Structural Avalanche Defenses

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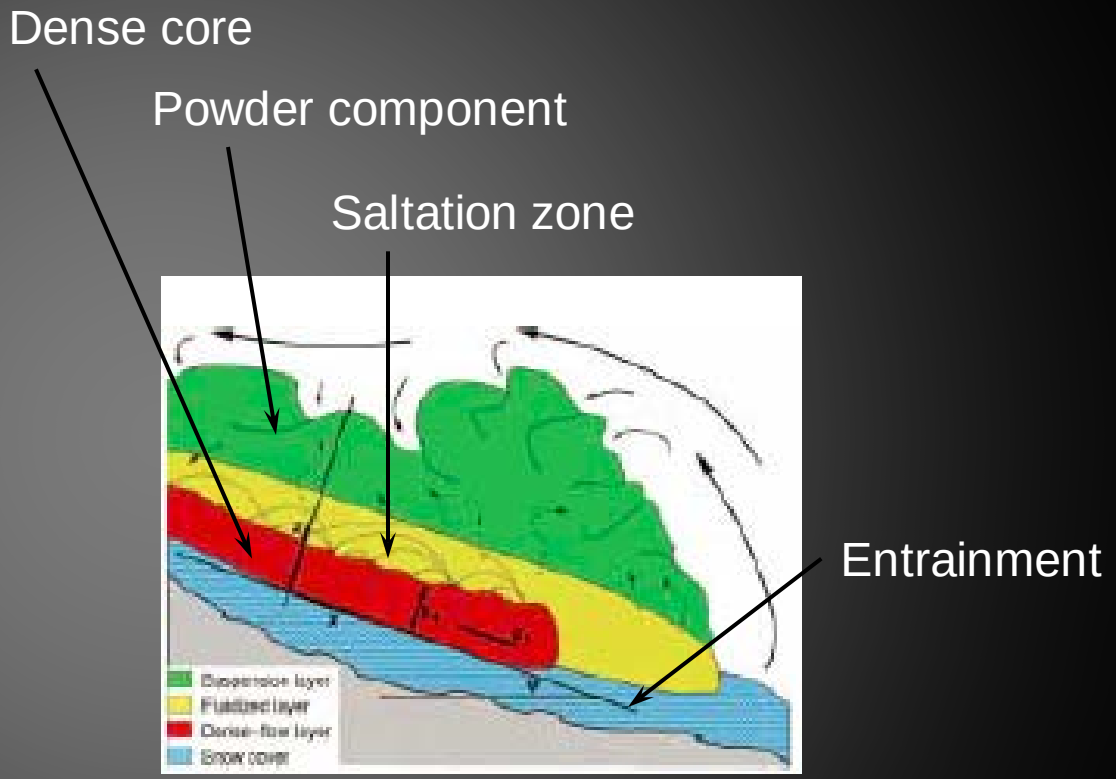
Outline

- Design Avalanche
- Types of Structures
  - Deflecting/Diversion
  - Dams & Retarders
  - Snowsheds
  - Snow Supporting
  - Direct Protection
- Example Project
  - Snoqualmie Pass, WA

The Battleship, US 550
Tim Lane Photo

Snow Avalanches

1773 Engraving
"Topographie der Schweiz"
David Herrliberger



Tomas Johannsson & Peter Gauer

2009 Diagram
The Design of Avalanche Protection Dams
European Commission

Design Avalanche

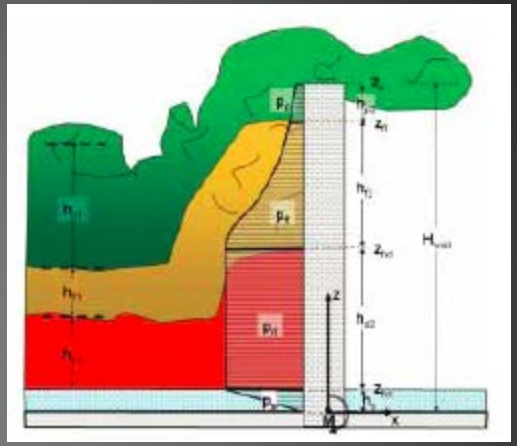
- Probability
- Avalanche type
  - wet, dry, powder
- Consequences
- Other factors
  - Political
  - Economic
  - Legal

