ABSTRACT: Since 2009 the Seehore test site is operative within the Monterosa Ski resort in Aosta Valley (NW Italy). This real scale test site was intended to study the dynamics of small/medium avalanches, the avalanche release processes and the interaction between avalanche flows and obstacles. From 2570 to 2300 m asl, the slope presents a NNW aspect, a mean inclination of about 28° and it is instrumented with a galvanized steel obstacle to measure avalanche impact forces and their effects on it. Though most of the avalanches are artificially triggered on a routine basis to secure the ski-runs of Monterosa Ski resort, the system records also natural events. In case of avalanche release, the erosion/deposition mass and the front velocity are evaluated by laser scan measurements and photogrammetry. Avalanche outline is recorded by using GPS devices coupled with snow depth, density and granulometry measurements. In the release zone, snowpack properties and release features are recorded by field surveys. A specific survey is done for the snow deposited around the obstacle. Since Summer 2012, a high sensitive low noise infrasonic microphone was placed near the obstacle to understand the characteristic frequency range in infrasonic waves produced by avalanches. Moreover, the site was implemented in Fall 2012 with a snow/weather station installed on the ridge at 2570m asl to understand the influence of snowdrift on avalanche release. The data registered by obstacle and snow/weather station are locally stored by data-loggers and remotely transmitted to Politecnico of Torino. This paper describes the experimental test site and presents measurements/surveys performed during the last operating seasons.

KEYWORDS: small/medium avalanches, real scale test site, dynamics, impact forces, snowdrift

1 INTRODUCTION

All data recorded from experimental snow avalanche test sites have improved our understanding of physical processes within avalanche flows and are used to calibrate dynamic models that describe the flow behavior through equations. Experimental test sites can be at laboratory scale or real scale but, about the formers the scale factor has to be taken into account when transferring the results to the real scale (Lang and Dent, 1980) instead the latter present more complex logistics, and more expensive engineering. Since the last century, other experimental test sites have been equipped in Europe to study avalanche dynamics (Jóhannesson et al., 2006).

A new experimental test site at a real scale has been realized in Aosta Valley in the North-Italian Alps, in order to address specific research topics:
- dynamics of small and medium avalanches (EAWS, 2003);
- avalanche release processes;
- interaction between avalanche flows and obstacles.

The new test site is managed in order to study artificially released small and medium avalanches, while the majority of the existing sites refer to large avalanches. Initially born to study avalanche dynamics, the test site has recently been implemented to study the snowdrift process and its influence on avalanche release.

The test site belongs to the authority Regione Autonoma Valle d’Aosta and is operative since winter 2009–2010, whereas the instrumented obstacle is operating from the winter season 2010–2011.
2 DESCRIPTION OF THE SITE

2.1. Location and morphology

Seehore test site (45°51′05″N; 07°50′34″E) is located at the head of the Lys Valley, near the village of Gressoney-La-Trinité on the Monte Rosa Massif in the North-western Italian Alps. The test site is included in the MonterosaSki resort and it is one of the slopes where avalanches spontaneously occur and may reach the ski run that crosses the bottom of the slope (Fig. 1). Tables 1 and 2 summarize the main features of the test site. Therefore, it is a routine to artificially release the avalanches after critical new snow amount has been reached and/or snow drift occurred, in order to guarantee the safety of the ski-runs.

Table 1: Topographical features of the test site (Maggioni et al., 2013). The width varies from about 80 m at the top near the ridge to 40 m in the middle of the avalanche track, to more than 100 m in the deposition zone. The ground roughness is very high, as the ground is covered by debris of different size, with single rocks up to 4 m of diameter.

