The results from two years of testing The Wyssen Avalanche Tower in Norway

Njål Farestveit* Norwegian Public Roads Administration and Sara Skutlaberg
SWECO Norge AS, Norway

ABSTRACT: The Wyssen Avalanche Tower LS12-5 has been tested for the first time in Scandinavia by The Norwegian Public Roads Administration (NPRA) in cooperation with Wyssen avalanche control AG and SWECO Norway AS. Between January and May in 2011 and 2012 there has been detonated 24 charges.

Big areas of the Norwegian mountains are residues of a relict, fluvial landscape with gentle slopes and undulating mountain plateaus. This topography results in a considerable amount of drifting snow, giving rise to big avalanches also in quite small slopes. Lake Tyin is situated 30 km southward from the highest peak of Norway, Galdhøpiggen (2469 m a.s.l.). It´s location, 61°N, results in a very dark winter season, compared to many other mountain areas in the world. Maintenance of roads in these harsh, Nordic winter conditions with a lot of snow drift and avalanches is often a big challenge.

Investigation of the technical reliability of the system in the Nordic environment, challenges concerning drifting of the system, in addition to getting the system approved by Norwegian authorities, has been two major goals for the project. Additionally, the avalanche danger has been decided by digging snow pits and testing snow stability (the CT, the ECT and the SLAB test). This is done in relation to most of the detonations, for investigating the success of releasing avalanches in relation to The European Avalanche Danger Scale. This work has been done by bachelor students supervised by the authors.

The results are mainly positive and we hope that this project can lead the way for more use of artificial avalanche release for protection of infrastructure in our country.

KEYWORDS: Avalanche tower, Norwegian Public Roads administration, Tyin

1 INTRODUCTION

1.1 Background

Norway is a long and narrow country, situated along the Caledonian Mountain Range on the Scandinavian Peninsula. It´s latitude, between 58N and 71N, is comparable to Alaska, Greenland and Sibir, although the climate is much milder, with warm water from the Mexican Golf reaching the Norwegian Sea through the North Atlantic Current.

* *Corresponding author address:* Njål Farestveit, Norwegian Public Roads Administration, Askedalen 4, 6863 Leikanger, Norway; tel: +47 99715116; email: njaal.farestveit@vegvesen.no

The climate is very humid, mainly bacause of precipitation along low pressure fronts entering from the Atlantic Ocean, followed by orographic precipitation in the mountains. In some mountain areas the precipitation exceeds 4000 mm annually.

The highest mountains are located to south central Norway with the highest peak, Galdhøpiggen, reaching 2469 m a.s.l. (Figure 1). The mountains are incised by steep fjords. Southern Norway has the 2nd and 3rd longest fjords in the world, respectively the Sognefjorden (203 km) and the Hardangerfjorden (179 km).

There are 5 million inhabitants and the country has an extensive public road network, totally 55.000 km of national highways and county roads in addition to 38.000 km of municipal roads. Figure 1 shows some of the most important roads in the Norwegian Public Roads Administrations (NPRA) western region and the locations of some of the avalanches cutting the connection between the capital, Oslo, in the east and the second larg-

est city, Bergen, on the west coast, during a major storm in 2008 (Farestveit 2009).

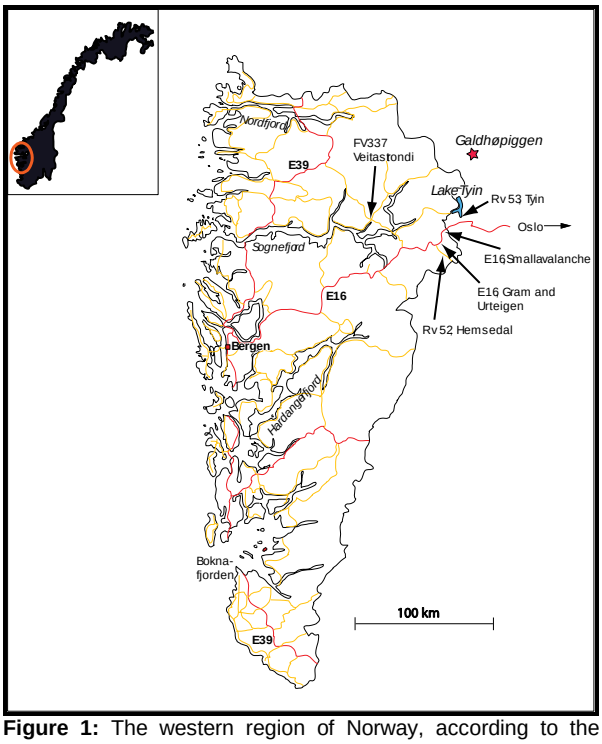


Figure 1: The western region of Norway, according to the organization of NPRA. The arrows indicate some of the avalanches cutting the connection between east and west during a storm in 2008.

