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Measurements and analysis of full-scale avalanche impact pressure at the Vallée de la Sionne test site

Betty Sovilla *, Mark Schaer, Lambert Rammer [1]

WSL, Swiss Federal Institute for Snow and Avalanche Research SLF, CH-7260, Davos Dorf, Switzerland

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Abstracts

Impact pressures of eight snow avalanches measured at the Swiss avalanche test site Vallée de la Sionne are reported. Avalanche typologies varied between dense and powder. Measurements were performed on obstacles of different shape and dimension. High-frequency pressure sensors were mounted on a 20 m high tubular pylon and on a 5 m high steel wedge. To interpret the influence of sensor dimension on impact pressure measurements, the total pressure exerted on the steel wedge was recorded using two bi-axial sensors and compared to the pressure recorded by the high-frequency sensors. On a small concrete wall, a 1 m^2 pressure plate mounted with 4 load-gauge bolts measured normal and tangential forces. Along the tubular pylon (between 1–6 m above ground) optoelectronic sensors recorded the avalanche flow velocity. Flow depths were measured by mechanical sensors. Analysis of high resolution impact forces in combination with velocity measurements allowed us to reconstruct the flow structure. We combined impact pressure with observation on avalanche structure to obtain load distribution and size effects for different avalanche typologies. Measured pressures are compared to the existing Swiss calculation procedure. It is shown that actual calculation formulas are not able to properly reproduce the measured pressure values and the load distribution.

Keywords: Vallée de la Sionne; Avalanche impact pressure; Avalanche velocity

1. Introduction

The design of avalanche defense measures requires an estimate of impact pressure and vertical load distribution. Different countries use different procedures which raises questions on the validity of the different calculation methods. In this work we will concentrate on avalanche impact pressure on small obstacles and on the Swiss procedure described in Salm et al. (1990). Salm et al. (1990) estimate avalanche impact pressure using a simple hydraulic relation of the form $p = \frac{1}{2} C_d \rho v^2$ where ρ is the snow density, v the avalanche velocity and C_d a drag coefficient. While in granular flow literature C_d is a complex function of flow regimes, obstacle shape and dimension (Wassgren et al., 2003), for the Swiss procedure C_d is a simple function of obstacle geometry and varies in the range 1–2 for small obstacles of square and round shapes, respectively. The Norwegian procedure (Norem, 1990) applies a similar hydraulic relation to predict the magnitude of the pressure but applies a different range of C_d (up to 6 for mast-like structures).

* Corresponding author. Swiss Federal Institute for Snow and Avalanche Research Flüelastrasse, 11, CH-7260 Davos Dorf, Switzerland. Tel.: +41 81 417 02 63; fax: +41 81 417 01 10.
E-mail address: sovilla@slf.ch (B. Sovilla).
[1] Austrian Institute for Avalanche and Torrent Research, Innsbruck, Austria.

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The most important shortcomings of Salm et al. (1990) formulation are the too simple definition of the drag coefficient and the fact that this calculation method does not take into account different avalanche regimes, i.e. slow wet avalanches or fully fluidized powder flow. Sovilla et al. (submitted for publication) show a correlation between drag coefficient C_d and avalanche flow regimes with C_d varying widely.

Another important concern is the necessity to take into account the avalanche stagnation height when calculating vertical load distributions.

The Swiss procedure assumes the maximum height the avalanche reaches on the obstacle, as the sum of the snow cover lying on the ground, the avalanche incoming flow depth and a kinetic term describing the stagnation height of the flow, i.e. the height the avalanche can climb the structure using part of its available kinetic energy. Dissipation effects are taken into account by an empirical coefficient λ.

The concept of stagnation height or avalanche run-up was also employed in previous studies on avalanches on slopes opposite to the avalanche track (McClung and Mears, 1995). The aim of these studies was to determine how much the avalanche can climb the opposite slope using its available kinetic energy and taking into account the energy dissipated in the impact.