<table>
<thead>
<tr>
<th></th>
<th>Altitude (m a.s.l.)</th>
<th>Slope angle (°)</th>
<th>Aspect (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entire slope</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>2147</td>
<td>28</td>
<td>324</td>
</tr>
<tr>
<td>Minimum</td>
<td>2123</td>
<td>10</td>
<td>271</td>
</tr>
<tr>
<td>Maximum</td>
<td>2570</td>
<td>48</td>
<td>348</td>
</tr>
<tr>
<td>Release zone</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>2521</td>
<td>39</td>
<td>316</td>
</tr>
<tr>
<td>Minimum</td>
<td>2475</td>
<td>27</td>
<td>271</td>
</tr>
<tr>
<td>Maximum</td>
<td>2570</td>
<td>48</td>
<td>337</td>
</tr>
<tr>
<td>Track zone</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>2426</td>
<td>35</td>
<td>331</td>
</tr>
<tr>
<td>Minimum</td>
<td>2184</td>
<td>29</td>
<td>327</td>
</tr>
<tr>
<td>Maximum</td>
<td>2472</td>
<td>37</td>
<td>335</td>
</tr>
<tr>
<td>Deposition zone</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>2147</td>
<td>17</td>
<td>325</td>
</tr>
<tr>
<td>Minimum</td>
<td>2123</td>
<td>10</td>
<td>297</td>
</tr>
<tr>
<td>Maximum</td>
<td>2584</td>
<td>29</td>
<td>348</td>
</tr>
</tbody>
</table>

Figure 1: Winter view of Seehore peak from North-East (photo: A. Welf). The insert shows the geographical location of the test site.

Table 2: Main characteristics of the Seehore test site (Appendix A in Maggioni et al., 2013) following the layout used in Jóhannesson et al. (2006) to easier compare it with the other European test sites.

<table>
<thead>
<tr>
<th>Site Location</th>
<th>climate:</th>
<th>transitional</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>accessibility:</td>
<td>one cable car from Gressoney-La-Trinité and 600 m by ski or foot. After artificial release, path accessible by ski or foot</td>
</tr>
<tr>
<td>Topography</td>
<td>n. of paths:</td>
<td>3 release areas which join into a unique path</td>
</tr>
<tr>
<td></td>
<td>starting zones:</td>
<td>open slope, near the ridge, mean (max) slope angle 30° (40°), NWW, width up to 80 m</td>
</tr>
<tr>
<td></td>
<td>track:</td>
<td>open slope, mean slope angle 35°, width 40 m</td>
</tr>
<tr>
<td></td>
<td>run-out zone:</td>
<td>open slope, slightly convex, mean (min) slope angle 17° (10°), width up to 150 m</td>
</tr>
<tr>
<td></td>
<td>drop height:</td>
<td>300 m</td>
</tr>
<tr>
<td></td>
<td>warm length:</td>
<td>500 m</td>
</tr>
<tr>
<td></td>
<td>average inclination:</td>
<td>28°</td>
</tr>
<tr>
<td></td>
<td>surface roughness:</td>
<td>high, with rocks in the release, track and run-out zones</td>
</tr>
<tr>
<td>Avalanche characteristics</td>
<td>avalanche type:</td>
<td>mostly dense (dry or wet), mixed, small-medium size</td>
</tr>
<tr>
<td></td>
<td>spontaneous:</td>
<td>2-3, when the ski resort is closed</td>
</tr>
<tr>
<td></td>
<td>artificial release:</td>
<td>DaisyBallift or Carla Vassallo by the Monterosa s.p.a. (snow threshold of 30 cm)</td>
</tr>
</tbody>
</table>

Initial and final conditions

| release and deposit | manual measurements, snow stakes, GPS, laser scanner, video and photography |
| snow properties: | manual measurements and automatic weather station |
| shape, trajectory: | image processing of video recording |
| Depth-averaged flow variables | |
| front velocity: | image processing of video recording |
| velocity distribution: | no |
| flow depth: | at the obstacle (from video) |
| seismic and acoustic: | no |
| signals: | |
| Internal flow variables | |
| velocity profile: | no |
| flow density profile: | no |
| pressure profile: | at the obstacle (on 5 instrumented plates) |
| Interaction with obstacles | |
| 10 load cells on the obstacle | |

Data acquisition system

| sampling frequency: | 2000 Hz |
| storage capacity: | 4 GB |
| data transmission: | Optical Fiber LAN |

