Structural Avalanche Defenses

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Outline

• Design Avalanche

• Types of Structures
  – Deflecting/Diversion
  – Dams & Retarders
  – Snowsheds
  – Snow Supporting
  – Direct Protection

• Example Project
  – Snoqualmie Pass, WA
Snow Avalanches

- Dense core
- Powder component
- Saltation zone
- Entrainment

1773 Engraving
“Topographie der Schweiz”
David Herrliberger

2009 Diagram
The Design of Avalanche Protection Dams
European Commission

Tomas Johannsson & Peter Gauer
Design Avalanche

• Probability
• Avalanche type
  – wet, dry, powder
• Consequences
• Other factors
  – Political
  – Economic
  – Legal

Swiss Federal Office of Topography

Robert Petley photo
Design Parameters

- Flow velocity
- Flow heights
- Flow densities
- Flow directions
- Existing snow height
- Snow erosion height
- Geometry of structure
  (Height, Deflection angle)

Figures from:
The Design of Avalanche Protection Dams
European Commission, 2009
Structural Defense Locations

- Starting Zone Structures
- Deflection Structures
- Dams/Retarding Structures
- Direct Protection
Diversion Structures

- Redirect flow
- Small deflection angles
- Deposition depends on slope angle
- Must consider redirected flow impacts

Stoli Boli, Iceland
Photo: Reynir Vilhjalmsson

Selkingen-Biel, Switzerland
Photo: Charlie Wuilloud
Diversion Structures

San Juan County, CO

Arinsal Andorra

Pitkin County, CO

Siglifjordur, Iceland
Dams & Retarding Structures

Galtur, Austria

Neskaupstadur - Drangagil, Iceland

Switzerland: Hans Frutiger photo

Pas de la Casa, Andorra
Snettisham, AK

Photos: AEL&P
Snow Sheds (Galleries)

Shed Loading – from Peter Schaerer
ASCE Journal of the Highway Division 1966

Mine Conveyor, Grand County, CO

Splugen Pass, Switzerland
1843 - 1950
Central Pacific Railroad
Sierra Nevada Snowsheds

- Timber Construction
- 1867-1869
- Two types:
  - Avalanches
  - Snow protection
- 37 miles total
- Fire problems
- Replaced w/ concrete & tunnels
Great Northern RR
Stevens Pass Snowsheds

Tye Shed, 1929

Washington State Historical Society photos
Wolf Creek Pass – US 160

- Site of 2 avalanche fatalities in 1950-51
- Built in 1965 after series of snowy winters
- Shed impacted once in last 19 years
- Shed removal likely at end of service life due to low return period and effective forecast & control program
East Riverside – US 550

- 3250’ Vertical fall
- 80 acre starting zone
- Reaches highway multiple times per year
- 6 Persons Killed (since 1963)
- Built in 1985 for $1.6 million
- Recommended Length = 400’
- Constructed Length = 180’
- Design Loads:
  - Static 1800 psf
  - Dynamic 1000 psf
Starting Zone Structures

Design Parameters

- Max. Snow Height
- Slope angle
- Snow Density
- Ground roughness
- Aspect

Rigid Structures

Flexible Structures
Flexible Starting Zone Structures
Snow Nets

Jackson, Wyoming
Pas de la Casa, Andorra
Mt. Crested Butte, CO
Photo: Vela, Italy
Rigid Starting Zone Structures

Davos Switzerland, SLF photo

Concrete Structures
Photo: Hans Frutiger

Galtur, Austria
Direct Protection

- No off-site Land Required
- Protection/materials focused at Resource
- Allows development in “Moderate Hazard” Areas
- Usually Reinforced Concrete
- Steel, Masonry, Boulders also used
- Off-site deflections possible
420 kV Line - Eastern Iceland

Aluminum Smelter

Hydroelectric Plant

Reykjavik
Lessons from Europe 1999

- Severe Winter w/ extreme avalanche conditions
- Forests very effective
- Starting Zone Structures very effective; some overtopped
- Dams caused new hazards & damages
- Powder component exceeded mapped limits
- Multiple events w/in single path caused damage
- Measured record velocities (110 m/s or 245 mph)
I-90 Snoqualmie Pass, WA

- 30,000 ADT
- 35 million tons freight/yr.
- Cost of Closures
- 1100’ Snowshed
- 3700’ Snow nets
- Ditches & Walls
East Shed – Snoqualmie Pass

WSDOT photo
Snoqualmie Pass East Shed

Existing Snowshed (1951)
- 2 lanes
- 500 feet long
- 4:12 (33%) Roof pitch

Planned Snowshed (2012)
- 6 lanes
- 1100 feet long
- Roof pitch 5%

Artist’s conception by WSDOT
Slide Curve
Starting Zone Structures

- 1140m (3740’) structures
- 3.0m, 3.5m & 4.0m heights
- Special designs for high density snow (400 kg/m³)
- Instrumented for loads & deflections
- Afforestation

Photo: John Stimberis, WSDOT

WSDOT photo
Design Climate
Washington Cascades vs. Swiss Alps

1. Total Precipitation
2. Seasonal Differences
3. Temperatures
4. Rain-on-snow
Snow Net Instrumentation

1. Uphill Anchor Tension
2. Post Compression
3. Post Inclination
4. Downhill Cable Tension
Thank You!

Suggested Reading:


Photo: Mike Janes, AEL&P