Snow Nets for Avalanche Protection

Chris Wilbur, P.E.
Wilbur Engineering, Inc.
Statewide Project Engineer’s Conference
Lake Chelan, Washington
October 15, 2013
Outline

• Origins in Europe
• Rigid vs. Flexible
• USA Applications
• Design Parameters

• I-90 Snoqualmie Pass East
  – Climate & Site Conditions
  – Project Challenges
  – Instrumentation & Outlook

• Questions
“Geonets are used by engineers to predict the occurrence of avalanches.”
ASCE Civil Engineering Magazine, June 1997
Primary Use in Europe:

Protect Villages

- Andermatt, Switz.
- Davos, Switz.
- Galtur, Austria
Walls/benches

Photos: Michael S. Falser, 2007
Historische Lawinenschutzlandschaften

K. Imhof 1912
Lawinenverbauungen
Early Structures

Pre-stressed Concrete
1966 photo by Frutiger & Martinelli
St. Antonien-Castels, Switz.

Aluminum Frame with Wood Cross Members
1959 photo by Wagner & Hopf
Mattstock Avalanche
Amden, Switz.

Photos source: Perla & Martinelli, 1978
USDA Avalanche Handbook 489
Orientation

Perla & Martinelli, USDA Avalanche Handbook 489
Snow Nets in USA

Climax Molybdenum Mine
Lake County, Colorado
Source: Frutiger & Martinelli, USFS, 1966
Sunlight Ridge
Mt. Crested Butte, Colorado

- Protects Condos
- 1989 child fatality
- Concrete wall in 1996
- Snow nets in 2006
- Dk 3.0m 1500 ft. length
- Cost “just over $1 million”
- 2007 Avalanche Maps revised
- Deep snow in January 2008
Teton Science School
Jackson, Wyoming

- Dk=3.0m nets
- Short slope
- Preventative measure
- Low visual impact
Alpental Subdivision
Snoqualmie Pass, WA

- 4.0 meter Geobrugg snow nets
- Installed after tree logging
- Contractor: Janod, Quebec, Canada
- Cost overruns due to unforeseen poor ground anchor conditions
WYDOT - US 89/191
MP 151 Jackson, Wyo.

- 8000 ADT (winter)
- Avg. Return Period 0.7 yrs.
- Replaced “Wind Sails” (from 2002)
- USFS Critical Big Game Habitat
- NEPA process
- Built in 2012-13
- $2.3 million
- Reforestation component

Photos courtesy of TLC Tree and Landscape Co.
The Canyons – Park City, Utah
Vela “Umbrella” Nets

- Individual Units
- Single Anchor
- Relatively New
- Considered for I-90

Photos from Vela
Design

- Creep
- Glide
- Factors
  - Snow height
  - Ground roughness
    - (glide factor)
  - Snow density
  - Terrain shape
  - Slope angle

Source: 2009 Swiss Guidelines
By Stefen Margreth, SLF
Snow Nets

Profile
Source: Figure 31, 2007 Swiss Guidelines

Double spiral cable anchor
(Maccaferri/Kane Geotech)
Typical Loads

for $D_k=4.0$, $N=2.5$, $f_c=1.1$ slope 45 deg. intermediate section

<table>
<thead>
<tr>
<th>Snow pressure</th>
<th>93 kN/m$^2$</th>
<th>93 kN/m$^2$</th>
<th>85 kN/m$^2$ (5.8 kips/ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure force (+)</td>
<td>+261 kN (A)</td>
<td>+365 kN (A)</td>
<td>-81 kN (A) (-18 kips)</td>
</tr>
<tr>
<td>Tension force (-)</td>
<td>+115 kN (B)</td>
<td>-44 kN (B)</td>
<td>+255 kN (B) (57 kips)</td>
</tr>
<tr>
<td></td>
<td>-182 kN (C)</td>
<td>-169 kN (C)</td>
<td>-322 kN (C) (-72 kips)</td>
</tr>
</tbody>
</table>

Source: Stefan Margreth, ISSW 2008 Whistler, BC, Canada
I-90 Snoqualmie Pass East

- 30,000 ADT
- 58,000 ADT peak weekends
- 35 million tons of freight/year
- Cost of Closures (120 hrs/yr average)
- Snow Nets (3 sites)
- Other mitigation bridge, ditch/wall systems
I-90 Snoqualmie Pass East
I-90 Snow Nets

Quantities:

• Slide Curve – 3693 l.f.
• E. S. Minus 1 – 540 l.f.
• Bald Knob – 103 l.f.
• Totals
  – 4.0 m 1941 l.f.
  – 3.5 m 1148 l.f.
  – 3.0 m 1247 l.f.
  TOTAL = 4336 l.f.

