U.S. Department of Transportation
Office of the Secretary of Transportation

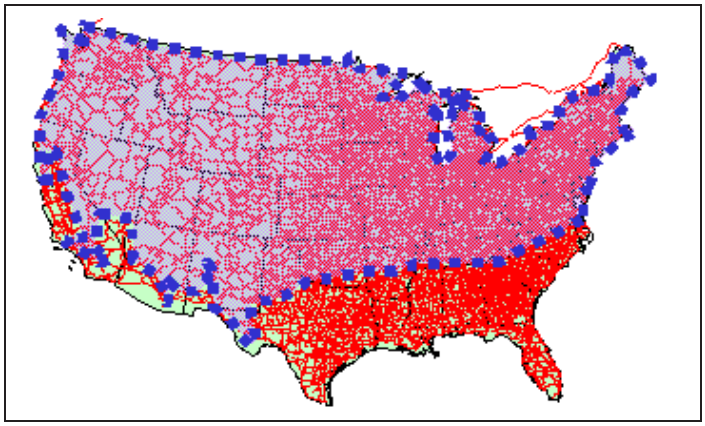
UTC Spotlight

University Transportation Centers Program

This month: University of Alaska Fairbanks | April 2015

Bio-Based Renewable Additives for Sustainable Roadway Snow and Ice Control Operations

Washington State University, a consortium member of The University of Alaska Fairbanks' Center for Environmentally Sustainable Transportation in Cold Climates, is researching the development of environmentally friendly and locally available anti-icing formulations for snow and ice control on highways. Environmentally friendly anti-icing agents, such as those produced from beet sugar refining by-products, glycerol, and other biobased additives, can help to prevent ice from forming on roadways and other transportation infrastructure. Reducing road and infrastructure icing can, in turn, reduce the need for chloride-based deicing chemicals, which can be harmful to infrastructure, motor vehicles, and the natural environment.



FHWA

Areas affected by snow and ice weather.

Deicing v. Anti-Icing Treatments

Deicing agents, such as road salts, have a negative impact on transportation infrastructure, motor vehicles, and the natural environment. The United States currently spends approximately $2.3 billion annually to keep highways free of snow and ice, and the associated corrosion and environmental impacts add at least $5 billion to the cost.

"One challenge with chlorides is that they do not degrade in the environment, so over a time scale of decades they may become a significant contaminant in the aquifer," said Xianming Shi, Ph.D., P.E., an Associate Professor of Civil and Environmental Engineering at Washington State University. A recent U.S. Geological Survey analysis revealed that chloride levels increased substantially over the last decade in the vast majority of urban streams analyzed.

Yet, conventional anti-icing agents are not without shortfalls and are plagued by growing concerns over their corrosion effect on metals, destructive impact on concrete and asphalt, and toxicity to aquatic resources.

Compared to deicing and sanding, anti-icing leads to an improved level of service, a reduced need for chemicals and associated cost savings, and safety and mobility benefits. Agencies are constantly seeking alternatives that maximize the benefits of acetates and agro-based products while minimizing their drawbacks. Meanwhile, research is needed for value-added utilization of desugared beet molasses and glycerol, which are the principal byproducts of beet sugar refining and biodiesel production, respectively.

A Greener Alternative

One answer to this dilemma may be the development of environmentally friendly anti-icing agents that can reduce the need for deicing road salts. Dr. Shi recently completed a study for the Alaska Department of Transportation and Public Facilities that turns locally sourced and environmentally friendly industrial byproducts (liquid wastes from a vodka distillery) into renewable additives for "greener" anti-icing formulations. Building on the success of this study, Dr. Shi initiated a UTC research project to develop innovative anti-icing formulations for snow and ice control on highways, using beet sugar refining byproducts, glycerol, and other biobased additives (e.g., those from flower waste) available in the Palouse region. The research team has begun outreach activities to identify "green" additives available in the region, and the project plans to take a mass customization strategy that requires modular product design. These additives will pose minimal toxicity to the environment (e.g., low nitrogen, phosphorus, and

heavy metal contents).

By design, the additives will be blended with conventional salt brine to boost their anti-icing performance and thus reduce the application rate required for given road weather scenarios. Further, these locally sourced biobased materials and some low toxicity commercial additives will be tested for their potential in freezing-point suppression, concrete protection, or corrosion inhibition. For instance, the team has developed a process to chemically and biologically degrade peony leaves and stalks into a mixture of molecules that can significantly reduce the corrosiveness of salt brine to carbon steel.

BillingsGazette.com

Sugar beet harvesting in Montana.

Using a statistical design of experiments, the research team is in the process of optimizing anti-icing formulations for a few specific application scenarios. The developed formulations will be evaluated in the laboratory for their performance and potential negative impacts. “We’ve become addicted to salt over the last 50 years, and this research aims to mitigate this addiction with the best possible technology under existing financial constraints”, said Dr. Shi.

A variety of agro-based chemicals have been used either alone or as additives for other winter maintenance chemicals since the late 1990s–often produced through the fermentation and processing of beet juice, molasses, corn, and other agricultural products. Recently, glucose/fructose and unrefined sugar have been mixed in sand to prevent freezing and added in salt brine for anti-icing. Agriculture-based additives increase cost but may provide enhanced ice-melting capacity, reduce the deicer corrosivity, and/or last longer than standard chemicals when applied on roads.

The deployment of commercial agro-based products has been hindered by concerns over their toxicity to the aquatic ecosystems adjacent to highways (due to high phosphate, nitrate, or total organic content), high cost, and quality control issues. The common agro-based products are proprietary and generally contain chloride salts and low molecular-weight carbohydrates derived from sugar beet, molasses, or corn; there are user concerns over their possible attraction to wildlife or high phosphorus content.

At this stage, no patents or products have specifically addressed the risk of anti-icing/deicing products to highway concrete or asphalt pavements. There is also little discussion in the published domain regarding the tailoring of product formulations to meet user priorities. These are two main areas of innovation inherent in the ongoing UTC project.

Development of alternative anti-icing products is expected to generate significant cost savings for DOTs and other maintenance agencies, benefit travelers through improved safety and mobility, and improve the environment. The use of alternative products has the potential to reduce corrosion and environmental impacts from winter roadway operations and provide maintenance agencies with more options in providing winter road service. The exploration of biobased renewable additives for anti-icing applications would also add value to agricultural by-products and stimulate local economies.

About This Project

Xianming Shi, Ph.D., P.E. (Xianming.shi@wsu.edu) is an Associate Professor in Civil & Environmental Engineering at the Washington State University. Prior to joining WSU, Dr. Shi served as the Founding Director for the Corrosion and Sustainable Infrastructure Laboratory and the Winter Maintenance & Effects Program at Western Transportation Institute. He is currently the WSU Assistant Director for the Center for Environmentally Sustainable Transportation in Cold Climates (CESTiCC). Dr. Shi holds a BS in Corrosion & Protection from Beijing Institute of Chemical Technology, a MS in Applied Chemistry from Tianjin University, a MS in Industrial & Management Engineering from Montana State University, and a Ph.D. in Polymer Chemistry from the Institute of Chemistry, Chinese Academy of Sciences.

The UTC Director is Jenny Liu, Ph.D., P.E. (jliu@alaksa.edu), at University of Alaska Fairbanks.