Measurements useful for conventional DRA models

| initial mass: | good measurements if good weather (laser scanner plus video) |
| trajectory and front velocity: | through image processing of video recordings |
| flow depth: | only at single points |
| pressure: | only at the obstacle, but distributed on a surface of 1 m² |

Additional measurements useful for P4S models

| cloud geometry: | through video analysis |
| internal velocity: | no |
| turbulence: | no |
| density: | no |
| salination layer: | pressure only at the obstacle |
| entrainment: | field observations, straw test at single points, laser scanner |

2.2. Snow and climate conditions

The test site is located in the south-eastern sector of the Aosta Valley Region characterized by precipitation associated to humid turbulent southern streams, usually coming from SE. Due to its mean aspect (NWW), the avalanche test site is favorably exposed to snow accumulation and, during or immediately after snowfalls, the wind from south/south-east tends to overload the slope with snowdrift redistribution of snow cover. To better understand the influence of the snowdrift on the snow spatial distribution in the
leeward side of a ridge, the starting zone of Seehore test site was instrumented in Autumn 2012 by: 1 anemometer, 1 wind vane, 1 snow depth sensor and 4 snowdrift sensors (Wenglor YH08NCT8 LASER) placed at variable heights of +110, +210, +310 and +550 cm above ground. The installation of this measuring system, first measurements and related analysis with respect to some avalanches triggered in Winter 2012-13 are presented in Maggioni et al. (this issue).

Close to the test site (less than 1 km East), two manual and automatic weather stations (at 2340 m and 2379 m asl) are located. The first (property of Servizio Idrografico e Mareografico Nazionale - Ufficio Idrografico del Po) has been supplying daily manual data (air temperature, snow depth, new snow) since 1919 by the personnel of the Lago Gabiet dam. The second one (belonging to Struttura Centro Funzionale of the Aosta Valley Region) has been recording snow depth and air temperature (every 30 minutes) since 2002.

3. MEASUREMENTS AND SURVEYS

3.1. Topographical surveys

Before and after avalanche release, a georeferenced laser scanner survey is carried out using a Riegl LMS-Z420 and Riegl VZ400 to describe the upper and the lower part of the site, respectively to get information about the deposit, snow erosion and deposition along the track (Prokop, 2008). The photogrammetric technique (using aerial and terrestrial photos) is used to avoid problems of areas not visible by laser scanner especially in the release zone. Additionally, it is tested to determine the DEM of the snowcover before and post an event when the laser scan is not available.

During the avalanche motion, videogrammetry is performed with a Canon 5D camera, with calibrated lens and fix focal length, in order to determine, by geo-referencing the scans, the front velocity all along the track. Since 2012, a new 3D mapping tool is testing at the Seehore test site to take the avalanche census and rapidly drawing the avalanche limits to implement the regional Cadastre. Thanks to digital photographs taken with a calibrated camera from the helicopter of the avalanche event, integrated with a digital terrain model and regional orthophotomaps, the method creates a 3D image geo-referenced in 3D-GIS environment (Bornaz et al., this issue).

3.2. Field activities

After the event, a GPS survey of the avalanche outline is made, together with measurements of the snow depth in some points around and within the avalanche deposit and track.

In the release zone, along or near the fracture line, snowpack properties (density, temperature, hardness, humidity, crystal shape and dimension) are measured together with stability tests (e.g., Extended Column Test (Simenhois and Birkeland, 2006)). The fracture depth is measured or estimated from below, depending on the safety conditions.

Along the avalanche path, erosion and deposition height are manually measured in some points with the straw test (Bovet et al., this issue).

A specific survey is done around the obstacle, focusing on snow properties (density, temperature, hardness, crystal type and dimension) upwind and downwind the obstacle and on shape and dimension of the eventual deposit created.

In the deposition zone, granulometric (Bartelt and McArdell, 2009; De Biagi et al., 2012), density and temperature measurements of the avalanche deposit are also made.

3.3. The obstacle

The main function of the obstacle is the measurement of velocity and impact forces generated by snow avalanches. The impact surface mounted on the structure is large enough to reproduce a small portion of a real building, and at the same time, to allow the safe operation of the system under the expected loads.

