Application of organics for infrastructure construction on permafrost and community resiliency in northern Canada

Egorov, Igor; Krys, Dennis; Charlebois, Lawrence

Igor Egorov[1], Dennis Krys[1] and Lawrence Charlebois[2]
[1]NRC Construction Research Centre | [2]NRC Ocean, Coastal and River Engineering Research Centre
Ottawa, Ontario, Canada

National Research Council Canada – Permafrost Engineering Research

Monitoring and mitigation of the ground temperature regime of ice-rich permafrost to stabilize highway foundations in Yellowknife, Canada

Problem

Permafrost thaw resulting from a changing climate during the construction of Highway 3 in Canada's Northwest Territories has caused differential settlement of the road and adjacent areas. This is most evident in sections where the highway is underlain by ice-rich permafrost and lithalsas (Fig. 1). Thermokarst has developed on the both sides of the roadway and climate warming will further intensify the thermokarst processes. As a result, annual operating costs have increased significantly.

Fig.1 – Northwest Territories study site located on raised terrain (former lithalsa) with ice rich silty clay sediments.

Approach

National Research Council Canada (NRC) and its partners have initiated a research project to evaluate permafrost mitigation techniques and their effectiveness in stabilizing the highway and reducing operational costs. Previous studies assessed the susceptibility of the highway, described sensitive ice-rich permafrost areas and estimated the potential impacts of the climate change on similar permafrost ecotopes (Wolfe *et al*., 2015; Morse *et al*., 2015, Gaanderse, 2015). Highway 3, where the highway is underlain by thaw sensitive permafrost, is particularly sensitive. NRC is proposing a conceptual solution and permafrost thaw remediation strategies using the findings of previous research in the area as well as results from Geological Survey of Canada (GSC) and NRC sites (Wolfe *et al*., 2015; Morse *et al*., 2015; Gaanderse, 2015).

The objectives of the research project are to: (i) evaluate the effectiveness of new methods of ground temperature investigations and monitoring (Fig. 2); (ii) analyze the thermal gradients, lags and amplitudes together with mean annual ground temperature (MAGT) profiles to identify thermal properties of the soils and forecast thaw sensitivity of permafrost; (iii) establish field pilot tests for demonstration of new passive and active techniques for moderating permafrost thawing and stabilizing the highway.

Fig. 2 – NRC ground temperature monitoring probe

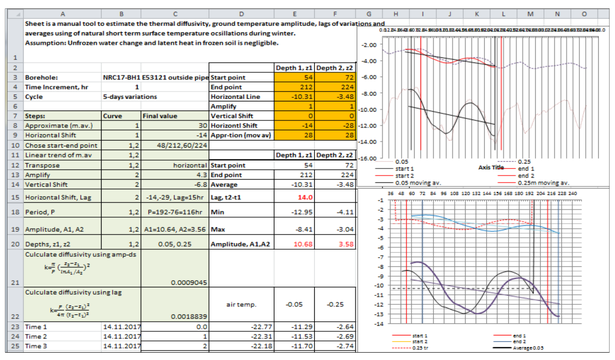

Fig. 3 – Analysis of thermal regime and diffusivity at the study site using NRC analysis software.

Fig. 4 – Preparation of the study site for instrumentation.

Impacts

This work evaluates the effectiveness of new methods of ground temperature investigations in warm permafrost. The research provides analyses of the thermal gradients, lags, and amplitudes together with mean annual ground temperature (MAGT) profiles to identify ground temperature trends, thermal properties of the soils, latent heat due to unfrozen water, and prediction of the thaw sensitivity of warm ice-rich permafrost. The work will also establish pilot field tests to demonstrate new passive and active techniques for moderating permafrost thaw in order to stabilize the highway and reduce operating costs.

Application of organics for infrastructure construction on permafrost and community resiliency in northern Canada

Problem

Permafrost underlies half of the Canadian landmass, vast tracts of coastline and large extents of seabed in the Arctic. In northern Canada, remote communities and extractive industries depend on energy and transportation infrastructure, much of which is built on thawing or thaw-susceptible ground. Cost effective means for preventing or moderating infrastructure damage due to permafrost degradation require further research and commercialization. Climate change coupled with residential and industrial development in the north have created a need for economical and reliable technologies to mitigate infrastructure damage.

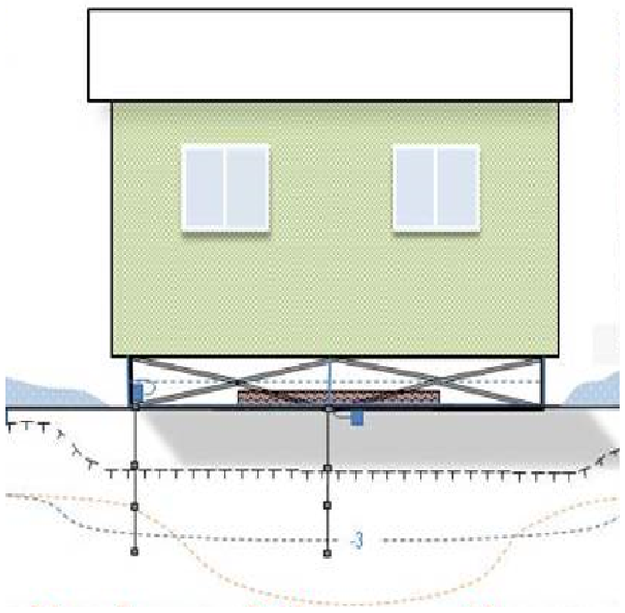

Fig. 5 – Attenuation of a thaw bulb beneath a heated dwelling using a passive organic technology.