In winter time, large amounts of snow results in severe avalanche related problems on Norwegian roads. The NPRA is responsible for the management and safety on national highways and county roads. This includes forecasting and protection against snow avalanches. The daily surveillance is performed by contractors supported by NPRA´s geologists or by consultants.

Different types of avalanche mitigation are commonly used, like dams, galleries, tunnels or closing of roads during unsuitable weather. Artificial release of avalanches is however a less used method, with exception of two ropeways (Magnhildskaret and Østerbø) and one location (Napefonn) using preplaced explosives. Since permanent avalanche mitigation, like tunnels and galleries, are economically unrealistic within reasonable future along many of the low priority roads in The National Plans for Transportation, in 2009 there was decided to carry through two year testing of the Wyssen Avalanche Tower in Norway. This would indicate the suitability and effectiveness of avalanche towers in Norway and their potential usefulness on roads where permanent avalanche mitigation is no economical option.

1.2 Challenges

Besides the technical perspectives, there are two main challenges to overcome for effective use of avalanche towers in Norway. First, the test tower has got a special approval tied to the specific test site during a two year period, but for using this system on a bigger scale, the authorities has to give the system a general approval. This is why there has been tight cooperation with the Norwegian authorities throughout the project.

Secondly, it is important to find out how (or if) such a system could be operated in the organisation of the NPRA.

1.3 The Wyssen Avalanche Tower

The Wyssen Avalanche Tower consists of an explosives magazine placed on top of an 8 m high mast. The explosives, hanging in a rope over the avalanche release area, are released via radio connection. The system is usually fed by a 12 V battery charged by a solar panel. Because of the dark winter season in Norway, we tested a combination of a solar panel and a wind generator for charging.

1.4 Test set up/Test performance/Project design

The test site is located along Road 53, on the western shore of Lake Tyin (1084 m a.s.l.), (Farestveit 2010). The tower is located at ca 1210 m a.s.l. and the road is at ca 1090 m a.s.l. This gives a vertical distance from the tower to the road at about 120 meters (Figure 2).

Figure 2: The location of the tower and the road shown after an artificial release the 21th of February 2012. The avalanche was about 30 meters wide on the road, and reached the Lake Tyin, that can be seen in the lower right corner. (Photo: Njål Farestveit, NPRA)

Road 53 has 9 known avalanche paths along 12 km of road (our test site being on of them). In the County plan for avalanche mitigation, Road 53 is proposed to be protected by a combination of dams, tunnels and road alteration. The total cost for these measures are stipulated to 500 million NOK (ca 80 million USD).

The particular avalanche is situated so close to the road that the entire avalanche area can be seen from it. This was demanded by the authorities, for guaranteeing no recreation skiers would be involved. This avalanche overruns the road annually and there is little space for avalanche measures, like i.e. an effective dam (Figure 3).

Before each blasting, the road was closed by the contractor, a ploughing truck was brought up and the area was visually controlled for skiers. The second season the authorities also demanded use of open connection (walkie-talkie) between the contractors and the user of the tower, in addition to a siren making people in the area aware of coming explosions.

We had no way to measure the size of the avalanches, so we used these criteria:

- Yes: If we could see that snow released as an avalanche due to the blast.
- No: If we could not see snow released as an avalanche due to the blast.

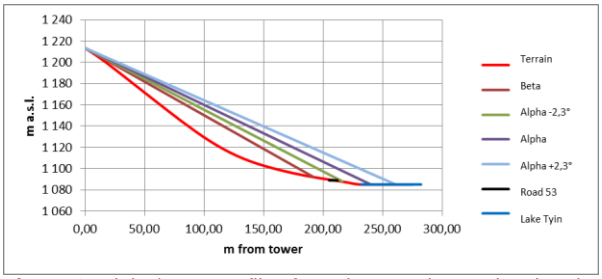


Figure 3: Alpha/ Beta profiles from the test site. Notice that the road is placed within the limit of the line: α=0,96β-1,4°, SD= -2,3°, (Modified from Langeland and Sund, 2012).