The obstacle was assembled by (Fig. 2):
1. a vertical obstacle made of galvanized steel profiles (4.0 m high, protruding 2.8 m from the natural slope profile), consisting of a lower section bolted to the concrete foundation, serving as a support for the upper part which carries the sensors, directly exposed to the avalanche impact;
2. a sealed electric cabinet that hosts the acquisition and control systems, terminal of the power supply line and of the optical fiber of the data transmission line, connected to the upper station of the Staffal-Gabiet cableway;
3. a galvanized steel shed that protects the cabinet from the direct impact of the avalanches and provides also a walking surface to reach the upper part of the obstacle for inspection and maintenance works.

The impact surface is made of an array of 5 aluminium grooved plates supported by two load transducers (load transducers U10M with nominal load of 5, 12.5 and 25 kN) in turn linked to obstacle with a hinged joint. The load transducers are mounted on slides that can be easily moved along vertical guides to place them at the desired height above the ground level. The total area of the impact plates is 1 m³.
Figure 2: View of the obstacle after an avalanche event. Only the upper part of the steel structure emerges from the snowpack.

In addition, acceleration of the structure by the impact and environmental variables (i.e., air temperature and atmospheric pressure) are measured thanks to 4 accelerometers and 1 pressure transducer fixed to the upper part of the target and 4 temperature transducers located at elevations of 0.1, 1.0, 1.9, and 2.8 m above the intermediate flanges of the obstacle. Fig. 3 shows examples of the recorded data (Barbero et al., 2013).

The measuring system is controlled and monitored by software developed within National Instruments - LabView environment. Depending on the experimental conditions, two operating modes are possible: (i) manual mode, when the sensors and the recording of data are commanded by the operators; (ii) automatic mode, when the sensors are permanently kept active, and the recording procedure is triggered by acceleration threshold of the structure. In both cases, measured data are temporarily stored in the data logger, then transferred via FTP to the PC located in the control room via the Ethernet LAN. The PC can be operated locally, when the experiments are attended in manual mode, or remotely, acting through the GPRS router that gives connection to Internet.

Next Winter, at the top of the upper steel frame, velocity sensors will be placed.

3.4. Infrasonic measurements

Since 2009 an infrasonic array technology is tested in Aosta Valley to real-time detect the natural and artificial avalanche activity in the Alpine areas. In winter 2012, an Infrasonic Array Network (IAN) has been operating in the Monte Rosa and Matterhorn areas (~250 km² of Valtournenche, Ayas and Gressoney Valleys) detecting small-to-medium size avalanches in real-time also in bad weather conditions (snow storms, fog, etc …) and in not-accessible areas (Durand et al., this issue). Helping the validation of IAN, since Summer 2012, the obstacle at Seehore accommodates a high sensitive low noise infrasonic microphone to understand the characteristic frequency range in infrasonic waves produced by different - in types and size - snow avalanches.

4. AVALANCHE DATA

The artificially released avalanches are generally small (sometimes medium) size: the threshold to operate an artificial release is around 30 cm of new snow. Therefore, the relea
-se volume is typically about 200–400 m$^3$ (up
to 1000 m$^3$ if a thick slab is released) and they
seldom reach the ski-run. Usually, P.ta Seehore
releases dense-flow slab avalanches, occasion-
ally (in high winter conditions with dry and cold
snow) powder clouds and, during spring, also
spontaneous wet, loose avalanches. The trig-
gering is usually performed at around 8:30 am
by helicopter, using the DaisyBell® (Berthet
Rambaud et al., 2009) or explosives.

During the first four winter seasons (2009–
2010 until 2012-2013), about 30 avalanches
were released at the site, both spontaneously or
by artificial triggering. In total, 15 experiments
have been realized, not all with a successful
release of an avalanche (Tab. 3). The most
common triggered avalanches were dense slab
avalanches of small dimension, with a mean
fracture depth of about 30 cm. The characteris-
tics of slabs are presented in Tab. 3 in Maggioni
et al. (2013).

