Name of research institute or organization:

Laboratory of Hydraulics, Hydrology and Glaciology, Swiss Federal Institute of Technology, Zürich

Title of project:

Glaciology : Stability of hanging glaciers

Project leader and team:

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Project description:

Goal of the project

The prediction of the breaking off time of unstable ice masses can be important if settlements or other installations (roads, railway, etc) exist within the potential hazard zones of a glacier. Until now predictions of the failure time of hanging glaciers is based on three studies: two studies (Röthlisberger, 1977 and Flotron, 1977) propose an empirical formula for the determination of the failure time. The third study (Iken, 1977) is a theoretical validation (with a numerical model) of the formula proposed by the two other studies for the special case of calving glaciers.

$$u(t) = u_0 + \frac{a}{(t_f - t)^m}$$

with $u(t)$ the speed of the measured point,
and u_0, a, m, t_f the parameters to be determined with data;
t_f corresponding to the time of breaking off.

Failure time formula by Röthlisberger and Flotron

The aim of the present project is a better prediction of breaking off events. The empirical formula (by Röthlisberger, 1977 and Flotron, 1977) for the determination of the failure time has to be validated in two ways: theoretically with a numerical model, and experimentally with measurements done on several hanging glaciers. Two types of hanging glaciers with different ice temperatures and different volumes of unstable ice blocks are considered (see Figure 1).

Measurements

All measurements listed in this section will be used in the present project. Two types of glaciers are -or have been- observed (see Figure 1). The first is a ramp-type glacier (ice slab frozen on the bedrock). In this classification are the hanging glacier on the Weisshorn north face (measurement were performed in 1973) and the hanging glacier on the south face of les Grandes Jorasses (measurements in 1997-98). The second type of observed glaciers are break-type glaciers (ice segment failure at the front of

the glacier). Among those are the hanging glacier of the Eiger west face (1990 and measurements in progress) and the Mönch south face glacier (in progress).

Temperature, ice thickness and velocity measurements have been performed on all glaciers mentioned above. Boreholes were drilled to determine the depth of the ice (radio echo sounding cannot be applied dire to the high density of cracks in such glaciers) and thermistors are installed into these holes to measure the ice temperature. The measurements are performed to determine the parameters for the numerical model computation aiming to simulate the movement of the glacier. The third measurement is the determination of the position in function of time of a finite number of points on the glacier. The points are marked with reflectors and the position measured with a theodolite-laser distometer. Acceleration curves are derived from these measurements.