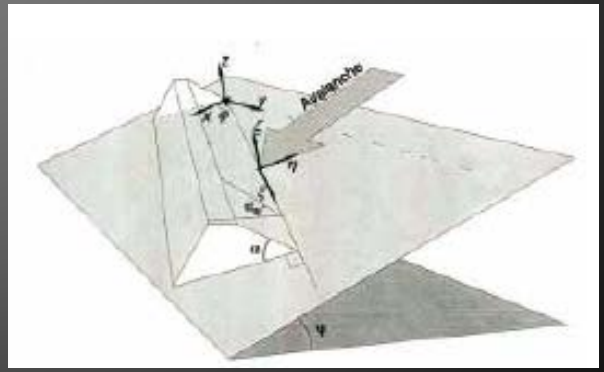
Swiss Federal Office of Topography

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

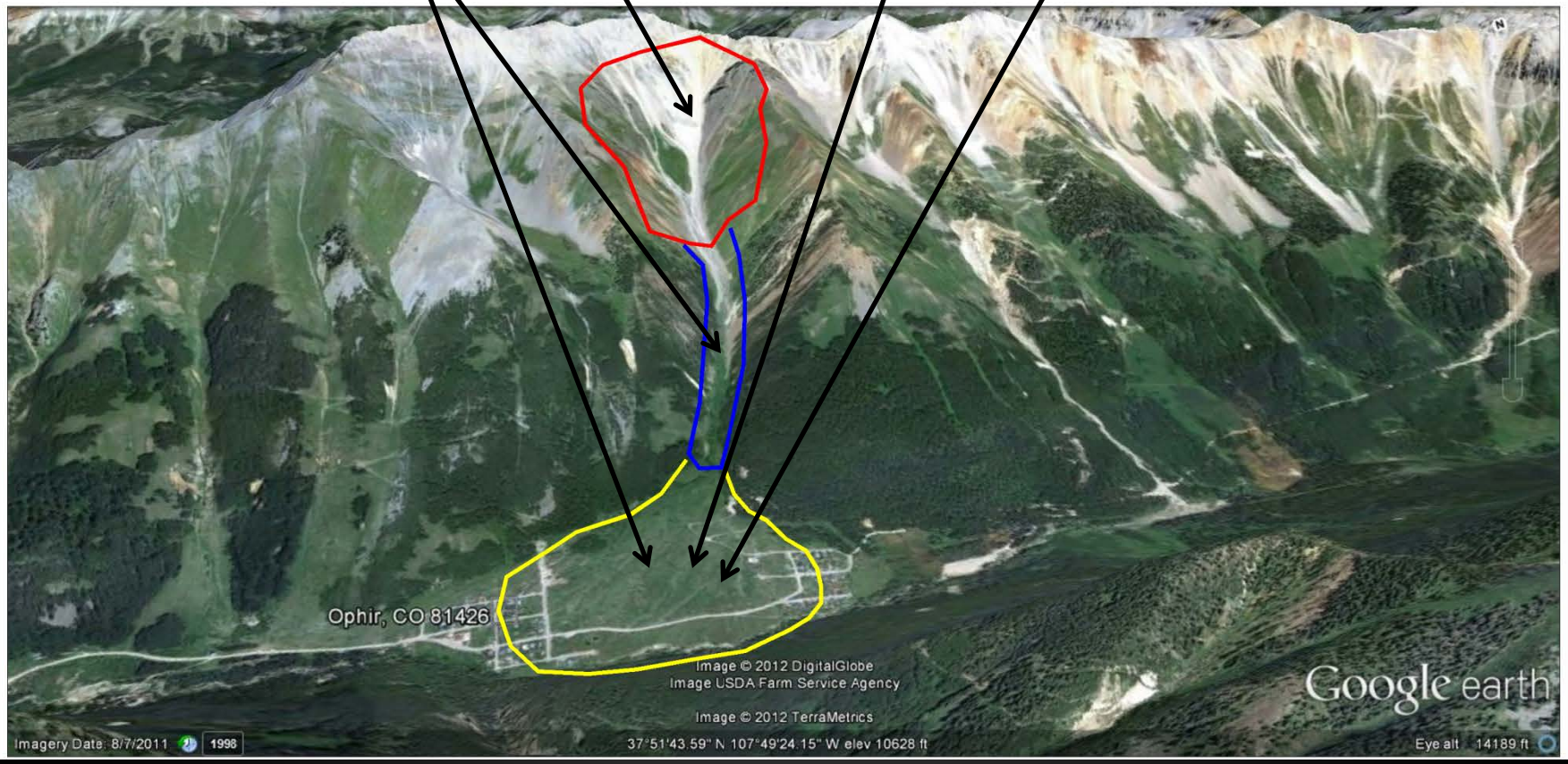
Structural Defense Locations

Starting Zone Structures

Dams/Retarding Structures

Deflection Structures

Direct Protection



Diversion Structures

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

Stoli Boli, Iceland
PhotoReynir Vilhjálmsson

Selkingen-Biel, Switzerland
