Canadian Strategic Highway Research Program (C-SHRP)

Anti-Icing and RWIS Technology in Canada

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Keeping Canadian roads and highways clear of snow and ice during the winter months is a significant challenge to agencies responsible for winter maintenance. A relatively new maintenance strategy that is seeing increased implementation in Canada and the United States is referred to as ***anti-icing***. The Insurance Corporation of British Columbia (ICBC) has recently produced a guide entitled "Proactive Guide to Snow and Ice Control: A Guide for Highway Winter Maintenance Personnel," which provides a comprehensive description of deicing chemicals, selection criteria, chemical production and storage, as well as application of anti-icing techniques to provide maximum road safety at minimum cost. The ICBC Guide is similar to that published by the Federal Highway Administration (FHWA) in 1996, with new and updated information.

This technical brief provides a brief introduction to the concept of anti-icing, as well as some of its accompanying technologies including road weather information systems (RWIS) and thermal mapping. Furthermore, the implementation status of anti-icing and RWIS technologies in Canada is presented as observed through a recent survey completed by the AASHTO Anti-Icing/RWIS Lead State Team.

BACKGROUND

At the onset of a winter storm, traditional maintenance operations involve waiting for a predetermined amount of snow to accumulate on the pavement surface before initiating removal procedures. In addition to plowing, most agencies also apply chemical freeze point depressants, more commonly referred to as deicing chemicals, to the roadway to aid the removal of snow and ice. Deicing is straightforward, however, the reactive nature allows the formation of a compacted snow layer on the road surface. This layer becomes tightly bonded under the compactive effort of traffic and requires a large amount of deicing chemical to penetrate the snow and ice and ultimately break the bond between the frozen material and the road surface.

Proactive vs. Reactive

As the name implies, anti-icing is a winter maintenance strategy that involves preventing or minimizing the formation of the bonded snow and ice layer. To do this, deicing chemicals are applied to the road shortly before the storm hits, so that precipitation in the form of snow or freezing rain is less likely to bond to the road surface. Unlike deicing, anti-icing is a proactive strategy and provides two primary benefits. First, because snow and ice are prevented from bonding to the roadway (or the accumulation is minimized), traffic safety is greatly increased during the storm. Second, a much smaller amount of chemical is required to prevent the bond from forming than if applied to an existing compacted layer of snow and ice. Therefore, anti-icing can be more cost effective than deicing and provide the same, or better level of service. Reduced environmental impact is another ob-

The Canadian Strategic Highway Research Program (C-SHRP) was established in 1987 to systematically extract the benefits from research undertaken by the Strategic Highway Research Program (SHRP) in the United States. SHRP was initiated in response to the continuing deterioration of highway infrastructure with the intention of making significant advances in traditional highway engineering and technology through the concentration of research funds in key technical areas. C-SHRP aims to solve high priority highway problems in Canada that are related to SHRP topics. The goal of both SHRP and C-SHRP is to improve the performance and durability of highways and make them safer for motorists and highway workers.

vious benefit resulting from the reduced amount of chemical used for winter maintenance activities.

Timing is the key...

Because anti-icing is a proactive strategy, the timing of chemical application becomes the critical factor to ensure maximum safety and cost effectiveness. Chemicals applied too soon before the storm may require premature reapplication, resulting in higher costs. Conversely, the chemicals cannot be applied too late otherwise the compacted snow and ice layer may form, reducing road safety. Accurate and timely weather information, therefore, is extremely important for timing the application of chemicals. Whereas regional and provincial weather data is sufficient for travellers, anti-icing operations require more detailed weather information. A system of technologies referred to as road weather information systems (RWIS) can be installed at strategic locations to provide site specific data for the deployment of anti-icing operations. Thermal mapping is another tool that can provide detailed information concerning the thermal properties of roadways, thus allowing the optimum placement of RWIS stations, as well as the development of heating and cooling models for problematic road segments to predict optimum chemical application times.

Part of a comprehensive plan...

Most jurisdictions produce a comprehensive snow and ice control plan to address the "who, what, where when and how" of winter maintenance activities. These plans are developed with customer input, while balancing legal concerns, level of service requirements, budgetary limitations, mobility and environmental issues. Anti-icing, RWIS and thermal mapping technologies are new (and powerful) tools, however, they should be incorporated in an agency's existing winter maintenance program, not directly replace existing strategies. Successful winter maintenance involves the selection and application of the most optimum strategy, over the most optimum time interval, to the correct location. In other words, "the right treatment at the right time to the right road."

