Optimizing Mitigation Measures Against Slush Flows by Means of Numerical Modelling

– A Case Study from Longyearbyen, Svalbard –

Árni JÓNSSON [1,*] and Peter GAUER[2]
[1] Natural Hazards Division, Norwegian Geotechnical Institute, Norway
*Corresponding author. E-mail: ajo@ngi.no

INTRODUCTION

Spitsbergen (also named Svalbard in Norwegian, located at lat. 78° north) is known for its cold climate and harsh weather conditions. In recent years, mild weather in mid-winter has become more frequent. This change brings the focus to snow-related problems such as slush flows that usually occurred only in May in the past.

Late in January 2012, a warm weather spell with precipitation caused a slush flow from the valley Vannledningsdalen near the main town of Longyearbyen (Fig. 1) into the canal on the alluvial fan (called Haugen) and down to the main road that connects the settlements of the Nybyen area of Longyearbyen to the centre of the town. At this time, the flow did not hit or damage any inhabited house on the alluvial fan. The settlement on the alluvial fan has increased through the years and now the fan area is almost fully developed.

Early in the settlement history of the alluvial fan, the local authorities realized the need for taking action to protect inhabitants and houses from slush flows. The stream/flow which could spread all over the fan was directed into a small canal. The canal has been modified after several major slush flow incidents, and as of today the canal also has a prominent wall on the southwest side.

After the incident in 2012, the local authorities decided to review the current mitigation measures as new laws and regulations had been adopted by the Norwegian parliament in 2010. NGI was asked to review existing mitigation measures and to propose a revision and/or extension to the existing measures to fulfill the new criteria.

METHODS AND RESULTS

There are many factors that can contribute to a release of a slushflow, e.g. temperature, volume of snow, texture and structure of the snowpack, precipitation and snowmelt, to name a few. The slush flow path starts in a relatively flat plateau at about 350 m asl. The average steepness of the creek in Vannledningsdalen is around 12 to 14 degrees, its length is about 1200 m, and the alluvial fan is about 700 m long. The path terminates in the Longyear river.

It was decided to carry out numerical simulations of slush flows with a quasi-three-dimensional (i.e., two-dimensional depth-averaged) model in order to assess the efficiency of the existing mitigation measures and to optimize the design of improved measures, if this turned out to be necessary. Presently, there do not exist practically usable and calibrated models for slush flows. Therefore we chose RAMMS from the Swiss Snow and Avalanche Research Institute (SLF) for this purpose as NGI has gained some experience in using this model (mostly

Fig. 1 The photo shows Vannledningsdalen, the existing canal and the wall on the southeastern side (to the right). The alluvial fan is almost fully developed. The Longyear river is visible in the foreground.

for snow avalanches). It implements the simple Voellmy friction law with a Coulomb friction law and "turbulent" drag term proportional to the square of the velocity. These contributions to the flow resistance are also thought to be relevant for slush flows. The effects of variable water content cannot be simulated in this simple framework, however.

The slush flow was first simulated on the existing terrain, without any proposed mitigation measures. The input parameters were optimized by simulating known slush flows. For the given terrain, we found the parameters μ = 0.05 and ξ = 5000 m/s^2 to give reasonable run-out of the slush flow. These chosen parameter values were then used in simulations where the terrain model was modified to include proposed mitigation measures. Given that the speed or behavior of slush flows is not very well known, we tested the proposed terrain modifications also with ξ = 3000 m/s^2 and 10,000 m/s^2 because this parameter strongly influences the flow speed, which in turn is decisive for the required height of deflection dams.

CONCLUSIONS

In our experience, RAMMS gives a realistic indication of how a slush flow might behave along its path and what flow thickness and speed are to be expected, if suitable values are used for the friction parameters. It has to be kept in mind, however, that these values are very different from those recommended for snow avalanches. We consider RAMMS to be a very useful tool for detecting possible deficiencies in the proposed design of mitigation measures.

Keywords: Svalbard, Longyearbyen, slush flow, mitigation measures, numerical modeling, RAMMS