Challenges from Climate Change to All Season Roads in Canada

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Synopsys

• What is Permafrost?
• Canadas North and Associated Transportation Infrastructure
• Climate Change in the Arctic
• Challenges to Road Infrastructures
• Mitigation Options
• Conclusions
Permafrost

“Soil or rock, with or without included water, that has remained at or below 0°C for 2 or more years.” (Muller, 1947)
Permafrost Distribution

Continuous

Discontinuous

Sporadic

Isolated

EXPLANATION

PERMAFROST EXTENT

Continuous (90-100 percent coverage)
Discontinuous (60-90 percent coverage)
Sporadic (30-60 percent coverage)
Isolated (10-30 percent coverage)

BGC

Transports Canada
Highway System in Canada
Typical Design Concept

- Protect the Permafrost
- Drainage Control
State of Climate - Canada

- Both past and future warming in Canada is about double the magnitude of global warming
- Northern Canada has warmed and will continue to warm at even more than double the global rate
- Precipitation has increased in many parts of Canada, and there has been a shift toward less snowfall and more rainfall
- Reductions in summer rainfall are projected for parts of southern Canada
- Extreme rainfall amounts will go 30-40% and the frequency of extreme hourly rainfall will go ~400%
- Extreme warm temperatures have become hotter
- Increased risk of water supply shortages in summer
- Coastal flooding is expected to increase in many areas of Canada due to local sea level rise
Permafrost Temperatures

a. Cold continuous permafrost, NW North America

- Happy Valley (20 m)
- Gailbrath Lake (20 m)
- Franklin Bluffs (20 m)
- Deadhorse (20 m)
- West Dock (20 m)
- Norris Ck (8.8 m)
- KC-07 (17.4 m)
- Barrow 2 (20 m)

b. Cold continuous permafrost, eastern and High Arctic Canada

- Pangnirtung (15 m)
- Pond Inlet (15 m)
- Arctic Bay (15 m)
- Alert BH1 (24.4 m)
- Resolute (15 m)
- Alert BH5 (15 m)
- Alert BH2 (24.4 m)
- Eureka EUK4 (10 m)
Ground Temperatures / Permafrost

- Affected by air temperature and rate of change
  - E.g. +1°C in 10 years vs. +1°C in 50 years
- But also other parameters including
  - Snow Cover (Drift)
  - Precipitation (pattern)
  - Vegetation / Evaporation / Snow (re)distribution
  - Hydrology / Freshet / Aufeis
  - Cloud Cover / Solar Radiation
Why is it so Challenging?

• Design and construction of infrastructure in permafrost is challenging even w/o climate change.

• Every structure affects the thermal regime with a varying degree of uncertainty.

• Uncertainties related to climate change are very high because of higher order effects.

• Design is not based on average conditions.
External Hazards

Retrogressive thaw slump

Dempster Highway, NWT ~km 30
Icing

November 11, 2014

Note the vertical displacement

Kokelj, 2016
Flooding
Changes, Changes, Changes

- Active layer thickening
- Permafrost degradation – Sinkholes
- Aufeis formation
- New mass movements
- Flooding
- Coastal erosion

New Hazards and new Risks

Higher Order Effects → Increased Uncertainty
Mitigation Options

- Air Convection Embankments
- Heat Drains
- Air Ducts
- Thermosyphons
- High Surface Albedo
- Gentle Slopes
- Gravel Surface
- Geotextiles
- Drainage Control
Thank you / Merci