ANTI-ICING TECHNOLOGIES

Chemicals

A number of different chemical freeze point depressants are available for anti-icing and deicing operations, however, most are based upon various combinations of sodium chloride (NaCl), magnesium chloride ($MgCl_2$), calcium chloride ($CaCl_2$), calcium magnesium acetate (CMA) and potassium acetate (KA). Other proprietary products such as ICEBAN™, which is derived from by-products of the agriculture industry, are also available. Selection of the appropriate chemical is based on a number of factors specific to different geographic areas and different agency specifications. The primary factors include desired performance, air and pavement temperatures, humidity and dew point, as well as cost, availability and past experience. Chemical composition and performance are usually described in terms of specific gravity, eutectic temperature and concentration.

Specific Gravity

The specific gravity of a substance is defined as the ratio of the mass of that substance relative to the mass of the same volume of a reference substance, usually distilled water, under identical conditions of temperature and pressure. For example, the specific gravity of wrought iron is 7.7, indicating that a cubic metre of wrought iron weighs 7.7 times that of a cubic metre of water under the same environmental conditions. Specific gravity of a deicing chemical is affected both by the type of chemical used and amount of chemical present in the solution (concentration). Specific gravity of the solution is an important consideration when sizing holding tanks and application equipment.

Eutectic Temperature

While various definitions exist, eutectic temperature may be defined for winter maintenance purposes as the temperature at which a given solution will freeze based on chemical concentration. Since the eutectic temperature varies with concentration, the optimum eutectic temperature is the lowest freeze point attainable for a given product or solution. Graphing the eutectic temperature with concentration produces a phase diagram, from which the optimum eutectic temperature may be determined. Figure 1 displays the phase diagrams for sodium chloride and calcium chloride. The optimum eutectic temperature is located at the point of the "V" on the diagram. As shown in Figure 1, NaCl has an optimum eutectic temperature of -21°C (-6°F) at 23% concentration, while $CaCl_2$ has an optimum eutectic temperature of -51°C (-60°F) at 30% concentration.

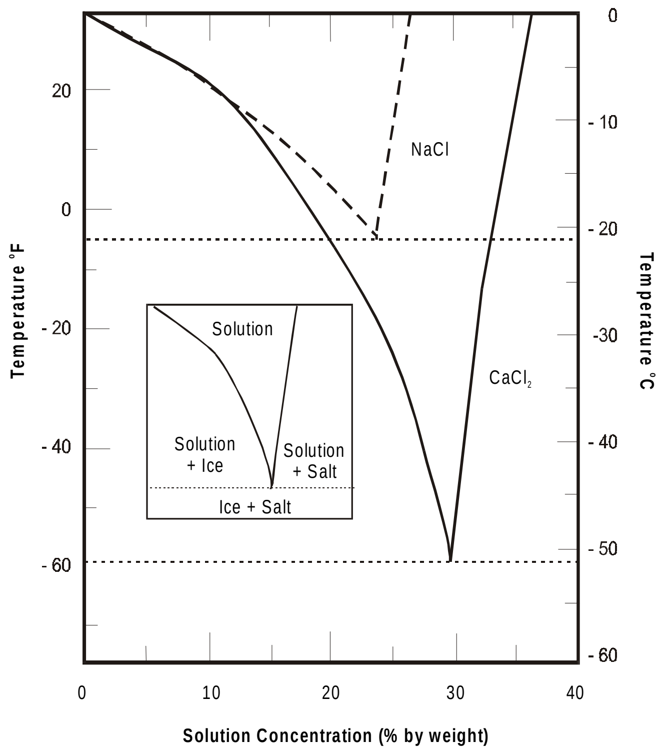

Figure 1: Phase Diagrams for NaCl and $CaCl_2$

Prewetting

Deicing chemicals may be applied in either solid or liquid form, however, solid chemicals require moisture to become effective. Many anti-icing strategies are therefore moving toward the use of liquids alone, however, solids are still frequently used since many agencies already possess the required spreading equipment. To increase the effectiveness of solid chemicals and retain the existing spreading equipment, many agencies are now using a technique referred to as "prewetting." Prewetting provides two primary benefits. First, moisture is applied directly to the solid chemical prior to application on the roadway. This provides the requisite moisture to (much more quickly) form a solution and break the bond between the ice/snow layer and the road surface. The second benefit of prewetting is that the granules adhere to the road surface much more readily than if dry. Therefore, less chemical is lost due to initial bounce and scatter, as well as subsequent traffic action. This in turn leads to a reduction in the amount of chemical required to achieve the same level of service. Any liquid may be used for prewetting of the solid chemicals, although the most commonly used liquids are salt brine (NaCl already in solution), calcium chloride and magnesium chloride. Water alone may be used, however, it is not common due to the potential for refreeze. Prewetting may be completed at the material stockpile by injecting a prewetting liquid directly into the stockpile or pre-mixing with a pugmill. Prewetting may also be completed by spraying a liquid onto a spreader during loading, or an on-board spray system mounted on the spreader may add the prewetting liquid to the dry chemical at the time of application. The use of on-board systems is most common.