2 TWO SEASONS TESTING OF THE WYSSEN VALANCHE TOWER

2.1 Test season 2010-2011

During the first season the avalanche tower was used at seven occasions and released avalanches 6 times. Additionally, two natural released avalanches occurred on Saturday the 5th of March and Thursday the 24th of March.

The early season of 2010/2011 was characterized by low temperatures combined with a very thin snow cover in southern Norway. This led to an extensive growth of depth hoar in general, in southern Norway (Figure 4).

Figure 4: Smal slab avalanche at Tyin released on depth hoar by ploughing truck 12th of January 2011. (Photo: Njål Farestveit, NPRA)

Our first release 13th of January removed the depth hoar in a limited area of the releasing zone (Figure 5 and 6).

Figure 5: The avalanche path after the release 13th of January 2011. Notice that there are uninfluenced areas both to the left and the right of the tower. *(Photo: Njål Farestveit, NPRA)*

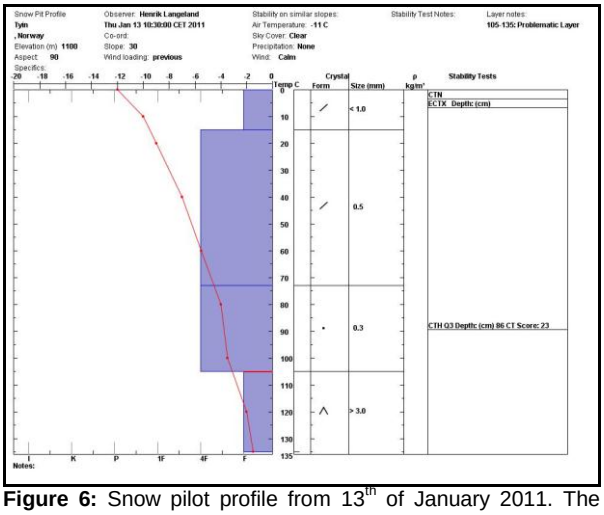


Figure 6: Snow pilot profile from 13th of January 2011. The slab is only 4 fingers hard. We think this is why we did not manage to release more of the release area.

The natural avalanche 5th of March released on depth hoar in the whole realising zone. This avalanche happened during a storm event when the road was closed. The maintenance personnel reported that this avalanche had a fracture line of about 150 metres.

The results, summarized in table 1, shows that power supply and mechanics worked well. We had no dots! Important lessons were that we had to be more on the site to monitor the situation, and that in situations with depth hoar, we should have more than one tower for controlling this avalanche path.

Tabel 1: Test results 2011.

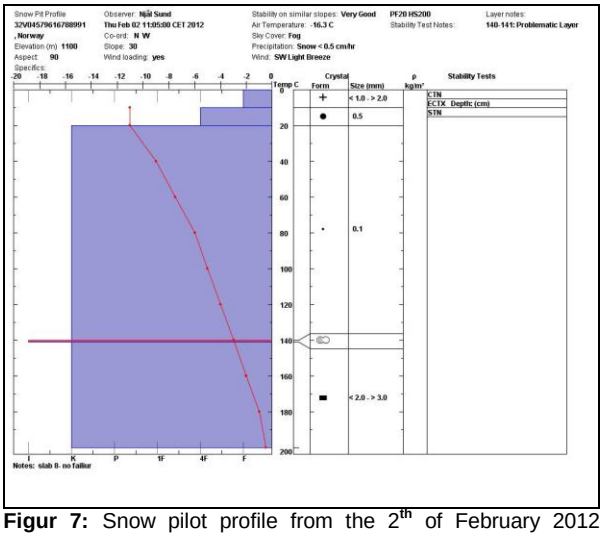
Date	13.1	17.2	10.3	17.3	29.3	6.4	28.4
Number of charges	1	2	1	2	2	2	2
Avalanche release	yes	yes	yes	yes	yes	yes	No
Power	ok	ok	ok	ok	ok	ok	ok
Test run	ok	ok	ok	ok	ok	Restart magazine	ok
Fire	ok	ok	ok	ok	ok	ok	ok

2.2 Test season 2011-2012

One lesson from the first test season was that we had to be more on the spot. (We rented a cabin in the area). The second test season started with a very strong hurricane, unfortunately damaging our wind generator. The first release was on the 2th of February because of low power. A natural avalanche released the 13th of January, and this avalanche crossed the road. Our release on the 21th of February closed the road in 30 metres length (Figure 2).

