FINAL REPORT

EXPLORING WAYS TO PREVENT BONDING OF ICE TO PAVEMENT

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ABSTRACT

The objective of this study was to explore all possible means of preventing ice from bonding to pavement. New technologies, including new chemicals, new means of application, pavement conditioning, and timing of chemical application, were explored.

The researcher recommends that (1) maintenance personnel at all levels be trained in anti-icing operations; (2) weather forecasting be an integral part of the anti-icing program to enhance the success of anti-icing; (3) liquid chemicals and prewetted salt be used to achieve maximum anti-icing benefit; and (4) anti-icing experiments be conducted with prewetted chemicals, liquid chemicals, and finer salt gradations than are currently used.

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INTRODUCTION

The Governor's Commission on Government Reform recommended that the Virginia Department of Transportation (VDOT) explore ways to prevent the bonding of ice to pavement, a technique known as anti-icing. VDOT's Commissioner requested that VDOT's Management Services and Maintenance divisions coordinate a study with the Virginia Transportation Research Council (VTRC) to address this recommendation. It was decided that VTRC would design and conduct the study and prepare a final report.

Anti-icing is the practice of preventing the bonding of ice to pavement by the timely application of a chemical freezing point depressant. It is a developing technology known to be more effective and efficient than conventional deicing methods in providing a high level of service. Clearing the road surface to bare pavement can be achieved quicker and with less effort with anti-icing.

Another benefit of anti-icing may be a reduction in the amount of chemicals applied for a storm; i.e., each truck route can be increased to cover more lane miles since the material is applied at a lower rate than with deicing operations. However, anti-icing can require more applications per storm. In these cases, the benefit of anti-icing is a higher level of service for a longer period of time.[1]

PURPOSE AND SCOPE

The objective of this study was to explore all possible means of preventing ice from bonding to pavement. New technologies, including new chemicals, new means of application, pavement conditioning, and timing of chemical application, were to be explored.

APPROACH

The researcher conducted a literature survey to determine the state of the art in anti-icing. Literature searches in the following systems were performed: Transportation Research

Information System (TRIS), Strategic Highway Research Program (SHRP), and university libraries.

In addition, the researcher surveyed 24 northern states and three Canadian provinces to determine their anti-icing practices. Cost, effectiveness, and all other pertinent data were requested during these surveys. The questionnaire is provided in the Appendix.

RESULTS

Literature Review

United States

In 1991, the Strategic Highway Research Program (SHRP) initiated a study to determine the conditions under which anti-icing will be effective and what anti-icing techniques will produce the greatest benefit over a range of weather conditions. In phase 2 of this study, nine states tested the techniques and methods discovered in phase 1.[2] The study evaluated specialized equipment, prewetted chemicals, liquid chemicals, and rates of application. Liquid chemical magnesium chloride was determined to be a successful anti-icing material when applied at a rate of about 7.7 g/m^2 (100 lb/lane-mile) when the pavement temperature was above -5°C (23°F). Above -10°C (15°F), prewetted salt was effective when applied at the same rate. Three findings from the study were: (1) the use of liquid chemicals in anti-icing operations is effective; (2) liquid chemicals are more effective than solid chemicals; and (3) no liquid chemicals are effective below -6°C (21°F). The only environmental parameter found to be statistically significant with treatment effect was pavement temperature. This finding lends support to developing systems that monitor pavement temperature. Alger et al. reported these findings in a study for SHRP Project H-208. [3]

A 2-year follow-up study completed in 1995 by the Federal Highway Administration (FHWA) produced a manual of practice[4] that provides information for implementing an efficient and effective anti-icing program. It also includes guidance for conducting anti-icing operations during six specific precipitation and weather events. The manual recommends applying liquid chemicals directly to the pavement and spraying solid chemicals with a liquid prior to their application (prewetting). Using these options, in certain situations, chemical rates of application can be reduced to 50 percent or less of the rates used by VDOT. The manual represented the state of the art for anti-icing practice in the United States as of mid-1996.

Kuennen determined that the use of enhanced salt (corrosion inhibited) and calcium magnesium acetate (CMA) had increased.[5] This probably indicated the desire of maintenance managers (1) to change their approach to fighting the roadway icing problems by changing the type, quantity, and time of application of the winter chemicals, and (2) to make their winter maintenance program more effective and environmentally conscious.