<table>
<thead>
<tr>
<th>WINTER</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>spontaneous</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>artificially triggered</td>
<td>4</td>
<td>10</td>
<td>0</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>n. experiments</td>
<td>5</td>
<td>6</td>
<td>0</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

Table 3. avalanche data in the four first opera-
tive seasons.

5. PRELIMINARY ANALYSIS

All the data recorded at the test site are used
to achieve the main goals of our research:
– study the dynamics of small and medium av-
alanches;
– study the interaction between avalanche
flows and obstacles.

5.1. Avalanche dynamics

Some well-recorded small avalanches trig-
gerated at the Seehore test site were simulated
with the numerical model RAMMS (Christen et
al, 2010). Some results presented showed in
particular the importance of including erosion
and deposition parameters (Maggioni et al, 2012)
and of the terrain modified by previous
deposits (Maggioni et al, this issue) in the inves-
tigation of the dynamics of small avalanches.

The Seehore test site has a great potentiality
for studying erosion and deposition processes.
In fact, the logistic of the experiments is relative-
ly simple and good data can be collected with
field works and then used in the back calculation
procedure with numerical models. Moreover,
from 2010 a new simple test to measure the net
eroded and deposited snow is used (straw test
by Bovet et al., 2012 and Bovet et al., this is-
sue,) and give additional information for the
modelling. Such tests are logistically impossible
to realize at larger scale.

5.2 Interaction avalanche flow/obstacle

The specific surveys done around the obsta-
cle are used to validate analytical models (as
the Mohr Coulomb theory, Baroudi et al. 2011,
applied to the tail of the avalanche as in Bovet,
2012), or to validate a FEM model (Bovet et al.,
2011 and Bovet, 2012) allowing to reproduce
the creation of a deposit up-wind the obstacle.
Consideration about the inclination of the obsta-
cle with respect to the avalanche flow are done
too (Bovet, 2012).

The data concerning the 11 events, both dry
and wet avalanches, recorded by the obstacle
allow different approaches of study. The analy-
sis focuses on the force distribution on the
plates, maximum values of the impact force,
duration of the impact, presence of different
waves in the avalanche flow, static load remain-
ning after the event.

6. CONCLUSIONS

This paper focus on describing the new ex-
perimental test site Seehore, which is dedicated
to the study of small and medium avalanches.

The site joins the other European real scale
test sites with the peculiarity of studying small to
medium size avalanches, while the majority of
the other test sites focuses generally on large
avalanches.

In the next future, the site will be implement-
ed with more specific sensors (avalanche veloci-
ty and snowpack properties) for a better
knowledge of the avalanche dynamics also with
respect to snowpack properties, in order to deal
with the avalanche risk management in possible
future scenarios.

7 ACKNOWLEDGMENTS

This work was possible thanks to the Opera-
tional Program Italy– France (Alps–ALCOTRA),
Projects “DynAval - Dynamique des avalanches:
départ et interactions écoulement/obstacles.”
and “Map3 – Monitoring for the Avalanche Previ-
sion, Prediction and Protection”.

The authors wish to gratefully thank all the See-
hore team:

M. Barbero, F. Barpi, M. Borri-Brunetto, V.
De Biagi and O. Pallara (DISEG, Politecnico di
Torino);
E. Bruno, E. Borgogno, A. Bruilport, D. Go-
done, D. Vignetti and E. Zanini (DISAFA and
NatRisk-LNSA, University of Torino);
N. Durand and F. Diotti (Fondazione Monta-
gna sicura - Montagne sûre, Courmayeur - AO);
the company Monterosa S.p.a., and in particular H. Grosjäques;

L. Bornaz (Ad Hoc 3D Solution S.r.l.) for the laser scanner measurements;

G. Ulivieri, E. Marchetti and M. Rippepe (Dipartimento di Scienze della Terra, Università di Firenze, Firenze – IT) for the infrasonic measurements;

P. Bartelt, Y. Buehler, M. Christen and L. Dreier (WSL-SLF, Davos - CH) for the RAMMS simulations;

the colleagues of IRSTEA (Grenoble, FR) partners of the project DynAval and MAP3.

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