Adaptation of transportation infrastructure in Northern Quebec and Canada: Problem assessment and development of solutions

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Introduction

• Social and economic subsistence and development of Northern regions depends heavily on effective transportation of people and goods.

• Reliable transportation systems are therefore essential.
Introduction

• Permafrost degradation is threatening the structural and functional capacities of this infrastructure
• Distresses observed on several airstrips and roads
  • Climate change
    • Poorly adapted design
Exemples de dégradations

- Tassements différentiels
- Thermokarst
- Érosion thermique
- Fluage des sols gelés
Exemples de dégradations

Photos: V. Romanovsky (Alaska)
Objectives of research program

- Improve knowledge on factors causing permafrost degradation underneath transportation embankments
- Assess the vulnerability of airstrips and roads in Northern Canada
- Propose adaptation strategies for vulnerable facilities
- Develop performing stabilization techniques and document their cost effectiveness
<table>
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</tr>
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| Identify solutions | • Review of the state of the art  
|           | • Development of preliminary concepts          |
| Refine    | • Numerical simulations                        |
|           | • Laboratory modelling                        |
| Experiment| • Full scale testing                           |
| Apply     | • Pilot projects                               |
5-steps research approach

Understand
- Problem assessment

Identify solutions
- Review of the state of the art
- Development of preliminary concepts

Refine
- Numerical simulations
- Laboratory modelling

Experiment
- Full scale testing

Apply
- Pilot projects
Understand: Problem assessment

- Site visits and documentation of distresses
Understand: Problem assessment

• Develop a better understanding of the geological context
Understand: Problem assessment

- Observation of instrumented sites
  - Beaver Creek and other sites in the Yukon
  - Several sites in Nunavik
Understand: Problem assessment

• Geotechnical characterization of unstable sites
Understand: Problem assessment

- Geotechnical characterization of unstable sites

Verreault et coll.

Allard et coll.
## 5-steps research approach

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| Apply     | - Pilot projects                                  |
Identify solutions:
Review of state of the art

• Several methods developed in Alaska in past 50 years
  • Hi albedo surfaces
  • Air ducts
  • Snow sheds
  • Air convection embankment

• Interesting related work done in China and Russia

• Adaptation and further development required
5-step research approach

Understand
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Identify solutions
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Experiment
- Full scale testing

Apply
- Pilot projects
Experimental developments

• Concept developments
  • Based on state-of-the-art review and technical exchanges
  • New ideas proposed

• Design optimisation and effectiveness assessment
  • Numerical simulations
  • Small scale laboratory simulations
Numerical simulations
Numerical simulations: Optimization of design parameters
Small-scale laboratory simulations

Air temperature: -18°C
Soil temperature: 0°C

Thermistor strings

7°C
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| Apply        | - Pilot projects                                                           |
Experimental projects

• Assessment of feasibility and documentation of construction operations
• In-situ (full-scale) assessment of effectiveness
• Preliminary assessment of cost effectiveness

• Several test sites monitored:
  • Salluit road (6 test sections)
  • Tasiujaq airstrip (4 test sections)
  • Beaver Creek (12 test sections)
  • High albedo surfacing materials
Tasiujaq experimental test site
Beaver Creek test site

- Light coloured aggregates (12)
- Grass-covered embankment (11)
- Snow removal (10)
- ACE uncovered (9)
- Heat drain with insulation (8)
- Longitudinal culvert (7)
- Snow/sunshed (6)
- Control (5)
- Heat drain on side slopes (4)
- ACE covered (3)
- Heat drain on full embankment (2)
- ACE on full embankment (1)

- Solar/snow sheds
- Air ducts
- Heat Drain
- Air convection embankment
Heat balance in the embankment slopes from 2009 to 2011
Salluit experimental site for high-albedo surfacing materials
ITH experimental site, NWT
Best performing techniques

- Gentle slope (in windy conditions)
- Heat Drain
- Ace
- Longitudinal culverts
- Sun/snow sheds
- High albedo surfacing materials
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Adaptation/stabilization projects in Nunavik
Puvirnituq airstrip pilot project

Problem:

- Important settlements observed above a thaw sensitive deposit
- Permafrost degradation under embankment slope
- Airstrip needed to be upgraded for B-737 service
- High risk of stability problems (settlements and possible embankment failure) if permafrost degradation continues

Modifié de Verreault et Doré, 2010
Thermal and mechanical stabilization of the Puvirnituq airstrip
Performance of protection systems
Salluit access road pilot project

Problem:

• Important settlements observed along the road

• Permafrost degradation caused by water, snow accumulation and dark asphalt surface

• High risk of stability problems (settlements and possible slope failure)
Stabilization techniques used in Salluit
Performance of the protection systems installed in Salluit

Roger et al., 2015
Performance of the protection systems

• At both sites, no sign of significant degradation

- Puvirnituq airstrip
  6 years after construction

- Salluit access road
  3 years after construction
Ongoing work:

- Thermal and mechanical design of embankments built on sensitive permafrost
- Design of low-impact drainage systems
- Stabilisation of retrogressive thaw-slumps
- Risk analysis procedure for linear infrastructure built on permafrost
Conclusion

• Much has been done to develop engineering methods adapted for the development of transport systems on permafrost

• Much remains to be done:
  • Understanding and control of degradation mechanisms
  • Detection of unstable permafrost areas
  • Development of effective and affordable stabilization methods
  • Development of design procedures
  • Decision making tools to support management of transport infrastructure in permafrost areas
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