The Washington DOT determined that a mixture of 25 percent CMA/water solution (CMA25) applied once to a pavement prior to a storm provided residual action for up to 24 hours under certain conditions. Areas treated three or four times with a sand/chemical mix could be treated once with CMA25 at an application rate up to 60 gal per lane-mile. The rate depended on the severity of the storm.[6]

Oregon has had a “no-salt” policy since 1977. The Oregon DOT focused its efforts on the corrosive effect of CMA25. Two bridges were studied for the corrosion effect of CMA25, and Oregon declared it an improvement over their no-salt procedure.[6]

In a joint project between the Nevada and California DOTs at Lake Tahoe, researchers estimated a 300 percent return on a 26-sensor pavement/weather network. On U.S. 395, these DOTs estimated they used 49 percent less chemicals and 74 percent less abrasives with anti-icing techniques and the roadway weather information system (RWIS) forecasts.[7]

In Virginia, the first winter a RWIS was in place on the I-295 bridge over the James River, it was estimated that $48,000 was saved in salaries and equipment expenses (Wyant, unpublished data). Since the RWIS setup cost $50,000, the setup was almost paid for the first winter, which was mild one.

As indicated by the FHWA and other organizations, additional research is needed to make anti-icing technology applicable to local conditions.[8] The FHWA further indicated that the education of DOT personnel is critical to the evolution of this technology. Further, educating the motoring public will be necessary to acquaint them with the timing of the application of chemicals, which is different with anti-icing operations.[9]

Abroad

The state of the art of winter maintenance technology in Japan and Europe is described in *NCHRP Research Results Digest No. 204*.[10] The report describes the findings of a seven-member group sent by the FHWA from the United States to examine snow and ice removal operations in Japan and Europe. The group discovered important differences between the United States and those countries in snow removal equipment, anti-icing/deicing materials and methods, weather monitoring, winter hazard mitigation, and road user information services. They also reported that these winter maintenance technologies can be used in the United States and would be cost beneficial. To implement these technologies, two things were critical. First, an agency or center needs to be charged with implementation. Second, an acceptance testing and evaluation process needs to be performed in each state or municipality. This led to the creation of a Pooled Fund Cooperative Program by AASHTO for snow and ice research (SICOP).

In the German state of Bavaria, the use of prewetted salt was attributed with reducing the usage of salt by approximately 50 percent. Over a 10-year period, beginning in approximately 1978, the Bavarian spreader fleet was converted to use the prewetted application method.[11]

In Europe, a unique automated, fixed, liquid snow and ice control spray system is in operation in many critical locations. An automated loop monitors the pavement, the bridge, and the climate conditions and determines when to apply chemicals to the bridge deck or road surface. Since the bridge deck will freeze before the pavement needs chemicals, and in some cases before the truck-mounted sprayers arrive, this fixed system can apply the necessary chemicals early and before an ice bond is formed. This system has performed well in Europe and can be used at on/off ramps, tunnel entrances, steep roads, and hazardous intersections. In the United States, tests of this type of system have been initiated.

In many locations in Europe, a finer gradation of granular NaCl is used than is used in the United States (Table 1). The finer material goes into solution more quickly than more coarse material, which can be beneficial in anti-icing operations. The United States follows ASTM D632, Standard Specification for Sodium Chloride, where the top size is 12.5 mm (1/2 in). In Sweden, the top size is 3.35 mm (sieve No. 6).[12] In some European countries, gradation is predominantly in the 1 to 2 mm range.

Table 1. NaCl Gradations: Weight (% Passing)

Sieve Size	U.S.*	Sweden
12.5 mm (2 in)	100	
9.5 mm (3/8 in)	95-100	
4.75 mm (No. 4)	20-90	
3.35 mm (No. 6)		95-100
2.36 mm (No. 8)	10-60	
2.00 mm (No. 10)		65-100
1.00 mm (No. 18)		26-50
0.60 mm (No. 30)	0-15	
0.50 mm (No. 35)		5-26
0.05 mm (No. 100)		0-5

*ASTM D632, Standard Specification for Sodium Chloride.

Japan also uses heated pavement. Electrical resistance wiring or water pipes embedded in the pavement are used to prevent pavement freezing at hazardous locations, i.e., tunnel entrances, sharp curves, and intersections. When the pipes are embedded in the pavement, hot water circulates through the pipes from nearby manufacturing plants or naturally occurring hot springs. In urban areas, these same techniques have been used in sidewalks and crosswalks.

Another unique technique used in Japan to keep snow from accumulating on pavement is a low-velocity, low-pressure sprinkler system that is activated during snowfall. The ambient and pavement temperatures must be above freezing for this system to work. The constant flow of water over the pavement surface prevents the snow from accumulating and melts it as it lands. The melted snow then runs off into a modified storm sewer system.

RWISs are a key to the winter maintenance programs of Japan and western European countries. They provide weather information to maintenance managers to aid them in making timely decisions before and during storms. The managers change the speed limit and variable message signs in accordance with the weather information received. The high capital expenditures needed to install a RWIS are easily justified by the improvement in winter maintenance operations and in the use of anti-icing/deicing materials. When RWIS forecasts and site condition updates are used, proper timing for applying anti-icing materials can be effective in preventing ice from bonding to pavement as well as reducing the quantities of anti-icing materials used. An RWIS is a critical part of a successful anti-icing program, since the chemicals are applied prior to or near the beginning of a storm. The approximate arrival time of the snowfall needs to be known as precisely as possible, so no ice bond is formed.