Environmental Impact

Winter maintenance is critical to ensure safe and efficient road transportation in Canada. However, because deicing chemicals are required for effective winter maintenance, the impact of such chemicals on the environment must be taken into consideration when developing and executing anti-icing and deicing operations. The main areas affected by deicing chemical application include air quality, surface and ground water, vegetation, soil, wildlife and vehicle and structural corrosion. The Transportation Association of Canada (TAC) has recently produced an information primer entitled "Road Salt and Snow and Ice Control" that provides a good introduction to the importance of road transportation to Canada's economy, role of winter maintenance in maintaining a safe and efficient road system, the role of road salt in winter maintenance, as well as environmental impacts and methods to reduce the effects of salt on the environment. Through their nature, anti-icing and prewetting strategies can greatly reduce environmental impact simply by reducing the amount of chemical required to achieve the same or better level of service.

RWIS

The term road weather information system (RWIS) is usually used to describe a system of sensors connected together to provide real time, accurate and site specific pavement surface conditions and weather data. For anti-icing operations, pavement temperature and presence of moisture on the road surface are the most critical, however, RWIS stations can be configured to provide ambient (air) temperature, relative humidity, solar radiation, wind speed and direction, precipitation, and many other climatic conditions. Individual RWIS sites are often referred to as remote processing units (RPU's), consisting of several atmospheric sensors mounted to a tower, sensors embedded within and below the pavement surface, all connected to a data processing unit and communications equipment. A typical RPU is shown in Figure 2. Data from the RPU is sent to a central computer, where it may be made available to other workstations for use.

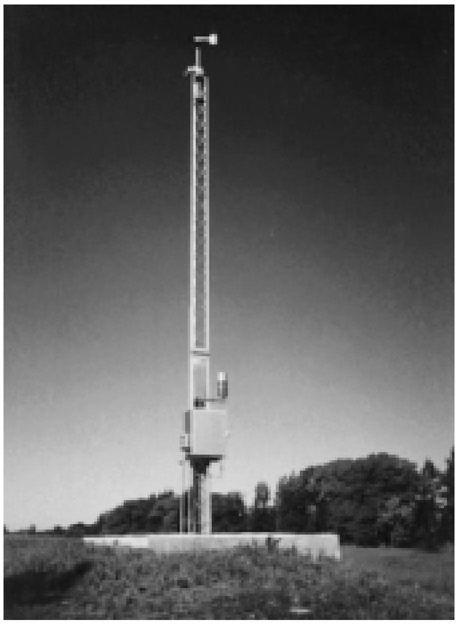

Figure 2: Typical RWIS Tower

The term "nowcasting" has been adopted to describe the use of real-time data for short term forecasting purposes. Nowcasting relies on RWIS data combined with radar and section patrols to predict the upcoming weather and pavement conditions, typically for the following hour or two. Personnel trained in basic weather concepts and who are familiar with local conditions are able to effectively use nowcasting to improve the overall effectiveness of a winter maintenance program.

Thermal Mapping

Thermal mapping, or thermography, utilizes mobile infrared sensors to determine the thermal profiles of road surfaces. The process is completed under multiple atmospheric conditions as the road surface radiation is influenced by cloud cover, wind speed and precipitation. Data from thermal mapping exercises can assist in the optimum placement of RWIS stations, can be used for forecasting in places without RWIS facilities and for developing snow and ice control strategies. Road climatology is an extension of thermal mapping where additional data such as air temperature, relative humidity and other characteristics are gathered. This information can be input to a short range (up to 4 hours) pavement temperature forecasting model to assist anti-icing operations.

