Thermal Stabilization of Transport Infrastructure Built on Thaw-Sensitive Permafrost Using High Albedo Surface

Simon Dumais, Caroline Richard, Guy Doré (Director)
Theme 3 - 2 M.Sc. projects

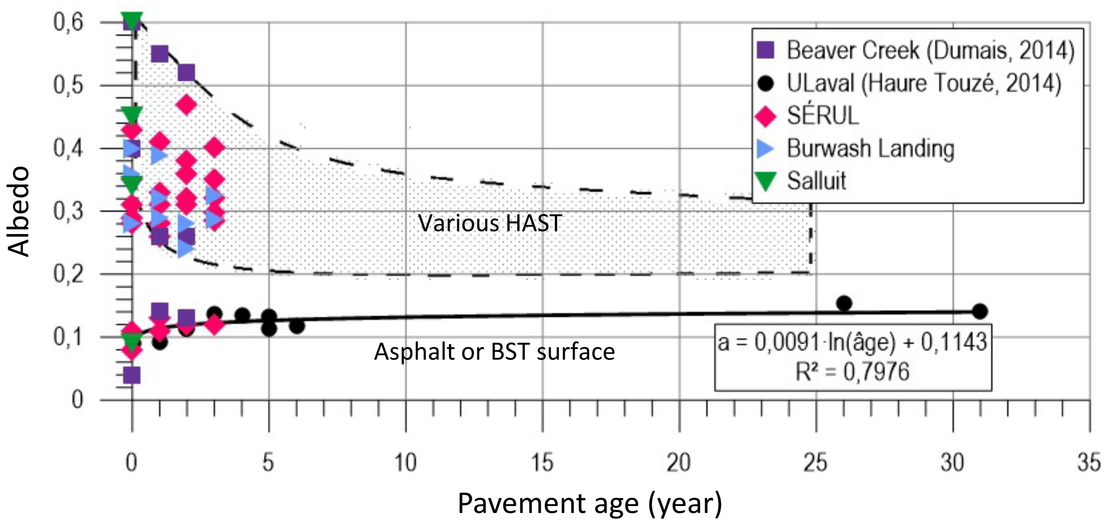
Objectives

Develop a method for thermal stabilization of transportation infrastructures built on thaw-sensitive permafrost, using High Albedo Surface Treatment (HAST) to limit heat absorption.

- Quantify the effect of a pavement's albedo on its surface temperature
- Develop an approach to assess the technical properties of HAST
- Document the evolution of albedo with time for various pavement surfaces
- Develop a thermal stabilization method using modeling

Salluit, Nunavik

Study sites : Alaska Highway (Yukon), Salluit and Forêt Montmorency (Québec)

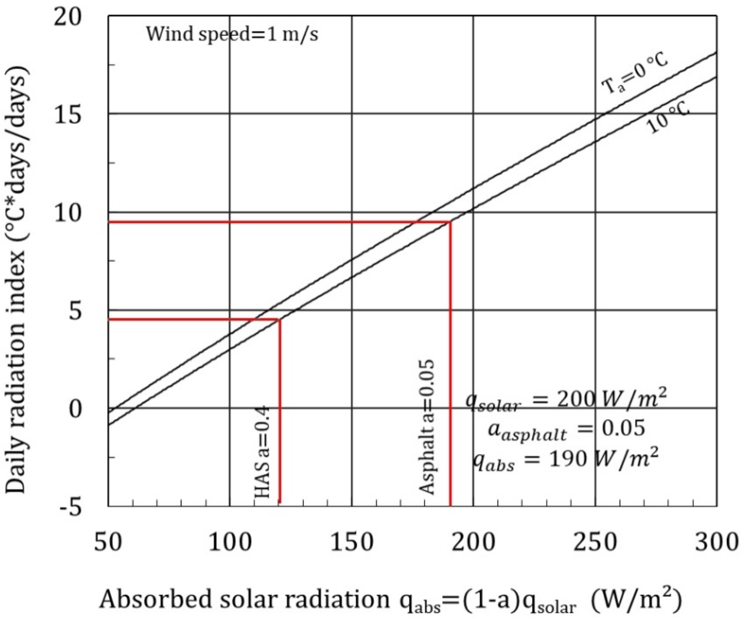


Evolution of albedo for protected and unprotected surfaces

While aging, the albedo of HAST tends to decrease due to the fatigue of the coating; while asphalt albedo tends to increase due to bitumen oxidation. The shaded area represents the estimated relation between albedo and time.