Photo: Charlie Wuilloud

Diversion Structures

San Juan County, CO

Arinsal Andorra

Pitkin County, CO

Siglifjordur, Iceland

Dams & Retarding Structures

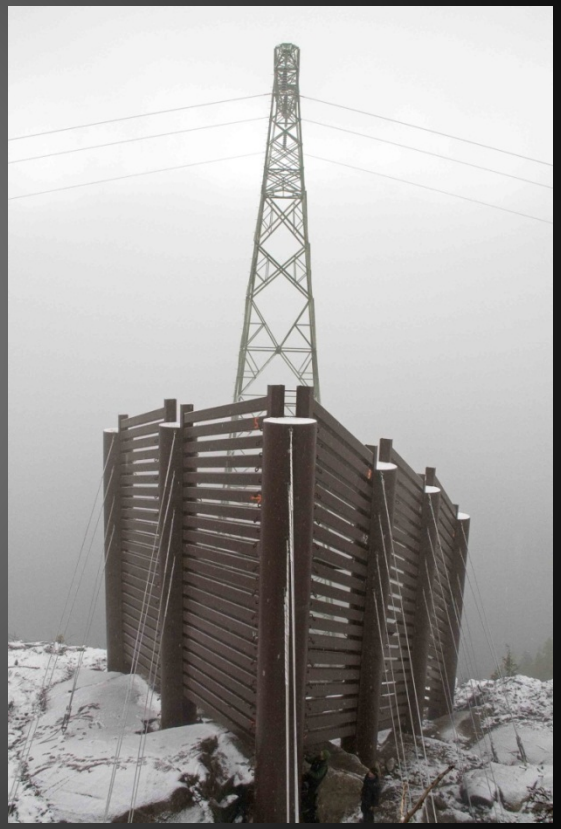
Galtur, Austria

Neskaupstadur - Drangagil, Iceland

Switzerland: Hans Frutiger photo

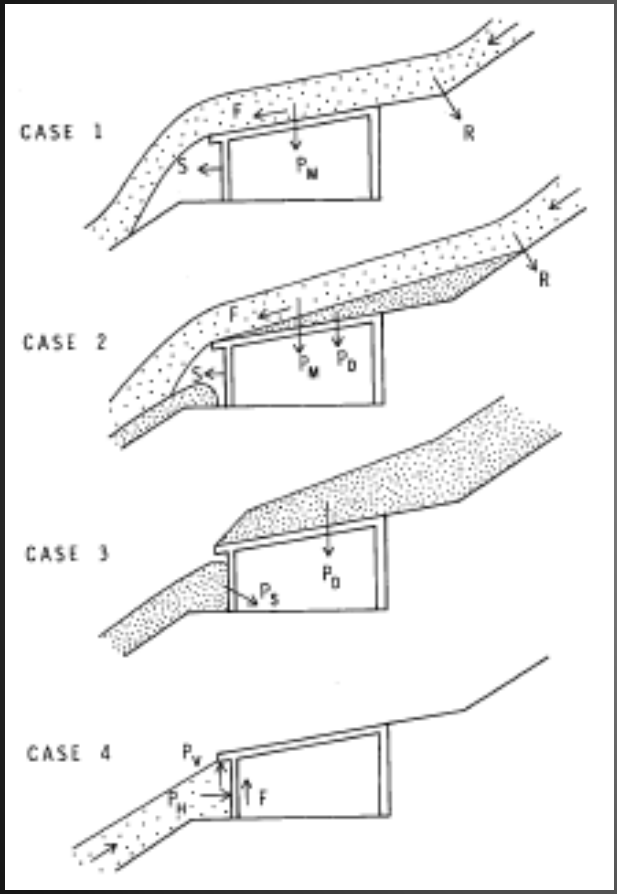
Pas de la Casa, Andorra

Snettisham, AK



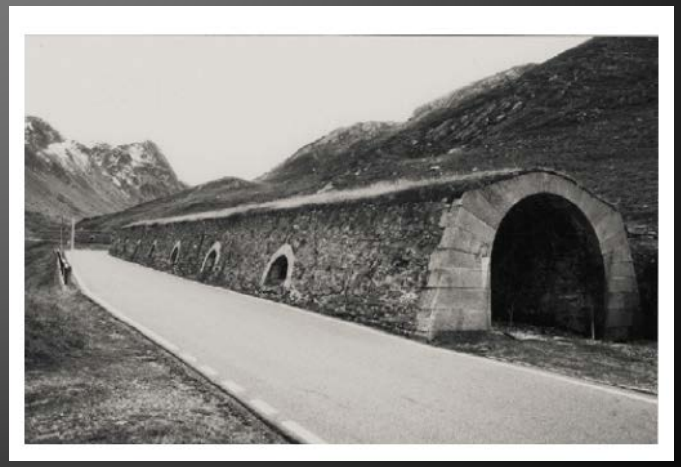
Photos: AEL&P

Snow Sheds (Galleries)



