



*Performance assessment of the
thermo-reflective snow-sun sheds at
the Beaver Creek road experimental
site*

Report for Policymakers

Daniel Fortier, Sliger, M., and Rioux K.
Université de Montréal, Montréal (QC)

Performance assessment of the thermo-reflective snow-sun sheds at the Beaver Creek road experimental site

Prepared for
Transport Canada

by
Daniel Fortier, Michel Sliger and, Karine Rioux
Geocryolab (Cold regions geomorphology and geotechnical laboratory)
Université de Montréal

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Notices

This report reflects the views of the authors and not necessarily those of Transport Canada or the co-sponsoring organizations.

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Since some of the accepted measures in the industry are imperial, metric measures are not always used in this report.

1 BACKGROUND

Permafrost, which is soil or rock that remains frozen during at least two consecutive years, is found across the Canadian North. Traditionally, permafrost was considered to be a solid foundation for northern infrastructure and ecosystems. However, natural and human impacts such as climate change, extreme weather events, wildfire, and infrastructure developments are causing the permafrost to thaw. Thawing or degrading permafrost has damaged infrastructure in the North and can result in significant cost increases for infrastructure owners and operators. As such, infrastructure planning in northern permafrost regions needs to consider the local weather and soil conditions to adapt designs. A number of techniques that could mitigate permafrost thaw are being developed and tested. This project assesses the performance of one specific technique tested on a northern highway: the thermo-reflective snow-sun shed (TRS-shed, hereafter).

2 PROJECT OVERVIEW

The Beaver Creek road experimental site in Yukon is located on the Alaska Highway, an important transportation link in the territory and the only terrestrial link between Alaska and the contiguous USA. At this location, the underlying permafrost is discontinuous and close to the thawing point, meaning that it is very sensitive to further warming and other factors that could accelerate its degradation. In 2008-2009, twelve mitigation techniques were established at the site to be tested in real conditions. One of the mitigation techniques involved the installation of two TRS-sheds – one on each side of the highway.

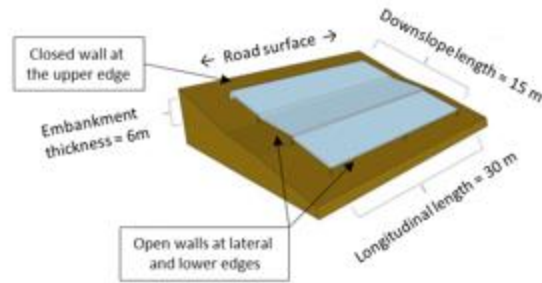
This project by Geocryolab looks at how the TRS-shed has performed since its installation, whether it has been successful at minimizing permafrost degradation underneath, and what changes have occurred to the highway infrastructure and to the TRS-shed itself over time. The results provide engineers with a documented experience of how the principles of shade and free air convection can be incorporated into road designs to better adapt to the unique northern context. They also demonstrate that the use of TRS-sheds has the potential to significantly limit the deterioration of highway infrastructure built in areas of discontinuous permafrost.

The work was supported by Transport Canada's Northern Transportation Adaptation Initiative, which seeks to ensure the necessary knowledge and tools are available to enable strategic choices regarding transportation operations and infrastructure management in Canada's North, and develop and test practical solutions for adapting new or planned northern transportation infrastructure to impacts associated with the changing climate.

3 DESCRIPTION OF THE WORK UNDERTAKEN

This project uses available data to identify the potential and limits of TRS-sheds as an adaptation technique for the preservation of ice-rich permafrost under road embankments in discontinuous permafrost zones in Northern Canada.

The TRS-shed tested is a wooden structure that is 30 m long and 1 m high, with a sheet metal roof that follows the slope of the road embankment. It is open on three sides, and has one wall along its top edge to prevent snow and gravel accumulation due to snow plowing operations.



