures due to snow avalanches influence the design of structures such as bridges and towers of powerlines, which are located in their potential path. The Division of Building Research of the National Research Council of Canada initiated observations of impact pressures with the objective of obtaining information concerning the characteristics of avalanches and the loads produced by them on structures. Studies were carried out at Rogers Pass, British Columbia, where numerous avalanche paths are easily accessible from the Trans Canada Highway.

Observation Site and Equipment

An avalanche path was selected where more than 10 avalanches occur every winter. The avalanches originate 2,100 m above sea level and fall over steep rock and a snow-filled gully to the observation site at 1,330 m. For 200 m above the measuring site, the avalanche track is a straight channel with an average incline of 33°.

Several load cells were mounted on a steel frame in the center of the track (fig. 1). The cells had a surface area of 645 mm^2 (1 $inch^2$). They were placed in cylindrical, streamlined steel holders, which, in turn, were mounted on a steel vertical beam. The beam had a width of 50.8 mm (2 in.) and so was a minor obstruction to the moving snow. Impact pressures were measured with strain transducers and recorded on a light beam oscillograph at a sheltered location.

Numerous difficulties and failures of equipment had to be overcome during the first 3 years before reliable observations were obtained. Between 1970 and 1972, however, impact pressures produced by several dry snow avalanches were recorded.

Figure 1.--Steel frame with two load cells.

[1]This paper is a contribution of the Division of Building Research of the National Research Council of Canada, and is published with the approval of the Director.

Characteristics of a Dry Snow Avalanche

Dry snow avalanches become a mixture of flowing and airborne powder snow when falling over steep and irregular terrain. Visual observations of moving and deposited avalanche snow indicated that the flowing part consists of an aggregate of particles that range between powder of size 0.1 mm to balls about 100 mm in diameter. The depth of the flowing snow could be estimated from traces on the side of gullies and from the height to which snow was pressed against tree trunks in avalanche tracks. Numerous observations of this depth were made in the Rogers Pass area, and it was found to be usually three to four times greater than that of avalanche snow after it came to rest. The bulk density of the flowing snow, therefore, can be assumed to be about 0.3 times the density of the deposited snow.

The speed of the avalanche was determined by timing the avalanche front as it moved over a known distance in front of the load cells. The speed of the avalanche front may not be equal to that of the flowing snow behind the front, but it was the only speed observation that was practical.

Recorded Impact Pressures

The number of pressure cells was limited and allowed the observation of the impact pressure of the dense, flowing part of the avalanche only to a height of about half its depth. Figure 2 shows the pressures observed during the passage of an avalanche.