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

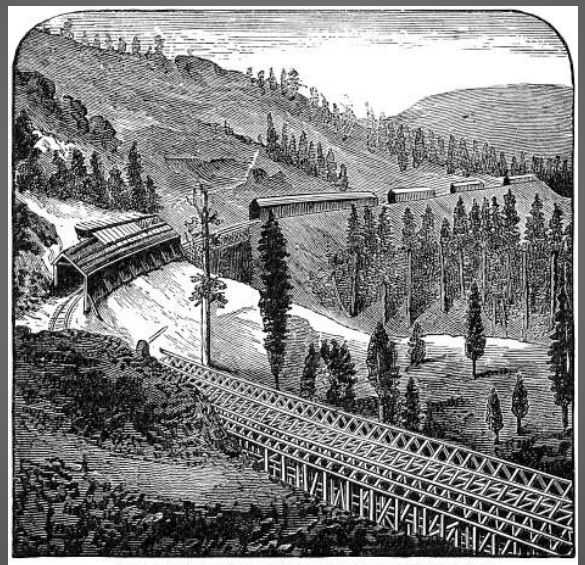
Mine Conveyor, Grand County, CO



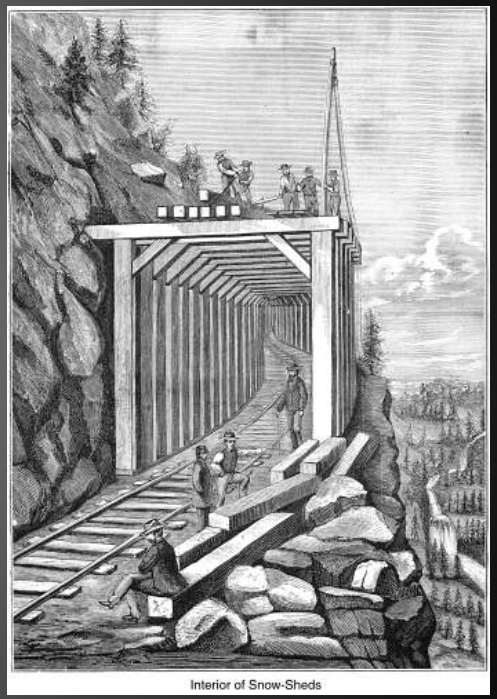
Splugen Pass, Switzerland
1843 - 1950

Central Pacific Railroad
Sierra Nevada Snowsheds

- Timber Construction
- 1867-1869
- Two types:
  - Avalanches
  - Snow protection
- 37 miles total
- Fire problems
- Replaced w/ concrete & tunnels