Preliminary Construction Cost:

Engineer’s Est.: $10.0 million
Bid Award: $6.0 million
Change Orders: $2.9 million
Total Cost: $8.9 million

Unit cost: $2053/ft
$6732/m

Not included: Training, spare parts, instrumentation.
Weather Stations

Legend:
- Red circle: Snow Net Site
- Blue diamond: Weather Station

Locations:
- Snoqualmie Pass
- East Shed Minus One
- Bald Knob
- Slide Curve
- Keechelis
- Stampede Pass
- Kachess
Snoqualmie Pass
Snow Depth

16.5 ft. March 1956

13.9 ft.
Design Climate
Washington Cascades vs. Swiss Alps

1. Total Precipitation
2. Seasonal Differences
3. Temperatures
4. Rain-on-snow
Slide Curve

- 3.0m, 3.5m & 4.0m heights
- High density snow
- Variable ground conditions
- Instrumentation
- Re-Forestation

Photos: John Stimberis, WSDOT
Upper Slide Curve

- High Glide Factor
- Greater Snow Depth
- Artificial Roughening
Surface Roughening

Photos: Stefan Margreth
SLF Swiss Federal Institute for Snow and Avalanches
Bald Knob

Smooth Rock – High Glide Factor
Convex Slope
East Shed Minus One

- Smooth Rock (High Glide Factor)
- Lower Elevation
- Water Flow at base of snowpack
East Shed Minus One

Photos: High Tech Rockfall, Inc.
Slide Curve
Iterative Design Process
East Shed Minus One

Bald Knob
Project Challenges

- Snow Conditions
- Variable Ground Conditions
- Limited Geotechnical Data
- Technical Specifications
- Limited Experience
  - Designers
  - Contractors
  - Owner

Slide Curve
Boulder Field
Addressing Challenges

- European Expertise
- Geotechnical Consultant
- Iterative Design Layout
- Artificial Surface Roughening
- Upsizing Snow Net Heights
- Incorporate New Data (2009 ROS*)
- Comprehensive Anchor Testing

Roberto Castaldini, Dr. Ing.
Studio Tecnico di Ingegneria
Verona, Italy

* Rain-on-snow - January 2009 event was classified as an extreme event, with a return period in excess of 100 yrs.
Snow Net Instrumentation

1. Uphill Anchor Tension
2. Post Compression
3. Post Inclination
4. Downhill Cable Tension
### Inspections

<table>
<thead>
<tr>
<th>Types of Inspection</th>
<th>L1</th>
<th>L2</th>
<th>SL2</th>
<th>L3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Periods</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Key structure: annually</td>
<td></td>
<td>all structures: before end of guarantee</td>
<td>Key structure: after extreme events</td>
<td>all structures: in vase of need</td>
</tr>
<tr>
<td>Standard structure: at least every 5 years</td>
<td></td>
<td>Key structure: every 5 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methods</td>
<td>visual</td>
<td>visual</td>
<td></td>
<td>advanced methods</td>
</tr>
<tr>
<td>Executed by</td>
<td>Lumbermen</td>
<td>Experts</td>
<td>Experts (interdisciplinary)</td>
<td>Level 3 Inspection</td>
</tr>
<tr>
<td>Result</td>
<td>Level 1 minutes</td>
<td>Level 2 minutes</td>
<td>Level 2 minutes</td>
<td>Level 3 minutes</td>
</tr>
</tbody>
</table>

From Florian Rudolf-Miklau, Wolfgang Schilcher, Johann Kessler and Jürgen Suda

- **Iceland Snow Nets**: Damaged due to insufficient lateral support
  Photo: Tómas Jóhannesson

- **Austria Snow Bridges**: Damaged by avalanche
  Photo: Florian Rudolf-Miklau
Outlook

- Highway Closure Reduction
- Forecasting & Control Resources
- Summer Maintenance
- Structure Retirements
- Structure Replacements
- Costs vs. Benefits

Slide Curve
Photo: John Stimberis, WSDOT
Snow Nets
Take-away

• Starting Zone Structures (snow nets and/or snow bridges) are a very effective passive avalanche defense
• Costs depends on size of starting zone, snow depth, ground conditions, land availability
• Eliminates decision making during extreme snow conditions
• Frees up avalanche forecast/control resources during winter big storms
• Inspections & Maintenance are required to achieve typical design life of 80 years
Thank You!

Questions?

John Scurlock, Photographer/Pilot