Results 2015 from SP 4 FoU Snøskred: Work Package 1 — Ryggfonn and Avalanche Dynamics

**Project nr:** 20140053-200  
**Title:** Ryggfonn and avalanche dynamics

<table>
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<th>Total budget (kNOK)</th>
<th>From Dept. Of Oil and Energy (kNOK)</th>
<th>Costs per 2015-12-31 (kNOK)</th>
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**Task 1: Avalanche experiments at the Ryggfonn test site**

The objective is providing experimental data from full scale avalanche experiments to:
- improve the understanding of the behavior of the avalanches with a focus on flow regime changes,
- obtain data of sufficient quality for model calibration,
- gain in-depth understanding of the interaction of snow avalanches with catching dams.

**Task 2: Avalanche Dynamics**

The objective is to provide improved tools for avalanche hazard mapping (with a focus on flow regime changes).

Har prosjektet oppnådd de oppsatte mål: Ja: [x] Nei: [ ]

**Begrunnelsel for eventuelle avvik og beskrivelse av korrigrende tiltak:**

Task 2: At the beginning of 2015, it was decided to intensify the development of statistical tools (WP2) during the second year of the project in order to have more time for testing them during 2016. For this reason, the development of dynamical models was deferred to 2016.

The main results are published or are going to be published in refereed journals and conference proceedings.

<table>
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<th>Dato</th>
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<td>2016-01-29</td>
<td>Peter Gauer</td>
<td>2016-02-03</td>
<td>Christian Jaedicke</td>
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Title: WP1 – Ryggfonn and model development
Project Manager: Peter Gauer
Project Members: Krister Kristensen, Erik Lied, Dieter Issler

TASK 1: AVALANCHE EXPERIMENTS AT THE RYGGFONN TEST SITE

Subtask 1.1: Maintenance of Ryggfonn

Under this task, necessary repairs and updating of the data acquisition system at the Ryggfonn avalanche test site were carried out so that the site is ready for the winter season 2015/16. In contrast to the previous year, no major damage had occurred.

Shortly before the end of the year, it was decided to buy a 3 m high pylon equipped with temperature sensors at a spacing of 10 cm. It will first be installed near the instrument cabin a few hundred meters downstream from the catching dam and will serve a dual purpose of recording temperature profiles and indicating the actual snow depth, with data transmission to Stryn and Oslo by Internet. Later on, installation near the starting zone of the Ryggfonn avalanche path is an option.

Subtask 1.2: Avalanche measurements at Ryggfonn

Two small to medium-size spontaneous avalanches occurred during the winter 2015. No weather situation occurred that held promise for artificially releasing a sizeable avalanche and obtaining good-quality measurements. In mid-April, an artificial release was nevertheless attempted, but resulted only in a small avalanche that stopped in the upper track. More detailed information on all three events can be found in Deliverable D1.4.

This year, the experiments were jointly planned and carried out by NGI and Statens vegvesen (SVV). One of the major goals of the joint experiments is to quantify the mitigative effect of a catching dam when it is overflowed by a part of the avalanche. Ideally, this question would be answered by setting up suitable sensors behind the dam. However, this was not possible yet in 2015, therefore the analysis would have been based mainly on photos and videos and post-event investigations of the deposit (density, thickness, hardness, granulometry). In order to visualize the impact of an avalanche more intuitively for the public, a wrecked car with dummies inside was placed on the dam. As the avalanche stopped long before reaching the dam, no results could be obtained in 2015. It is planned to place the wreck again on the dam at the next release attempt.

In the course of the last years, new techniques for analyzing the data from avalanche measurements have been developed at NGI. They made it worthwhile to reanalyze the data collected since the first experiments at Ryggfonn almost four decades ago. While not of the same quality as recent measurements with more sophisticated equipment, they make it possible to compare avalanches of widely different sizes and to study the probability distribution functions of several interesting quantities. This reanalysis is now essentially completed (Gauer and Kristensen, submitted).
TASK 2: AVALANCHE DYNAMICS

Due to the anticipated resource need in WP2 (statistical tools) in 2015, work on this task was essentially deferred to 2016. Some work was done on planning a MSc thesis at NTNU on the braking effect of forest on small to medium-size avalanches, which will be carried out in the first half of 2016 (Kahrs, 2015). Also, field observations from three special avalanches in Switzerland in 1995 were reanalyzed (Issler et al., submitted a,b).

PUBLICATIONS IN 2015

Gauer, P. & Kristensen, K. Four decades of observations from NGI's full-scale avalanche test site Ryggfonn—Summary of experimental results. Submitted.


PRESENTATIONS IN 2015


Issler, D., Gauer, P. & Kristensen, K. Future directions in avalanche dynamics – Lessons learnt from the Ryggfonn experiments, knowledge gaps and new opportunities. Invited oral presentation at the Niseko Workshop on Avalanche Dynamics, Niseko (Japan), 9–12 December 2015.

