Historical background of the research project: Snow Avalanches

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In the Norwegian Parliament it was once stated:

Slides and avalanches can be divided into two main groups:
1. Those which are released by gravity
2. Those which are released by themselves.

I will talk about group nr. 1
Startup in 1972

The Norwegian Parliament also stated:

- «Snow avalanche research will be located at the Norwegian Geotechnical Institute, Oslo.»
- «A snow avalanche research station is a prerequisite and must be built in an avalanche-prone area.»

Fonnbu, the research station, was built at Strynelfjellet, in 1973:

- Field work started January 3, 1974.
- The first avalanche was observed January 4.
1. Weather, snow cover and avalanches

**Purpose:**

- Investigate weather situations and snow cover characteristics with importance for snow avalanche release.
- Improve methods for snow avalanche hazard forecasting.
Snow cover and avalanches
Snow cover and avalanches

- Hard field work
- Several hundred pits and snow profiles were dug. Every two weeks, at several locations for several years
- Temperatures, densities, stratification were measured
- Shear tests performed
Snow cover and avalanches in the western mountains

Main conclusions:

- The top of the snow cover is the most unstable and most important for avalanche release
- The lower parts of the snow cover are usually stable, with high densities and strength
- Temperatures at the base are usually zero degrees
- Temperature gradients in the snow cover are usually low
- But not always....
Weather conditions and avalanches

Objectives:
1. Better understanding of the relation between weather and avalanche hazard
2. Improving hazard forecasting
Weather conditions and avalanches

Main conclusions:

- Nearly all winter avalanches are direct action avalanches. Triggered during a snow storm or shortly afterwards.
- Caused by heavy precipitation, often in connection with frontal passages and short-time intense precipitation.
- Very seldom triggered by structural changes deep in the snowpack.
Probability for avalanche release

- 3-day precipitation compared to avalanche probability
- 4 different avalanche paths
- Cumulative normal distribution
- Objective method for the probability of avalanche release

These results will be commented upon by Peter Gauer a little later.

Bakkehøi 1987
Mechanical properties of snow

NGI’s Direct simple shear test apparatus
Testing of the shear deformation characteristics of snow
Mechanical properties of snow

- Direct shear tests performed in the cold lab at NGI and at Fonnbu
- Peak strength and strain softening in snow were demonstrated.
- Strain softening may result in progressive failure in snow
- Important for understanding the process of avalanche release

McClung 1977
Snow creep against constructions on slopes

**Objective:** Measurement of snow creep forces.

Of importance for:
- Power line masts
- Skilift towers
- Avalanche supporting constructions
- Other kinds of buildings
Snow creep forces

- Maximum snow pressure in April/May when the snow cover is isothermal
- Measured snow pressures: 9–23 kPa
- Snow pressure is a function of snow creep and glide
- Important parameters are:
  - Snow density and strength
  - Snow depth
  - Snow temperature
  - Terrain inclination
  - Construction width.

Larsen et al. 1987
Avalanche full scale test site Ryggfonna since 1981

Objectives:

- Measurements and calculations of:
  - Avalanche dynamics,
  - velocities,
  - impact forces

- Testing of the effect of a 15 m high retaining dam

- Development and testing of dynamical avalanche models
Artificial release of avalanches

- **Purpose:** Controlled release of avalanches
- **Method:** 81 mm mortar
Very young, extremely motivated guys.
Snow avalanche geomorphology
Understanding of avalanche terrain

Based on mapping of about 1000 avalanche paths:

- Maximum runout distance
- Avalanche path geometry
  - Release area
  - Track
  - Runout area
- Erosion, transport and deposition of loose materials
- Avalanche effects on the vegetation cover
Avalanche runout models: Topographical/Statistical model

Basis:
- A great number of avalanches were mapped in their maximum known runout (100–300 years back)
- Many of these must have reached, or nearly reached, their maximum possible runout
- 200 avalanches, very well documented, were chosen for regression analysis of terrain parameters only

\[ \alpha = 0.96\beta - 1.4^\circ \]
\[ \text{SD} = 2.3^\circ \]
\[ R = 0.92 \]
Dynamical models at NGI: Development of the Norem–Irgens–Schieldrop model

- One of the first models that was based on a rheological description of snow
- Earlier models mainly used the friction parameters between the avalanche body and the substratum as a basis (boundary conditions).
- The NIS model was therefore an important step forward.
- NIS has been further developed at NGI in the D2FRAM model, which still is under development.
Personal run-out distance

Snow avalanche

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Frode Sanderson

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Ulrik Domaas

Erik Hestnes

Kriiter Kristensen
Slushflows, an important natural hazard
Slushflows

- Long-term research project at NGI
- Field test site in Nordland
- Small-scale tests in Davos
- Theoretical work with dynamical models
Slushflows

Study of:
- Topography
- Snow cover
- Weather conditions

- Releases in topographic depressions, most often following brooks
- Inclination commonly less than 30° in the release area and sometimes on nearly horizontal ground
- Runout distances between 3° and 20°
- Snow cover conditions: Loose, coarse-grained aggregate
- Weather: Heavy rainfall on snow-covered ground, or high temperatures

Hestnes 1985
Avalanche accidents.
Site inspections have been performed through 40 years

- Description of terrain formations
- Snow cover stratification at the avalanche crown
- Weather conditions prior to the accident
- The reason for the release
- Casualties and consequences for the people caught in the avalanches
- Important knowledge gained and used in several courses for many organisations
International projects on snow avalanches

Participation in several EU projects:

- Human Capital and Mobility 1992–1994
- SAME 1996–1998
- Cadzie 2000–2003
- Satsie 2003–2006
  - Leading partner
- Nordic Council project together with Iceland 1995–1997
Conclusions

What did we obtain:

- A high understanding of snow avalanche terrain and behaviour

What did we produce:

- 315 scientific papers in 42 years
- Average: 7.5 papers per year
Final remarks

- In all slopes where avalanches can be released, they will be released.
- In all slopes where avalanches cannot be released, they also will be released.
- It just takes a little longer time before it happens.