This concept is also used in the Swiss procedure to describe the run-up on small structures. The procedure introduces a reduction factor to take into account that the avalanche can partially escape laterally. However, for fast avalanches the run-up height and its contribution to the overall avalanche force may be very important.

On the contrary, Norwegian procedure localizes the avalanche main load at a height range corresponding to the upstream avalanche flow depth and only marginal loads are considered to act on the height ranges corresponding to the snow cover, saltation and suspension layers. There is no mention of avalanche run-up.

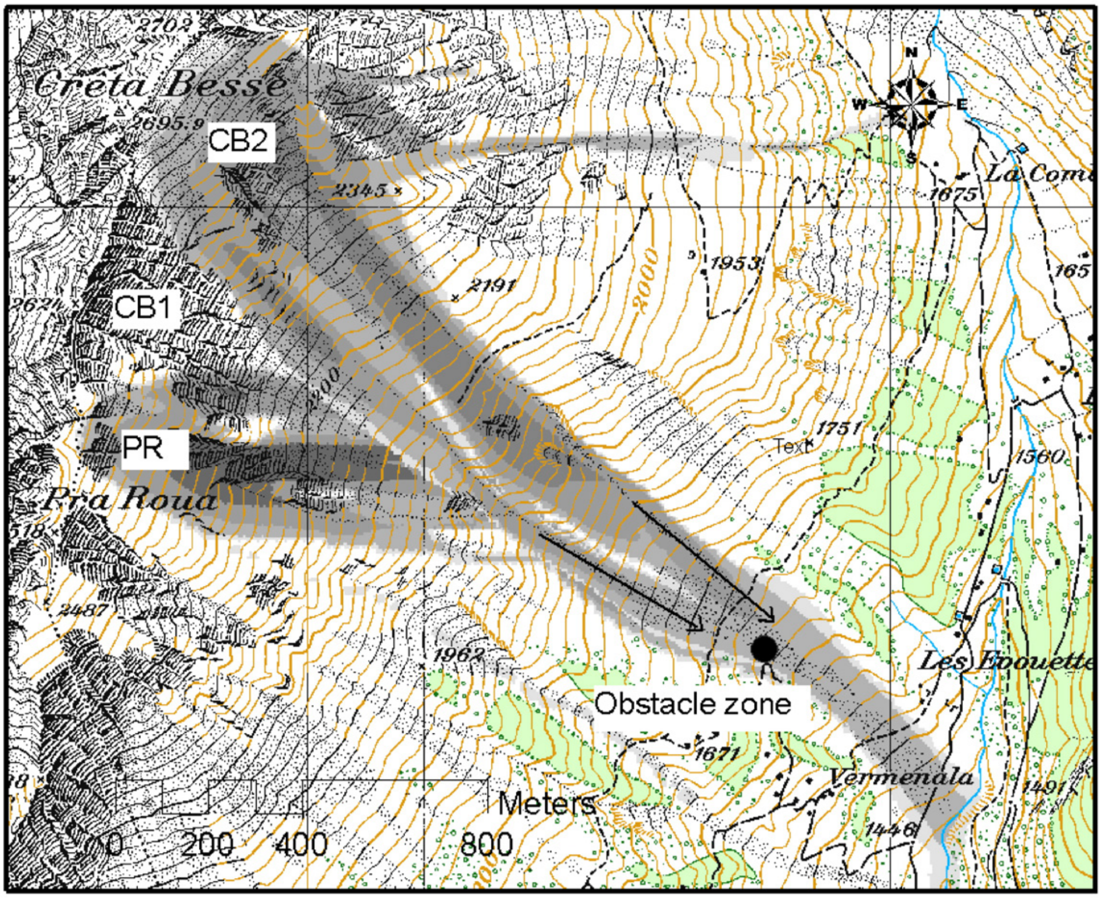

Fig. 1. Overview of the Vallée de la Sionne test site. The release zones Pra Roua (PR), Crêta Besse 1 (CB1) and Crêta Besse 2 (CB2) are marked. The shaded regions represent the typical paths followed by avalanches released from Pra Roua and Crêta Besse 2.