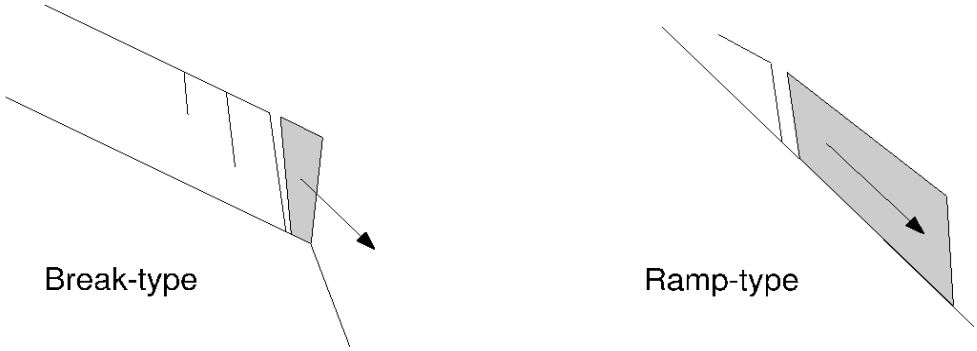

Figure 1 : The two principal types of hanging glaciers

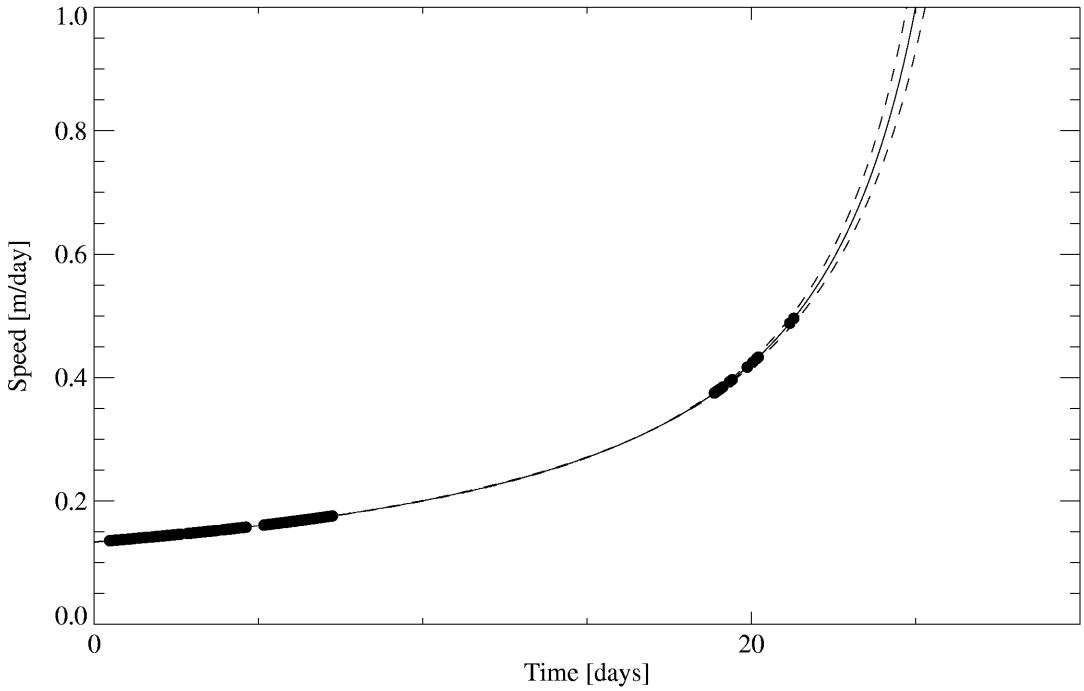

Figure 2 : Typical acceleration of ice mass before breaking off

This measurement has been performed on the Eiger glacier in 2001. The predicted failure time was on August 22 + or -1 day. Because of fracturation of the unstable ice mass, the first pieces of the unstable ice mass began to fall five days before the predicted time. The failure process continued over an entire week. This example illustrates the limitation of a forecast.

Six boreholes have been drilled in summer 2001 during a field campaign on the Mönch glacier. Ice thickness varied between 63 m and 82 m. Thermistor chains equipped with 8 thermistors were installed in each borehole. Temperature was measured during three month. The measurements showed that the glacier is temperate. Seven reflectors have been installed and an automatic theodolite-laser distometer measures their position every hour. One reflector is used to measure the surface velocity of the stable part of the glacier and the others to measure the displacement of unstable ice masses. Four reflectors have registred breaking off events and the two others are still measuring. The data processing is still in progress.

Two reflectors have been installed in July 2001 on an unstable ice mass at Eiger glacier. Figure 2 shows the result of these measurements. After breaking off, two other reflectors have been installed and are still measuring. Temperature measurements as well as the determination of the geometrical tongue profile have been performed in 1993 on this glacier (Lüthi, 1994).

Modeling

In addition to the validation of the failure time determination method, a special goal of the modeling is a better physical understanding of the breaking off process. The numerical model is a finite element model, in which a implemented continuum damage mechanics model is used to compute the progressive fracturation of ice. First results from this model are expected within half a year.

Key words

hanging glacier, prediction of breaking off, damage mechanics

Collaborating partners/networks:

http://glaciorisk.grenoble.cemagref.fr/

Scientific publications and public outreach 2001:

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