MPC-486
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Project Title:
Sustainable Heated Pavements for Infrastructure Longevity, Safety and Economic Competiveness

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Colorado State University

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Research Needs:
Icing of pavements during the winter leads to problems affecting the majority of the USDOT's strategic goals. Icy roadways clearly pose a hazard to the ***safety*** of drivers and vehicle occupants. Icy roads also affect ***economic competitiveness*** as truck based transport of goods is slowed or interrupted. The use of de-icing agents, such as salt and Magnesium Chloride, can help prevent ice build-up on the roads, but bring with them significant initial and long term maintenance costs. Beyond the costs associated with purchasing and applying the materials, the application of chloride based agents to steel infrastructure (e.g. reinforced concrete pavements and bridge decks and steel bridge components) can lead to corrosion and possible premature failures. The American Society of Civil Engineers current grade of the U.S. roads is a D and bridges are a C+ (ASCE 2013). The deterioration caused by corrosion raises technological and economic issues associated with the ***state of good repair*** goal including how to inspect, manage, and repair deteriorating transportation structures. The use of these chemicals to prevent icing also has environmental costs, relating to the goal of ***sustainability***. The climate of the Region 8 states served by MPC means that icy roads are a national issue of great local significance.

Heated pavements offer a potential solution for the problems caused by icy roads. New research is investigating the application of heated pavements to keep airport runways clear and decision making tools to help airport managers decide when the heated pavements or other snow clearing solutions are viable (Vigar 2013). Heating a full network of roads is likely not viable at this point, but the targeted heating of particular safety trouble spots, critical freight routes, and heavily salted areas has the potential to make significant contributions to the quality of U.S. and regional transportation networks. These networks often include generous right-of-way areas that may lend themselves to supporting a distributed energy producing infrastructure; potentially decreasing costs in remote locations. The presence of ice in concrete pores is a fairly well-understood process (Penttala 1998, Kauffmann 2004) that can accelerate environmental

degradation of pavements or other roadbases. A number of novel approaches have been attempted, including conductive concrete (Yehia and Tuan 1999, 2000, 2004, Tuan 2004), conductive asphalt (Chen and co-workers 2011), heated wiring (Tuan 2004, Zhao and co-workers 2010) and there has been at least one full bridge demonstration project reported in the literature (Tuan 2008). However, there are no broad-based design or implementation guidelines for use of this class of technology, nor is there a fixed approach for powering such methods.

Three key questions arise regarding the feasibility of a targeted heating approach:

1) How will locations where pavements will be targeted for heating be determined to make substantial contributions to improving safety, movement of goods, longevity of infrastructure and/or impact on the environment?
2) How will the appropriate source of energy necessary to heat the pavements be evaluated for each site in a sustainable manner (i.e. considering the triple bottom line)?
3) What type of paving technology can be effectively heated with the available energy or in a way that minimizes the energy demand?

Research Objectives:
The goal of this project is to investigate the feasibility and potential benefits of localized pavement heating using a prioritization tool that will target locations that are both high risk and located at sights compatible with novel off-grid power sources. To meet this goal, this project has the following research objectives:

1. Investigate characteristics of particular roads and sites that may make them attractive applications for this technology.
2. Investigate potential options for providing sustainable heating and associated costs.
3. Use site characteristics and heating solutions to develop an index for transportation decision makers to use in identifying sites that would most benefit from the heated pavement while simultaneously considering the most appropriate power source
4. Investigate pavement options that may provide a combination of durability and effective heat transmission and retention.
5. Build numerical models that can characterize the heated materials, predict rates of heating/cooling, and be used as a design an analysis tool to modify pavement mixes or modifications in heating sources.

Research Methods: This project will use a variety of methods to investigate the feasibility of localized pavement heating. Literature review and interviews with local agencies responsible for transportation assets will be conducted to investigate what attributes would identify a potential site for possible heating application to answer research question 1. Heating options will be investigated through Lifecycle Assessment to answer research question 2. Paving materials will be investigated through small scale laboratory tests. Finite element models of typical geometries will be built for transient heat transfer to compare with experimental and field data to answer research question 3. This project will focus on sites close to CSU, but will seek to provide results that are generalizable to the MPC states as a whole.

Expected Outcomes: The overall outcome of this project will be a comprehensive evaluation of the feasibility of using targeted pavement heating to more effectively deal with winter road conditions. Additionally this project will produce:

1. A tool or index that decision makers can use to identify sites where localized pavement heating would be practical and cost-effective.
2. Preliminary recommendations on heating sources and pavement types.
3. Technology transfer through scholarly publications to disseminate findings to the research community and presentations to local agencies to disseminate findings to practitioners.
4. Findings that can serve as the basis for additional funding to pursue a field demonstration project.
5. Results from predictive numerical models that can take the place of parametric studies of material type to optimize construction of future experiments or field studies.

In the longer term this line of research will produce outcomes that benefit society by helping keep roads open and safe during the winter with a reduction in both the maintenance spending and environmental impact associated with plowing and deicing chemicals.

Relevance to Strategic Goals:
As described in the Research Needs portion of the proposal, addressing icy road prevention in a sustainable way is relevant to the USDOT strategic goals of safety, economic competitiveness, state of good repair and sustainability.

Educational Benefits:
A graduate research assistant will be hired to conduct the research described in this proposal. Furthermore, the research process and findings will be shared in courses at CSU such as CIVE 302 Evaluation of Civil Engineering Materials, CIVE 303 Infrastructure and Transportation Systems, and CON 370 Asphalt Pavement Materials and Construction.

Work Plan:
The work plan for this project consists of the following tasks:

1. Collect data on Colorado and Wyoming winter roadway trouble spots from the Colorado Department of Transportation, Wyoming Department of Transportation, and select a sub-set of locations in both states close to CSU.
2. Collect cost data for existing snow removal operations (plowing, de-icing application)
3. Collect data on other costs associated with icy roadways (traffic accidents, travel delays)
4. Collect data on available energy sources with close proximity to trouble spots.
5. Collect cost data for different heating alternatives.
6. Build finite element models in for three-dimensional pavement systems including heating elements to predict rates of thermal change and behavior.
7. Investigate pavement composition and associated costs.
8. Use cost data to investigate the feasibility of pavement heating for the local sites.
9. Use cost data to develop a generalized index to determine which sites are good candidates for heating.
10. Disseminate project findings.
11. Seek opportunities for continued development through a demonstration project.

The approximate schedule for this work is shown on the following page.

	Project Months																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Task 1	■																	
Task 2		■	■															
Task 3		■	■															
Task 4				■	■													
Task 5				■	■													
Task 6		■	■	■	■	■	■	■	■	■	■	■	■					
Task 7											■	■	■					
Task 8														■				
Task 9														■	■	■		
Task 10																■	■	■
Task 11																		■

Project Cost:
Total Project Costs: $99,956
MPC Funds Requested: $49,000
Matching Funds: $ 50,956 Source of Matching Funds: CSU Faculty Time and Effort

TRB Keywords: Pavements, Snow Removal, Snow Melters, Winter maintenance

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