PROJECT-RELATED REPORTS IN 2015

Kahrs, K. The braking effect of trees on snow avalanches – Design of an experimental study. Project thesis TBA4510, Department of Civil and Transport Engineering, Norwegian University of Science and Technology (NTNU), December 2015.
DELIVERABLE D1.4
DATA REPORTING AND DATA ANALYSIS FROM MEASUREMENTS AT RYGGFONN

Spontaneous avalanches

Two spontaneous avalanches were recorded on 2015-01-12 and 2015-03-07. Only pressure data is available from these two events. They are therefore of limited value for further analysis. On 2015-04-17, an attempt at releasing an avalanche artificially resulted in a small avalanche that stopped in the upper track.

- The avalanche of 2015-01-12 stopped between the concrete wedge and the pylon before the dam. Pressures on the uppermost pylon and the concrete wedge were less than 10 and 30 kPa, respectively, and lasted for less than 5 s.
- The event of 2015-03-07 reached the foot of the dam and was recorded by its six lowermost pressure sensors (Figure 1). The peak pressure of about 150 kPa was larger than at the concrete wedge (approx. 100 kPa) despite lower velocity; this is attributed to the strongly different sensor sizes.

Figure 1. Avalanche test site Ryggfonn, spontaneous avalanche on 2015-03-07. Time evolution of pressure recordings on the 15 m high pylon in front of the dam.
Artificially released avalanche

During the entire winter, no weather situation developed where the chance of releasing a sizeable avalanche was considered to be good. Towards spring, it became desirable to launch a campaign even under less favorable conditions in order to test the collaboration with SVV under realistic conditions and to dispose of the explosives stored in the Wyssen tower. Weather conditions made it possible to man the observation point on Sætreskarsfjellet and to carry out a LiDAR scan of the path before and after the release.

The released avalanche was small, with an estimated volume of 2000 m$^3$. It stopped after a travel distance (measured from the fracture crown) of only 350 m, i.e. before leaving the bowl comprising the release area and entering the steeper middle track (Figure 2).

When the LiDAR data was analyzed, it turned out that the return signal from areas lit by sunlight were too weak for measuring the distance while areas in the shade gave analyzable signals. It is as yet unclear whether the problem is caused by direct reflections of the sunlight or by a sufficiently thick water film on the snow grains, which then would absorb the infrared light emitted by the LiDAR.

![Artificially released avalanche](image)

Figure 2. Artificially released avalanche at Ryggfonna, 2015-04-17. View from Sætreskarsfjellet. The avalanche stopped in the flatter part of the bowl visible in the picture. Photo, K. Kristensen, NGI.
Figure 3. Avalanche test site Ryggfonna, artificially released avalanche on 2015-04-17. Longitudinal profile of front velocity derived from video analysis.

Due to the topography of the Ryggfonna path, the Doppler radar located at the foot of the opposing slope is not able to see avalanches before they enter the steeper, channeled middle section of the track. Therefore, there are no radar measurements of the internal and front velocity of the small artificially released avalanche of 2015-04-17. However, from the video recordings, the evolution of the front velocity $U_f$ along the path could be extracted (Figure 3). Even though the uncertainty of the result is up to ±5 m/s, a fairly smooth curve is obtained. One may therefore find the retarding acceleration, $a(s) = g \sin \theta$, by numerical differentiation. This quantity is the starting point for analyzing the dynamics of the avalanche.

Back-calculations of the avalanche were carried out with the model RAMMS, using the observed release area and the estimated average release depth of 0.5 m, which gives a release mass of approx. 1000 m$^3$. First, the standard calibration of RAMMS recommended by SLF for tiny avalanches with a return period of 10 years was used together with the standard entrainment model. Under these conditions, the avalanche velocity peaks at 15–20 m/s (Figure 4, left panel), which is significantly less than the observed maximum front velocity (Figure 3). Yet the avalanche creeps at least 700 m farther along the path than observed (corresponding to a vertical drop of some 400 m), at a velocity of about 5 m/s. This is a consequence of the relatively low value of the dry-friction
parameter $\mu$ which determines the maximum slope angle at which the avalanche flow can stop.

Much better results were obtained using a modified version of the alternative calibration proposed by Gauer (2014), see Figure 4, right panel. The dry-friction parameter $\mu$ is set to 0.64—a value close to $\tan \alpha$, where $\alpha$ is the observed run-out angle. The “turbulent” friction parameter $\xi$ of RAMMS is chosen as 29 000 m/s$^2$ in order to make its contribution as small as possible. This is in stark contrast to the standard calibration, which results in $0.32 < \mu < 0.47$ and $\xi = 1000–1500$ m/s$^2$.

Considerable evidence has been obtained in the past years in favor of the new calibration, and it is increasingly used at NGI in consulting projects, both with RAMMS and MoT-Voellmy.

**Figure 4.** Back-calculations of the avalanche that was artificially released at Ryggfonna on 2015-04-17 using RAMMS. Left panel: Friction parameters chosen according to SLF’s calibration for tiny avalanches with return period 10 years. Right panel: Parameters chosen according to calibration based on run-out angle.

**REFERENCES**