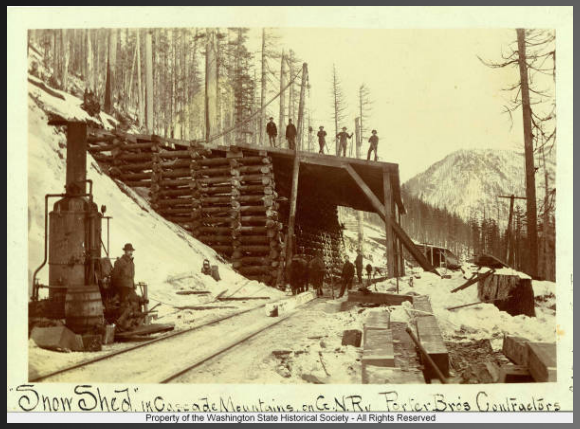


Snow Galleries, Sierra Nevada Mountains

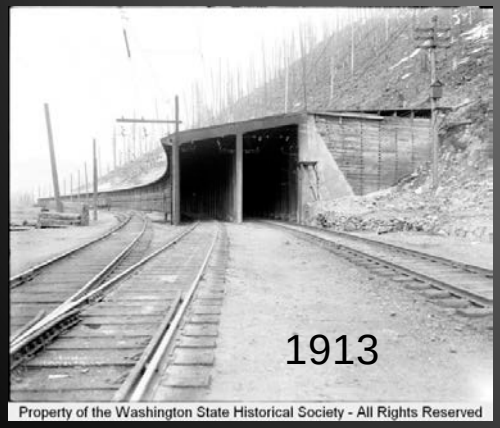


Interior of Snow-Sheds

Great Northern RR
Stevens Pass Snowsheds

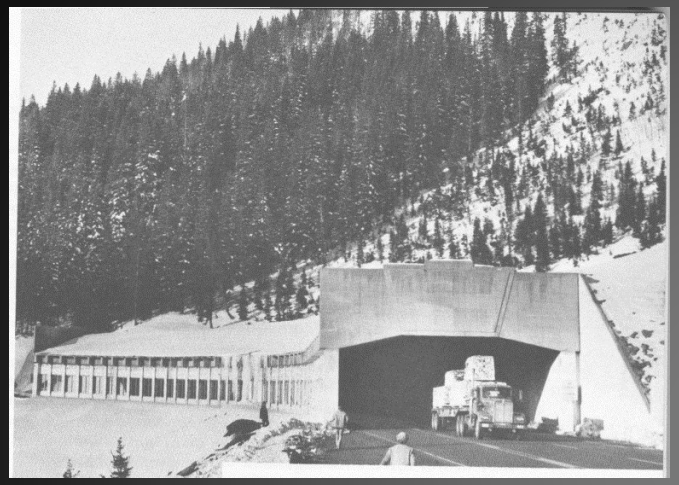


Tye Shed, 1929



Washington State Historical Society photos

Wolf Creek Pass – US 160



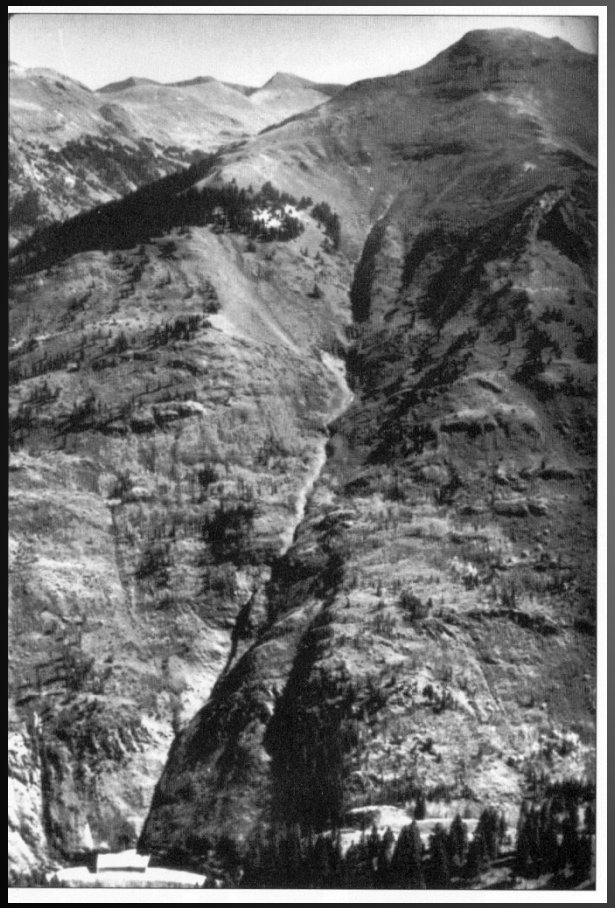
Wolf Creek Pass 1966
Hans Frutiger photo