From we started with the first release, to the end of the season, we had no avalanches on the road that we did not release ourselves.

The hurricane did not damage the tower, and we had no dots! According to depth hoar formation this season was opposite to the last one. Due to the hurricane we had an “ice sandwich”, as the lower most layers until February - March (Figure 7).



Figur 7: Snow pilot profile from the 2th of February 2012 shows no formation of depth hoar.

The results from the second season are summarized in table 2.

Tabel 2: Test results 2012

Date	2.2	15.2	21.2	29.2	13.3	26.3	27.3	12.4
Number of charges	1	1	1	2	1	3	1	2
Avalanche release	No	Yes	Yes (crossing road)	Yes	Yes	No	Yes	Yes
Power	ok, but low	ok	ok	ok	ok	ok	ok	ok
Test run	ok	ok	ok	ok	Restart magazine	ok	ok	ok
Fire	ok	ok	ok	ok	ok	ok	ok	ok

CONCLUSIONS AND RECOMMENDATIONS

The two test seasons indicates good technical functionality of the Wyssen Avalanche Tower for Scandinavian conditions. We had no dots, and no

problems related to explosives. The wind generator although, failed the tough test of the Dagmar hurricane on the 26th of December 2011. This led to reduced power supply and no testing before more effective charging could be obtained via the solar panel a month later. Consequently, the natural avalanche on Friday the 13th of January 2012 could not be artificial pre-released. The last season we did not have naturally released avalanches in the avalanche path from the time that we "really" started the surveillance. This season we were able to run the tower better since we were stationed at the site for longer periods.

A total amount of 12 artificial released avalanches out of 15 test occasions indicates that the system is adequate for releasing avalanches in our environment. Although we really have not shown the relation between avalanche danger, snow pack and artificial release in our project, we are convinced that by the right surveillance, the avalanche paths along this road can be controlled to a level that we are comfortable with.

Speaking of residual risk for this project, we have not had natural avalanches released, after an artificial release, which can be related. This does not mean that it never can occur.

We find local managing crucial for best possible functionality. This will often mean that the maintenance contractors are the obvious users of the system. Here, the drawbacks of shifting contractors, resulting in knowledge discontinuity, have to be overcome. One obvious factor is the system´s software, that we didn´t find very user-friendly. In the case of daily use by shifting contractors it would be a great advantage to develop more intuitive software with simple menus and commands.

In years when there is depth hoar formation it is possible to wait with the first release until there is a solid slab. To avoid the uncertainty we will recommend an extra tower for the avalanche path that has been targeted for this project.

We mean that artificial avalanche release in Norway can be used instead of traditional measures. Mainly for low priority roads, at least until we have more experience. Artificial release can be an appropriate alternative to a tunnel or dam that "never" is built, but in each single case there must be made a cost-benefit evaluation together with a risk analysis.

Many roads can still have to use some degree of road closure, but with good management the number of days closed can be minimized. Additionally, it will provide a higher degree of security for users of the road and the maintenance personnel, which are by far the most avalanched exposed people on Norwegian roads.
Our cooperation with the Norwegian authorities responsible for explosives has been positive. When this paper is being written, it looks like the Wyssen tower will be approved in Norway based on our project.

Along Road 53 there is a 12 km long, avalanche exposed section, with nine avalanche paths in total. Existing plans are a combination of tunnels, dams and road alteration. Based on this project we recommend that these avalanche paths should be controlled by 13 avalanche towers and some road alteration. **This will reduce the investment costs by 95% compared to the original plan.** The realization of the project is dependent on financing, and the final approval from the authorities responsible for explosives.

For more information about weather, avalanche danger and case studies of selected releases, we refer to the bachelor thesis, or the authors can be contacted.

4 ACKNOWLEDGEMENT

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