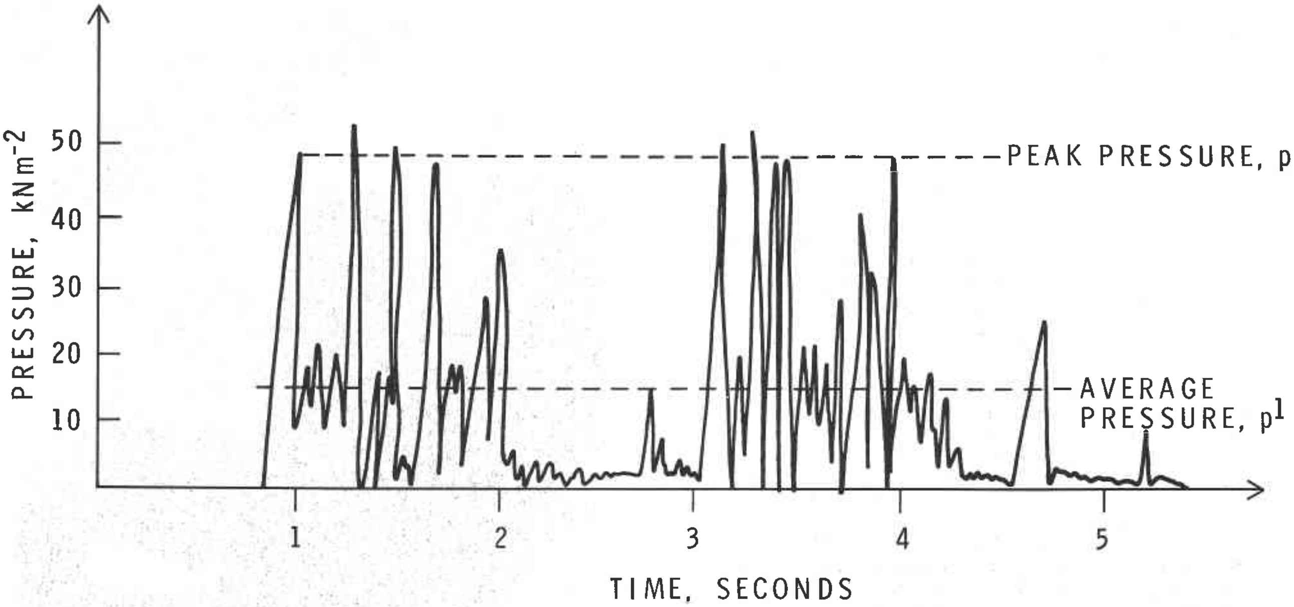

Figure 2.--Record of observed pressures.

Noteworthy is a series of pressure peaks with a duration of about 1 second and a recurrence period of about 2 seconds. They are probably the result of the complex nature of the start of the avalanches in irregular terrain. Snow would start to slide almost simultaneously at many places, but arrive at different times in the principal avalanche track, and, therefore, continue its motion in several mass waves. Recurring sets of peaks were not observed with minor avalanches that contained snow from only one small area of more or less uniform slope. Differences in particle size and bulk density are responsible for the fluctuations in pressure. Snowballs impinging on the load cells produced the peak pressures, and snowdust the low pressures.

A more uniform pressure with a small variation between extremes would probably be observed by using a cell with a larger measuring surface.

Analysis

The most advanced studies of avalanche dynamics are those by Salm (1967), Shen and Roper (1970), and Voellmy (1955). They considered the moving snow to be a compressible solid body or fluid.

If it is assumed that there is little compaction of the snow and little drag resistance associated with small obstacles, such as the load cells and the supporting frame used for the study, the impact pressure on unit surface area perpendicular to the flow can be expressed as:

$$p = \frac{v^2}{2} \rho$$

It was found that the observed peak pressures, p, agreed with the calculated pressures when v = the speed of the front of the avalanche, and ρ = the density of the deposited snow after the avalanche had stopped. (The density of the deposited snow would probably be equal to the density of large particles in the moving snow.)

The observed average pressure agreed with the calculated pressure

$$p = \frac{v^2}{2} \rho'$$

when ρ' was the average density of the following snow, or $\rho' = 0.3\ \rho$. Values of observed peak and average pressures, and corresponding calculated values are presented in table I.

TABLE I

OBSERVED AND CALCULATED IMPACT PRESSURES

Date	Speed, v $m\ s^{-1}$	Density of Deposit, ρ $kg\ m^{-3}$	Peak Pressures p $kN\ m^{-2}$* Observed	Peak Pressures p $kN\ m^{-2}$* Calculated	Average Pressure p' $kN\ m^{-2}$* Observed	Average Pressure p' $kN\ m^{-2}$* Calculated	Depth of Flowing Snow m
7 Dec 1970	35.7	350	182	222	62	67	2.5
30 Dec 1970	53	310	256	435	105	131	1.8
16 Jan 1971	14.8	260	30	28	7.7	8.5	1.5
27 Jan 1971	14.7	225	35	24	8.3	7.2	0.9
30 Jan 1971	19.1	320	60	58	16	17.4	3.0
23 Dec 1971	21.6	210	33	49	11.0	14.7	1.5
16 Jan 1972	16.9	300	38	43	11.7	12.9	1.5
20 Jan 1972	18.5	280	48	48	13.8	14.4	1.2

* $1 kN\ m^{-2} = 0.145$ psi

Conclusions

The study indicates that for practical purposes the impact pressure produced by dry snow avalanches can be calculated from the speed of the avalanche front and the density of the deposited snow.

The observations were made on avalanches of relatively low speed with a small loading surface. In future studies it will be necessary to measure: (1) impact pressures on large surfaces; (2) impact pressures produced by avalanches with high speed; and (3) the distribution of the pressures over the full depth of avalanches.

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