Alberta Path & Alberta's Cousin

Wolf Creek Pass 2010

- 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



Art Mears photo

- 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

Art Mears photo

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

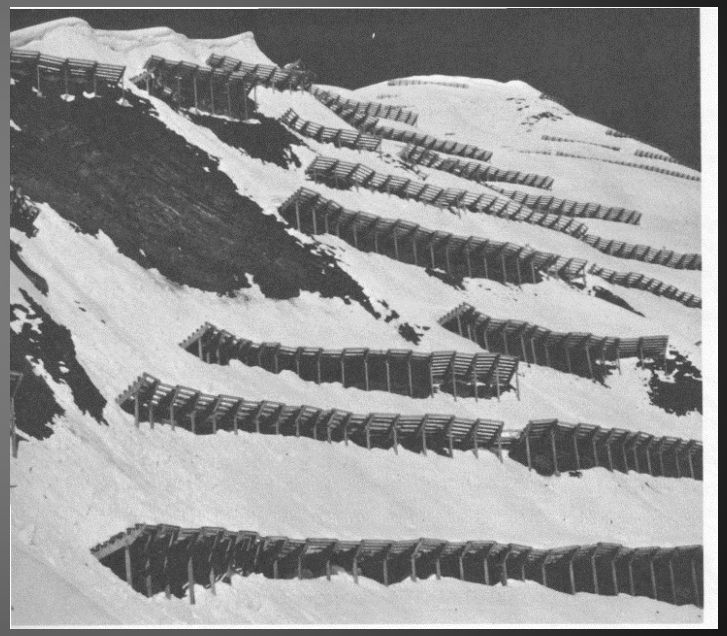
Mt. Crested Butte, CO

Photo: Vela, Italy

Rigid Starting Zone Structures

Davos Switzerland, SLF photo

Galtur, Austria



Concrete Structures

Photo: Hans Frutiger

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

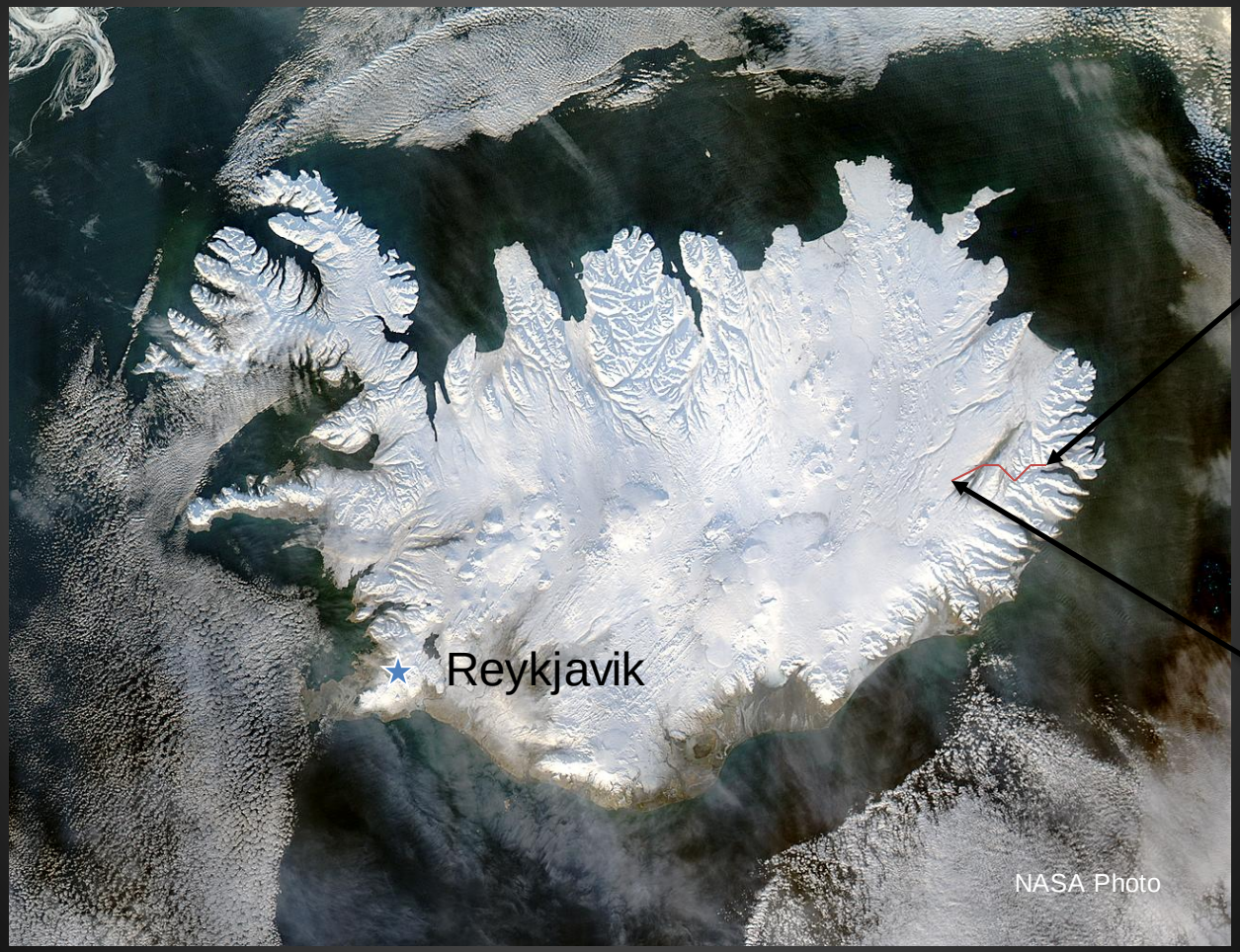
Ketchum, Idaho