TECHNOLOGY IMPLEMENTATION

Reduced insurance claims in BC

Anti-icing in British Columbia began in 1995/96 as a result of the previous year's increase in snow pack days and the resulting increase in accidents in the City of Kamloops. An increase in of 18% in total insurance claims into the Kamloops office of the Insurance Corporation of British Columbia (ICBC) translated into an estimated $3.9 million increase in claim costs in just two months. ICBC partnered with the City of Kamloops to begin an anti-icing strategy of pretreating 161 lane-km of major arterial with liquid magnesium chloride. A further 156 lane-km within the City of Kamloops were also pretreated by a local contractor as part of the study. At the end of the second year, the study found that there was a reduction in the number of collisions by up to 73% on the pretreated sections, while collisions increased on the untreated sections by up to 84%. The total accident claims for the entire city were reduced by 6% on snow days, resulting in an estimated savings of $300,000 to $600,000 per winter to ICBC. The City of Kamloops has since expanded its anti-icing efforts to include 465 lane-km, resulting in a reduction of total claims on snow days within Kamloops of 8%, thus providing an additional savings of $50,000 to $150,000 to ICBC per year for Kamloops alone. Subsequently, the cities of Vernon, Kelowna and North Vancouver have initiated anti-icing strategies.

In addition to reduced accident claims, ICBC estimates that the use of prewetting techniques and expanded anti-icing will reduce windshield damage caused by typical winter maintenance activities (solid sand and salt) by 10% in a single season, providing an annual savings of up to $6 million.

AASHTO Lead State Team

Since 1987, C-SHRP has continued to further SHRP technology implementation in Canada. However, as the original Strategic Highway Research Program concluded in 1995/96, the American Association of State Highway and Transportation Officials (AASHTO) created the Lead State Initiative to further SHRP implementation throughout the United States. One of seven such teams, the Anti-Icing and RWIS Lead State Team was charged with promoting the implementation and usage of anti-icing and RWIS technologies. To measure the success of their efforts, the team developed a baseline implementation survey in 1997 and a follow up survey in 1999/2000. Since the baseline survey, the reported use of anti-icing strategies rose from 79% to 90% and the number of states with chemical application rate guidelines rose from 43% to 60%, a clear testament to the dedication of the Lead State Team. The final report entitled "1999/2000 Technology and Usage Survey Results: Anti-Icing Techniques and Road Weather Information Systems Technologies" is available through the Iowa Department of Transportation (see References).

Anti-Icing and RWIS Usage in Canada

Through cooperation with C-SHRP, the 1999/2000 Lead State survey was also sent to representatives of the Transportation Association of Canada (TAC) Chief Engineers Council to provide Canadian input to the survey. A total of 32 Canadian responses representing each of the 10 provinces and one territory were collected. It should be mentioned that although the responses received are likely representative of Canadian implementation, they are by no means exhaustive.

Anti-icing implementation results are shown in Table 1. At this time, agencies in the Northwest Territories, British Columbia, Manitoba, Ontario, New Brunswick and Prince Edward Island have implemented anti-icing strategies; many with over 2 years of experience. The percentage of total lane kilometres treated with anti-icing techniques per agency (non-trial sections) ranged from 4% to 100% with an average of 37%. The chemical of choice for most agencies is sodium chloride (salt), in solid, prewet and liquid (brine) forms. Magnesium chloride appears popular in British Columbia and the City of Calgary, Alberta uses calcium chloride for anti-icing purposes. Anti-icing trials will be completed in Alberta, Saskatchewan and Ontario (Ministry) within the next year and many agencies with existing anti-icing programs plan to expand their efforts in the future.

Survey results of RWIS usage in Canada are displayed in Table 2. As shown, half of the responding agencies own or operate RWIS equipment. The number of RWIS tower sites ranged from zero to 18 with an average of 6 per agency. Every agency indicated that embedded pavement sensors were incorporated into their systems, while only 6 indicated that video cameras were used for surveillance and precipitation detection. Thermal mapping is currently used by 3 of the responding agencies whereas nowcasting is used to monitor storm initiation and progression by almost every agency. Finally, computers in maintenance facilities to assist weather monitoring and anti-icing efforts were reported by all agencies with RWIS systems.

SUMMARY

In the fight against snow and ice accumulation on Canada's roadways, anti-icing, RWIS and thermal mapping technologies are becoming valuable tools to provide maximum safety at minimum cost and minimum environmental impact. As indicated in the Lead State survey, implementation of these technologies throughout Canada is well underway and will likely continue as more experience is gained and more benefits are realized.