Results

- A calculation tool, using a simplified energy balance, and abacus was developed to assess pavement surface temperature and thaw penetration based on the surface albedo; allowing to quickly determine the need to use HAST on a specific site.
- A relation between the albedo and pavement age was made.
- Technical specifications of HAST was identified to assure efficient, sustainable and safe use of these products in permafrost regions, and were considered by the two private collaborators (Colas Canada and Nippo Corporation) manufacturing the products.
- Thermal stabilization approach was provided and includes: 1) A model (using TEMP/W) to determine thaw depth depending on site characteristics and albedo; 2) A chart to assess the difference of temperature required (Tinterface – Tpermafrost) to limit heat input and stabilize the infrastructure.



CHART

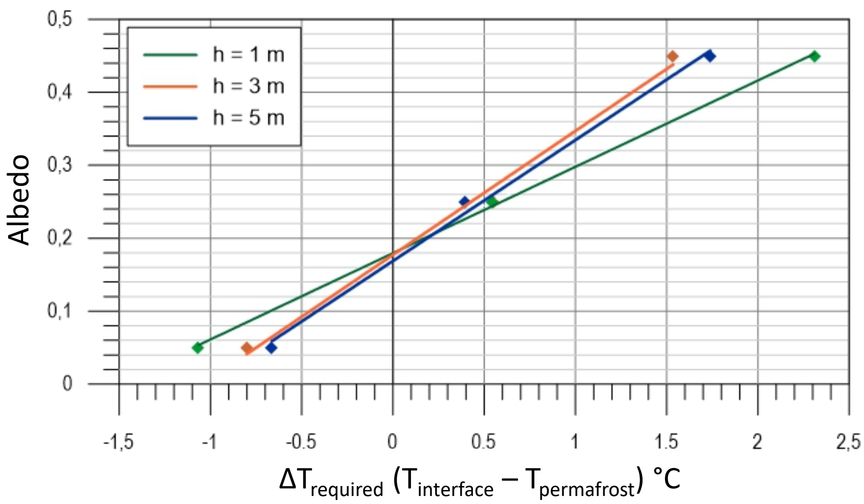
Calculation of daily radiation index for pavement surface.

1. Calculate solar radiation absorbed by pavement surface $q_{abs} = (1 - a)q_{solar}$
2. Obtain radiation index uncorrected (RI) using the chart
3. Other charts were developed to obtain correction factor for wind speed and convection, respectively ΔRI_U and ΔRI_q
4. Calculate total radiation index of pavement surface

$$RI_T \text{ or } RI_F = (RI + \Delta RI_U + \Delta RI_q)t$$

5. Calculate the thawing index of pavement surface $TI_s = TI_a + RI_t$

Detailed calculation method available in S. Dumais, G. Doré, Cold Regions Science and Technology 123 (2016) 44–52



Surface albedo required to thermally stabilizes the paved infrastructure according to $\Delta T_{required}$ for various embankment thicknesses. Based on Beaver Creek site, Yukon, for a permafrost temperature of -0.6 °C and a MAAT of -4.9 °C.

Example

$$\Delta T_{required} = T_{interface} - T_{permafrost} = -0.3 - -0.6 = 0.3\ °C$$

Benefits

- The thermal stabilization approach will allow managers to use the embankment thickness (reload) and HAST to thermally stabilize paved sections of roads or airstrips built on thaw-sensitive permafrost.
- The technology has been transferred to our industrial partners: Colas Canada via Skookum based in Whitehorse and Nippo Corporation based in Japan. This should make them key players in the implementation of high albedo surface treatment in Yukon, Alaska and perhaps other countries.
- The next step will be to perform a large scale pilot application (around 1 km of road) to document the cost-benefit of the technique.