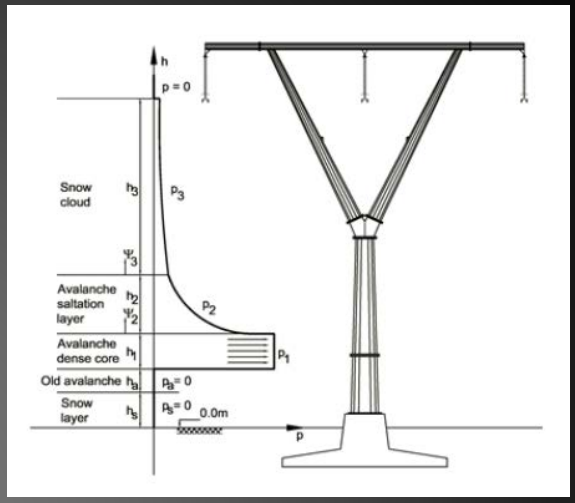
Sun Valley, Idaho

Sun Valley Idaho

Ophir, Colorado

420 kV Line - Eastern Iceland





by Ragnar Jónsson

Photo: IceGrid

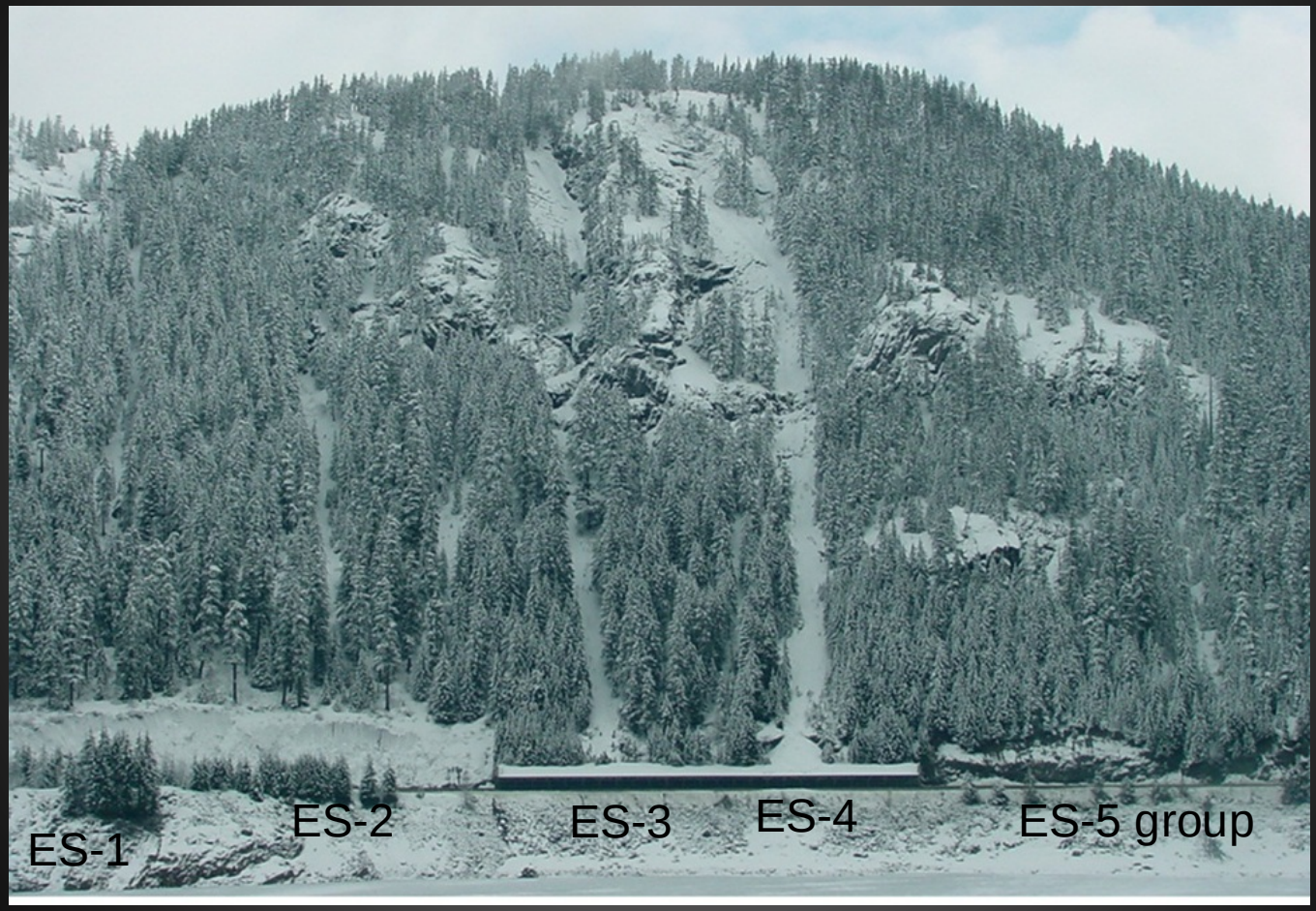
Lessons from Europe 1999

- 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%

Slide Curve

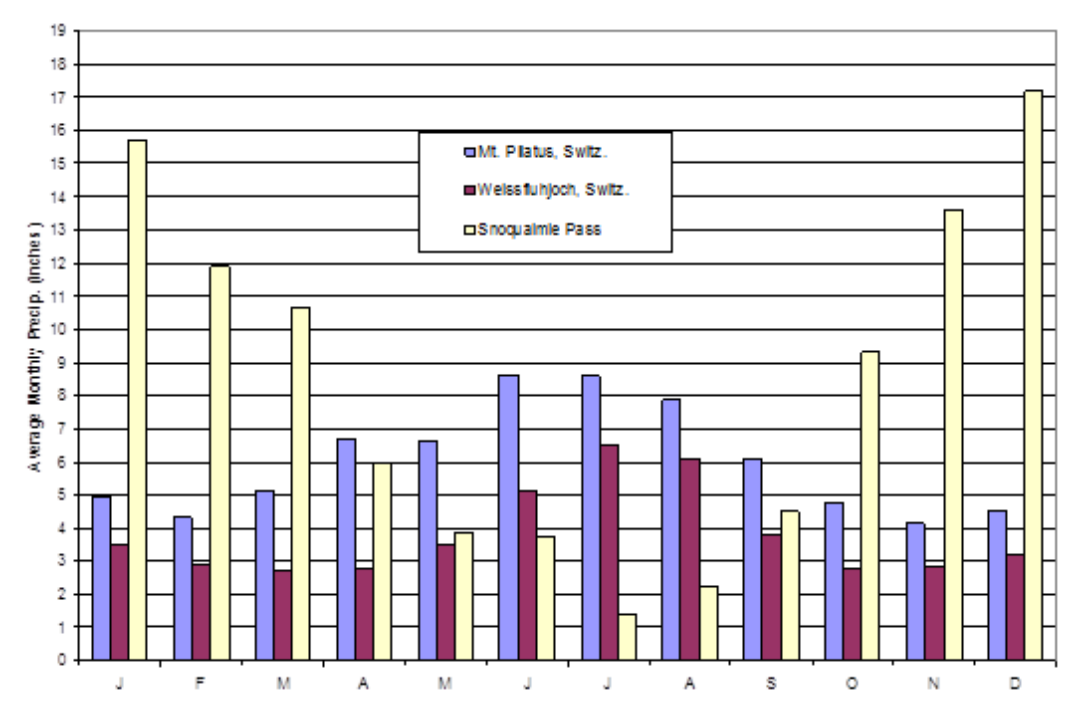
Starting Zone Structures

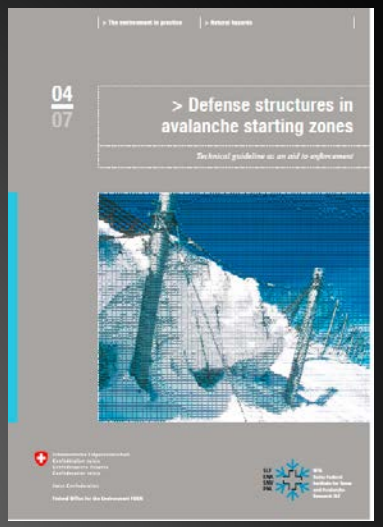
Photo: John Stimberis, WSDOT

- 1140m (3740') structures
- 3.0m, 3.5m & 4.0m heights
- Special designs for high density snow (400 kg/m^3)
- Instrumented for loads & deflections
- Afforestation