The design of the TRS-shed aims to preserve permafrost by providing shade to the embankment (which limits solar radiation and minimizes summer warming), and by allowing for free air convection (which limits the insulating effect of the snow and maximizes winter cooling). A number of temperature sensors were installed in the embankment, under the TRS-shed, and in a nearby control section (i.e., a section that does not contain any permafrost mitigation technique/technology) to gather data on the changes in ground and air temperatures over time. Two high-precision topographical surveys of the road and the TRS-shed were done in 2014 and 2017, and these, combined with site photographs, 3D models and visual inspections, allow the project team to identify and measure how the ground and the TRS-shed have shifted since installation. The data from these instruments, as well as a preliminary thermal analysis are available directly from the Geocryolab, or through the associated technical project report (Fortier et al. 2018¹).

4 RESULTS

4.1 FINDINGS

Overall, the analysis determined that the TRS-shed was effective at extracting heat in the winter, reducing the heat input during the summer, and decreasing or completely stopping the thawing of underlying ground ice. In other words, the TRS-shed has been very successful at re-establishing surface conditions that sustain permafrost.

Temperature

In comparison with the control section, the winter temperature of the surface under the TRS-shed was approximately 7° C cooler and had a wider variation. The ground surface annual mean temperature under the TRS-shed spanned between -10 and -35 °C while that of the control section was found between -5 and -10 °C. During winter, the ground covered by the TRS-shed was typically able to dissipate more than four times the heat (411%) dissipated at the control section on a yearly basis.

The summer temperature under the TRS-shed remained markedly lower, with peak temperature being about 5 °C cooler than at the control section. Since the TRS-shed was installed, the covered surface of the embankment has absorbed only about 60% of the heat absorbed by the control section on a yearly basis.

In summary, the TRS-shed provided for 311% more cooling (winter) and 38% less warming (summer) at the ground surface, yielding an overall surface cooling efficiency of 349%. In other words, the TRS-shed covered

¹ Fortier, D., Sliger, M., Rioux, K. 2018. Performance assessment of the thermo-reflective snow-sun sheds at the Beaver Creek road experimental site. Final technical report prepared for Transport Canada. Geocryolab, University of Montreal, 48 pp.

embankment is 3.5 times more efficient than the uncovered control section at keeping heat out of the ground to preserve the underlying permafrost.

The assessed efficacy however is not uniform under the TRS-shed. The ground surface under the centre of the structure remained colder than that at the periphery. The corners are warmer all-year-round, and the spatial disparities in temperature are greater in winter.

Topographical changes

The road embankment and the TRS-shed have been subject to ground deformations. Ground settlement under the center of the TRS-shed is minimal, but is stronger around the periphery. This is due to the cooling efficacy noted above, which has the same pattern. The differential settlement resulted in deformations to the TRS-shed and its anchoring system, damaging the wooden structure and breaking many anchors and supporting cables.

4.2 RECOMMENDATIONS

- i. The project team strongly recommends the use of TRS-sheds over embankment slopes in continuous and discontinuous permafrost zones as a mean of mitigating permafrost degradation and ground-ice preservation (of note, no analysis of cost effectiveness was undertaken).
- ii. The frame and anchoring system of a TRS-shed should accommodate potential slope movements and surrounding settlement. As such, a complete review of the design is recommended. The success of the TRS-shed at mitigating permafrost thaw exacerbated the differential settlement around the structure, where it was anchored, and induced a corresponding tension and compression pattern on the TRS-shed structure.
- iii. The TRS-shed should be used in conjunction with light-colored road surface for extending the surface cooling to the centerline of the road, beyond the reach of the TRS-shed.
- iv. The use of the TRS-shed should be complemented with a water drainage design component to limit water ponding and associated permafrost degradation at the base of the shed.
- v. The elevation difference between the lower and upper edges of a TRS-shed should be sufficient to enable the chimney effect (free convection) during winter, especially where strong winds are not frequent.
- vi. The geometry and extent of the design should consider the edge-effect (decrease in efficacy at the periphery) related to snow accumulation, sun exposure and any air flow limiting features.
- vii. Additional work is recommended to evaluate the potential efficiency of the TRS-sheds in a warming climate using regional climate model simulations for the expected design service life of the infrastructure.
- viii. We recommend using numerical thermal modelling of convective and conductive heat exchanges to improve the design (e.g. geometry, cost effectiveness, heat extraction) of the TRS-shed.