



Addressing Resilience in Project Development

Addressing Environmental Conditions in the Design of Roadways Built on Permafrost

This study provides general background on permafrost thaw, the implications for roadways, how future thawing can be projected, and what can be done to adapt to the impacts.¹

Issue Overview

Permafrost, soil that has remained at or below freezing (32 degrees Fahrenheit [0 degrees Celsius]) for two or more consecutive winter seasons and the intervening summer,² is common throughout the Arctic. In the United States, approximately 80 percent of Alaska is currently covered by permafrost³ along with a handful of isolated mountainous areas in other states. In Alaska, thawing is ongoing given the well above average temperatures observed over recent decades, and that trend is expected to accelerate as environmental conditions continue to change.

Projections

Global models vary in their ability to accurately represent the Arctic regions. Practitioners in these areas should rely on models that best represent their region, such as those vetted by the Scenarios Network for Alaska and Arctic Planning (SNAP) at the University of Alaska Fairbanks.⁴

The key variables required to understand expected impacts on permafrost thaw are:

- Average daily temperature.
- Daily precipitation (only required for more advanced modeling efforts).

Fortunately, these variables are readily available from existing modeled data.

Analytical Approach

Determining the future depth of permafrost thaw along a roadway requires thermal modeling. Thermal modeling uses generally recognized equations for thermal transfer to calculate the temperatures at various ground depths given ambient air temperatures and soil properties. Although setting up a thermal model is a significant undertaking, it is relatively straightforward to incorporate projected future changes in ambient temperature.

Permafrost Thaw Impacts

There are three primary impacts of permafrost thaw on roadways.

Differential Longitudinal Settlement: Permafrost can contain varying quantities of ice longitudinally along a roadway. As the permafrost melts, this heterogeneity results in some parts of the roadway settling at much greater rates than other parts over short distances, causing a wavy pattern of differential settlement that requires intensive maintenance.

Shoulder Rotation: Often, the permafrost under the shoulders of the roadway thaws before the permafrost under the center of the roadway embankment. This thawing causes the ground to subside and the shoulder to rotate, forming long longitudinal cracks.

Slope Failures: Thawing permafrost can cause instability and slumping in both natural and engineered slopes along roadways resulting in slides.

¹ This snapshot summarizes one of nine engineering-informed adaptation studies conducted under the Transportation Engineering Approaches to Climate Resiliency (TEACR) Project. See <https://www.fhwa.dot.gov/environment/sustainability/resilience/publications/> for more about this study and *Synthesis of Approaches for Addressing Resilience in Project Development*. The original case study provides full citations.

² Andersland and Ladanyi, 2004.

³ Chapin et al., 2014.

⁴ <https://www.snap.uaf.edu/>

Adaptation Options

There are three primary types of adaptation solutions.

Avoid Permafrost Areas

If possible, avoid constructing new roadways over permafrost. This is the surest way to prevent long-term damage.

Delay or Prevent Thawing

There are several strategies to delay or prevent thawing (Table 1).

Image source: Google Earth Street View



Figure 1: ACE on Thompson Drive embankment in Fairbanks, AK.

Strategy	Description
Air Convection Embankments (ACE)	Highly permeable, coarse-graded rock piles throughout the roadway embankment, or just on the shoulders (see Figure 1). This passive system relies on a natural temperature gradient to increase winter freezing. Relatively low cost.
Thermosiphons	Passive heat exchange devices generally consisting of a closed tube containing a fluid such as carbon dioxide or propane that transfers heat from the soil to the air. Generally effective, but expensive.
Insulation	Panels of extruded insulation installed in the roadway embankment to insulate the ground. Limited effectiveness for insulating roadside slopes.
Other Techniques	Includes slope shading, air ducts, and laying back side slopes to make them flatter.

Table 1: Potential strategies to delay or prevent permafrost thaw.

Enhance Maintenance Activities

When expected warming is too great to fully prevent permafrost thaw, the goal of the adaptation strategy should be to delay the thawing (and associated higher maintenance costs) for as long as possible. The best way to reduce costs is to use unpaved roadways, which are easier and cheaper to maintain on shifting ground than conventional asphalt or concrete pavement.

For More Information

Resources:

Transportation Engineering Approaches to Climate Resiliency (TEACR) project website

www.fhwa.dot.gov/environment/sustainability/resilience/ongoing_and_current_research/teacr/index.cfm

HEC 25 Volume 2: Assessing Extreme Events

www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=192&id=158

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