Approach

Under its Arctic research program, NRC has initiated a research project to evaluate the application of organics and organic-rich soils (including peat moss, for example) as a passive means of protecting permafrost around existing and planned infrastructure developments (Fig. 5). The research project comprises numerical, bench-scale and field evaluations. Sites for data collection have been established in the Northwest Territories and at the NRC research campus in Ottawa, Canada (Fig. 6). Numerical evaluations will be undertaken to optimize the effectiveness of organic ground cover technology on mean annual ground temperature. Bench-scale and pilot field tests of organic covers will be initiated in 2018.

The objectives of the research project are to: (1) evaluate the effectiveness of organics (namely peat moss) as an engineered insulating ground cover; (2) identify alternative organic materials with similar properties, and; (3) establish bench-scale and field pilot trials for demonstration of passive permafrost protection techniques and technologies (Fig. 7, 8, 9).

Fig. 6 – Test site at the NRC Ottawa research campus.

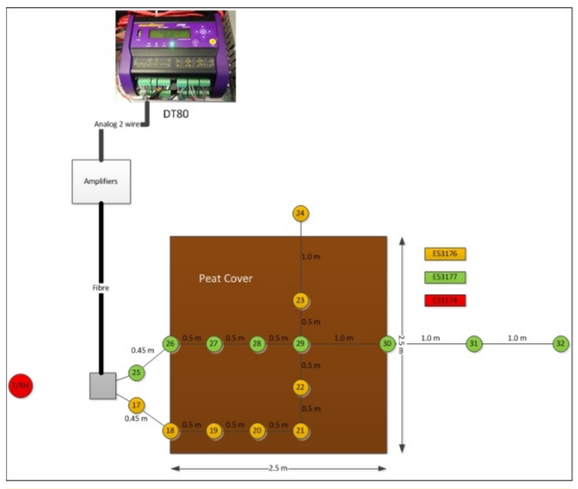

Fig. 7 – Instrumentation and data acquisition system layout at the Ottawa research campus test site.

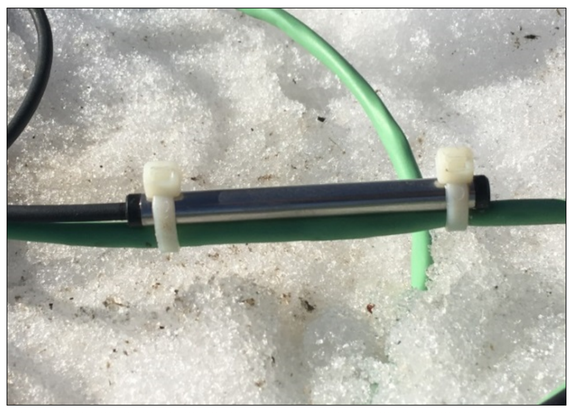

Fig. 8 – Instrumentation pairing for cross-validation.

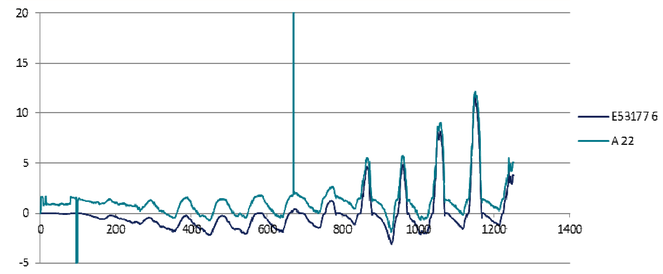

Fig. 9 – Comparison of fiber optic and digital thermistor signals (instruments shown in Fig. 8)

Impacts

This work evaluates the application of organics in a passive ground-insulating technology. Laboratory and numerical analyses yield the optimal design of engineered ground covers incorporating organic materials and local climate. Pilot field trials in 2018 will investigate the topics of constructability and deployment strategies in order to introduce a commercially viable mitigation technology to the market.

REFERENCES

Gaanderse, A.J.R., 2015. *Geomorphic origin of a lithalsa in the Great Slave Lowlands, Northwest Territories, Canada*: Carleton University, 171 pp.
Morse, P. D., Wolfe, S. A., Kokelj, S. V., & Gaanderse, A. J. R., 2015. The Occurrence and Thermal Disequilibrium State of Permafrost in Forest Ecotopes of the Great Slave Region, Northwest Territories, Canada. *Permafrost and Periglac. Process 2015,* DOI: 10.1002/ppp.1858.
Wolfe, S.A., Morse, P.D., Hoeve, T.E., Sladen, W.E., Kokelj, S.V. & Arenson, L.U., 2015. Disequilibrium permafrost conditions on NWT Highway 3. *Proceedings of GeoQuébec-2015, 68th Canadian Geotechnical Conference and 7th Canadian Permafrost Conference*.

COLLABORATORS

NORTHWEST TERRITORIES GEOLOGICAL SURVEY
Northwest Territories Transportation
Carleton UNIVERSITY
uOttawa
LAURIER Inspiring Lives.

National Research Council Canada | Conseil national de recherches Canada
Canada