Table 1: Anti-Icing Usage in Canada (from Lead State Survey)

Province or Territory	Agency	Total Lane Km Maintained	Lane Km Treated with Anti-icing	Primary Anti-icing Chemicals	Applied in What Form?	Experience with Anti-Icing
Northwest Territories	Department of Transportation	2200	700	Sodium	Solid	Over 2 years
British Columbia	City of Vancouver	1400	500	Sodium Chloride	Liquid	Over 2 years
	City of Kamloops	1500	610	Magnesium Chloride	Liquid	Over 2 years
	Insurance Corporation of British Columbia (ICBC) Anti-Icing Pilot Project*	> 50000	5000 (approximate)	Magnesium Chloride and Sodium Chloride	Liquid and Prewet Solid	1-2 years
	Emcon Services (Ministry contractor)	13894	550	Magnesium Chloride	Liquid	2 years
	Main Road Mid-Island Contracting (Ministry contractor)	2056	1303	Sodium Chloride	Liquid and Prewet Solid	Over 2 years
Alberta	Alberta Infrastructure	Trials scheduled for 2000/2001				
	City of Calgary	7000	10	Calcium Chloride	Liquid	1 year
Saskatchewan	Highways and Transportation	32600	20 (Trial)	Sodium Chloride		Trial this winter
Manitoba	Public Works	4208	1080	Sodium Chloride	Liquid	Over 2 years
Ontario	Ministry of Transportation	Test sections to date; More trials to begin 2000/2001		SodiumChloride Prewet with Magnesium Chloride		2 years
	Region of Ottawa-Carleton	3200	30-40	Sodium Chloride	Liquid	First Season
	City of Ottawa	875	875	Sodium Chloride Prewet with Calcium Chloride		Over 2 years
	McCormick Rankin Corp. (Ministry contractor)	5000	2500	Sodium Chloride	Solid	Over 2 years
Ontario and New Brunswick	Integrated Maintenance & Operations Services Inc. (Ministry contractor)	3000	300	Sodium Chloride	Liquid	Over 2 years
New Brunswick	Department of Transportation	35200	Variable	Sodium Chloride	Solid	Over 2 years
Prince Edward Island	Transportation and Public Works	5800	300	Sodium Chloride	Solid	Over 2 years

* the ICBC Anti-Icing Pilot Project consists of 17 municipalities and 4 highway contractors

Table 2: RWIS Technology Usage in Canada (from Lead State Survey)

Province or Territory	Agency	No. of RWIS Towers	Embedded Pavement Sensors	Video Cameras	Thermal Mapping	Nowcasting	Computers in Maintenance Facilities
British Columbia	City of Kamloops	4	Yes	No	No	Yes	Yes
	Ministry of Transportation and Highways	31*	Yes	Yes	Yes	Yes	Yes
Alberta	Alberta Infrastructure	Trials scheduled for 2000/2001					
	City of Calgary	7	Yes	Yes	No	Yes	Yes
Manitoba	Public Works	2	Yes	Yes	Yes	Yes	Yes
	City of Winnipeg	2	Yes	No	No	Yes	Yes
Ontario	Ministry of Transportation	18	Yes	Yes	No	Yes	Yes
	Region of Ottawa-Carleton	5	Yes	No	No	Yes	Yes
	City of Ottawa	Pavement and air temperature sensors on supervisory vehicles					
	Ottawa Regional Centre (Environment Canada)	35**	Yes	Yes	No	Yes	Yes
	McCormick Rankin Corp. (Ministry contractor)	8	Yes	No	No	Yes	Yes
	County of Huron	0	No	Yes	No	Yes	Yes
Ontario and New Brunswick	Integrated Maintenance & Operations Services Inc. (Ministry contractor)	11	Yes	No	No	Yes	Yes
Québec	Ministère des transports	10	Yes	No	Yes	No	Yes
Nova Scotia	Department of Transportation and Communications	5	Yes	Yes	No	Yes	Yes
Prince Edward Island	Transportation and Public Works	2	Yes	No	No	No	Yes

*Includes 18 RWIS towers installed or to be installed in 2000

**The Ottawa Regional Centre of Environment Canada monitors and polls data from stations belonging to other agencies.

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Contact Ingrid Brakop (ingrid.brakop@icbc.com) at ICBC to purchase the ICBC Guide.

Federal Highway Administration. "Manual of Practice for an Effective Anti-Icing Program: A Guide for Highway Winter Maintenance Personnel." Report No. FHWA-RD-95-202. June 1996.

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Visit the Iowa DOT Winter Maintenance website at http://www.dot.state.ia.us/winter.htm to download the Lead State survey results.

This technical brief has been prepared and distributed by:

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