MONTANA Department of Transportation
Research

Technical Brief

MDT RESERCH FEASIBILITY STUDY OF GEOTHERMAL ENERGY FOR BRIDGE DECK DEICING

About This Research

Objectives

- Explore shallow geothermal systems for snow/ice control on bridges.
- Analyze impacts of surface temperature, frost depth, and cracking.
- Predict surface temperature with machine learning using various scenarios.

Benefits

- Enhance traffic safety by reducing snow and ice accumulation on bridges.
- Provide maintenance benefits by reducing reliance on deicing solutions, which chemically attack concrete and corrode steel reinforcement.



Understanding the capacity of using geothermal energy for deicing will result in safter roads and less maintenance costs for Montana.

About This Project

Project title: A Feasibility Study of Road Culvert/Bridge Deck Deicing Using Geothermal Energy

Project number: 9890-784

Technical Panel

Jeff Jackson (Chair, MDT)
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Research Need

In cold regions such as Montana, bridge decks face heavy snow, frequent freeze–thaw cycles, and accelerated concrete deterioration. Traditional deicing methods, including salt-based chemicals and mechanical snow removal, become ineffective below 15 °F and contribute to structural degradation through corrosion and cracking. This research explored using geothermal energy, specifically groundwater heat for bridge deck deicing and the mitigation of concrete deterioration. Led by Montana State University (MSU) and funded by the Montana Department of Transportation (MDT), the project represents the first comprehensive evaluation of such systems under Montana's environmental conditions.

The overarching goal was to determine whether geothermal energy could maintain bridge deck surface temperatures above 32 °F during winter events, reduce freeze-thaw cycling, and improve concrete durability during early-age curing and under thermal stress. This project is a critical step in evaluating sustainable, low-maintenance alternatives for improving winter road safety and extending infrastructure lifespan in Montana.

"This project will help MDT evaluate and implement alternative methods to prevent and/or minimize snow and ice accumulation on our bridge decks and extend the bridge deck design life via reduced concrete deterioration."

—Jeff Jackson, Project Champion

Research Process

- *Survey*: a targeted survey was distributed to MDT personnel to assess current deicing practices, costs, and limitations, with responses highlighting corrosion, joint deterioration, and early-age cracking as recurring maintenance concerns, reinforcing the need for alternative deicing solutions.
- *Laboratory Testing:* a scaled concrete bridge deck model embedded with geothermal piping was constructed and tested in the Subzero Research Laboratory at MSU to evaluate the system's thermal performance under simulated winter conditions.
- *Numerical Modeling:* a validated COMSOL model was used to simulate more than 2,300 system configurations, evaluating the effects of inlet fluid temperature, ambient air temperature, solar intensity, and wind speed on system performance.
- *Machine Learning*: simulation data were used to train two machine learning models, one to predict time-to-deicing effectiveness, and a second to predict full temperature profiles under varying environmental conditions.

Research Results

Geothermal energy is most effective when designed to complement solar gain and optimized for local weather and subsurface conditions.

- Geothermal energy raised surface temperatures above freezing during stages with solar radiation, reducing ice formation risk.
- Geothermal energy reduced thermal strain and lowered contraction in the bridge deck during solar gain periods.
- Researchers developed an interactive web-based tool that allows users to estimate bridge surface temperatures under various design and climate conditions.

Research Implementation

MDT is planning a workshop with department administrators, technical staff and MSU researchers to focus on field implementation. The workshop goals will explore how and where to apply the research in the state. Ideally, a suitable bridge could be used to test this research under real-world conditions. If successful, it might be utilized across the state (when conditions are appropriate) to help save money and improve safety.

MDT Research would like to thank the Project Champion and Technical Panel

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Learn More About This Project

Final report is available in **ROSA P**.