Design Climate

Washington Cascades vs. Swiss Alps

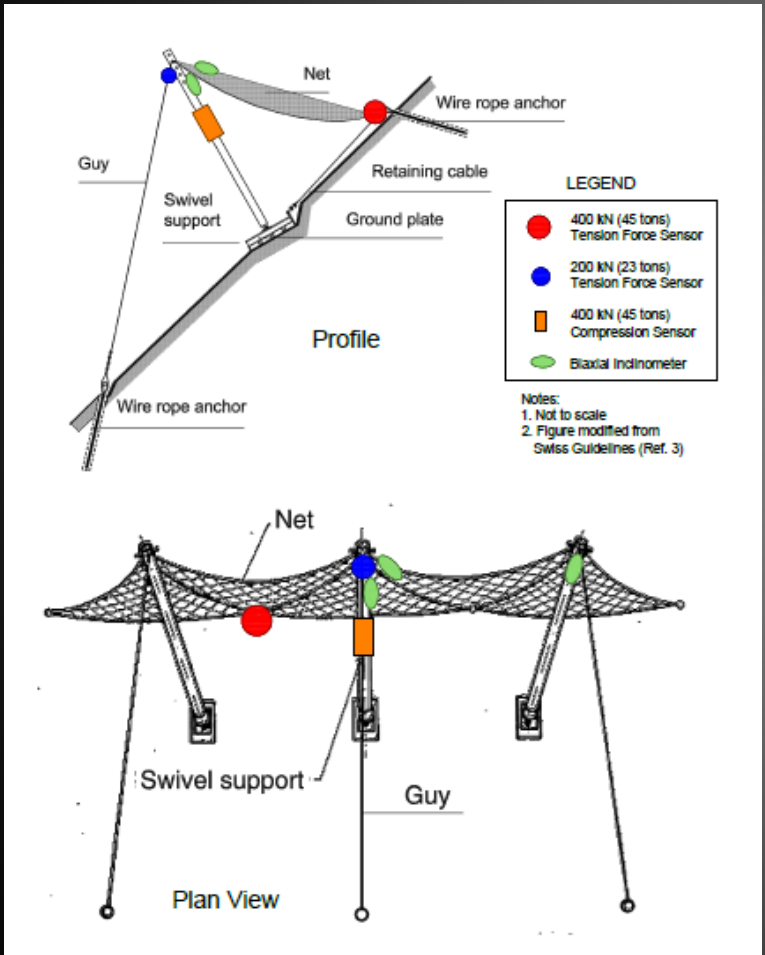




Swiss Design Guidelines

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:

1. Living and Dying in Avalanche County, John Marshall & Jerry Roberts, 1998
2. Avalanches and Snow Safety, Colin Frazer, 1978
3. Snow Avalanches Along Colorado Mountain Highways, Hans Frutiger, 1964
4. The Avalanche Handbook, David McClung & Peter Schaerer, 2006
5. *RGS Story Vol. III, Vance Junction to Ophir,* W. George Cook, Dell A. McCoy, Russ Collman, Sundance Publications, Ltd., 2000.

Photo: Mike Janes, AEL&P