Survey of States and Canadian Provinces

Surveys of the 24 northern states and the three Canadian provinces revealed a few new technologies. Fifteen of the 27 agencies surveyed indicated they were using anti-icing techniques. Several states indicated that only bridges received anti-icing treatment. The quantity and type of anti-icing chemical applied varied, and the rate of application varied from 8 to 31 g per lane-meter (100 to 400 lb/lane-mile). The chemicals used were sodium chloride, calcium chloride, CMA, sodium formate, magnesium chloride, urea, and potassium acetate. Some states used a liquid chemical as their anti-icing product, either alone or as an additive to their dry anti-icing material. Caltrans was so pleased with liquid magnesium chloride that they were expanding its use to include pretreatment of selected bridges. The Colorado and Washington DOTs are expanding their anti-icing operations on interstate routes from one to five counties. Nevada and Oregon are expanding their anti-icing operations to environmentally sensitive areas (the Lake Tahoe Basin and the city of Portland).

VDOT is evaluating the use of anti-icing materials and equipment in Northern Virginia. They pilot tested CMA during the 1993-94 winter on I-66 near Gainesville, among other locations. As in Scandinavia and Europe, CMA was applied prior to the storm. No field data were collected on this project, since the study was performed primarily to determine how difficult CMA was to handle, store, and apply and what problems would be encountered in the modification and calibration of the equipment.[13] Although no unusual difficulties were experienced with the material or equipment, public reaction to its use was negative. CMA creates a mealy snow and does not produce slush. The public had great difficulty recognizing that any action had been taken on the road section, which generated complaints. The tests were abandoned after one winter.

Several surveyed agencies indicated they had heated bridge decks similar to VDOT's experimental deck under evaluation in Amherst County. All the heated decks in other states were also considered experimental and had been installed only recently. British Columbia indicated that maintaining the electrical systems on their bridge decks was difficult, especially after resurfacing or patching. Wyoming was the only state that had installed a heated pavement, and that was on a northern-exposed viaduct roadway.

Alaska reported experimenting with rubber asphaltic mixes. They were trying to produce a pliable mix that would flex and break the ice as the temperature changed. Alaska felt little benefit was received from this experiment.

CONCLUSIONS

Most of the earlier anti-icing efforts were in Europe, where Finland reported extensive activities with dry salt applications in the 1970s and then more recently with prewetted and aqueous sodium chloride. In the United States, anti-icing efforts are starting to increase with increased concern over the impact of winter chemicals on the environment, roadways, bridges, and automobiles. States are starting to conduct further testing and evaluations to determine the best rate of application, the type of anti-icing material to use, and the time of application for their specific conditions.[14]

Anti-icing is not new, but the integration of RWISs with new materials and application methods is new. The integration improves the winter maintenance program. Many materials used in deicing operations are used in anti-icing operations, but they are used in a different form, are applied in different quantities, and are applied on the roadway at a different time.

Educating DOT personnel is critical to the evolution of this technology. Educating the traveling motorist may also be necessary.

RECOMMENDATIONS

1. Train maintenance personnel at all levels in anti-icing operations. The learning curve with an anti-icing program is steep.

2. Make weather forecasting an integral part of the anti-icing program to enhance the success of anti-icing.

3. Use an initial application rate of 7.7 g/m^2 (100 lb/lane mile) for an anti-icing program using liquid chemicals if the temperature is above -5°C (23° F), there are no high winds, and the chemicals are applied at an appropriate time.

4. Use liquid chemicals and prewetted salt to achieve maximum anti-icing benefit.

5. Conduct anti-icing experiments on prewetted chemicals, liquid chemicals, and finer salt gradations than are currently used.

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APPENDIX

1. Do you have a computerized weather system used to acquire:

    Regional weather data: yes ___ no ___
    Local weather data: yes ___ no ___
    Pavement condition data: yes ___ no ___

2. Do you practice: anti-icing ____ or deicing ___

3. What chemicals and rate of application (lb/lane-mi) do you use for anti-icing and/or deicing?

    Sodium chloride ___________ Calcium chloride __________

    Calcium magnesium acetate ___________ Urea __________

    Sodium formate ______________ Other ____________________

4. Do you apply any chemicals listed above as a liquid? ________

5. If yes, which chemicals, when they are applied, the rate of application, and any other pertinent information.

6. Do you use any specialized equipment other than a conventional snow plow or V-plow?

7. Do you use any other technologies to prevent ice from bonding to a pavement surface?