Snow and Ice Control at Extreme Temperatures

Prepared for
Bureau of Highway Operations

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Request for Report

Using salt to clear snow and ice from roadways is effective at temperatures of about 10 F or higher. At lower temperatures, higher volumes of salt are required, and its use becomes less cost-effective. When the temperature gets extremely low, state agencies tend to plow the roads, rely on abrasives, and/or use high volumes of salt. In more urban areas with high traffic volumes, abrasives are less effective and other strategies can result in overuse of salt, equipment, and manpower.

The Clear Roads winter maintenance pooled fund is interested in identifying additional strategies for maintaining roads in extreme temperatures, including preventing blowing and drifting. As a member state in the Clear Roads pooled fund, Wisconsin DOT asked us to review existing research and other states' practices in this area as a precursor to a full-scale research project.

Summary

As expected, most state and provincial DOTs that we spoke with are using traditional methods to prevent and remove snow and ice at very low temperatures. In addition to a review of current research, we spoke with six winter maintenance professionals at state and provincial DOTs with cold climates, including Maine, Ontario, Alberta and Manitoba.

The most innovative strategy in use among these agencies is the hot-water sand spreader being tested by the Ontario Ministry of Transportation. Originally developed in Europe, the spreader delivers sand that is prewetted with hot water (about 200 F). This technology is designed to keep sand on the road for much longer than conventional sand spreading techniques.

Norway has also tested the use of hot water as a prewetting agent for salt, and one article about this research noted that testing was planned to assess how this technique affects the temperature limits of salt application.

Other strategies identified that may be less common include constructing snow ridges rather than snow fences to control blowing and drifting; and for areas where snow storage is required, use of an in-traffic loading technique that minimizes lane closures.

Both traditional and innovative strategies are summarized below, and are detailed in the **State Practices** section of this report beginning at the bottom of this page. Relevant **State, National and International Research** begins on page 6.

State Practices

Use of Abrasives

- Applying sand, either dry (not prewetted) or prewetted with calcium chloride (CaCl), magnesium chloride (MgCl), an agricultural by-product, or with a blend of salt brine and another deicing agent.
- Applying sand with a hot-water sand spreader.

Use of Deicing Agents

- Applying salt, sometimes in large quantities, prewetted with deicing agents that are effective at lower temperatures than salt, such as CaCl or MgCl.
- Direct liquid application of CaCl, MgCl or a blend.
- Application of a salt slurry (salt mixed with CaCl or MgCl).

Plowing

- Setting realistic level of service expectations.
- Use of scarifying or ice chipping blades.

Controlling Blowing and Drifting Snow

- Installing snow fences.
- Constructing snow ridges.
- Incorporating control of blowing and drifting snow into highway design.
- Plowing highway shoulders to keep snow away from the roadway.
- Using weather forecast data to plan deicing treatments for after drifting has concluded.

Snow Storage

- In-traffic truck loading using two vehicles, minimizing lane closures.
- Incorporating the need for snow storage into highway design.

In addition to these subtopics, this section includes a summary of an informal evaluation of several locations' responses to a low-temperature snow event. See **Maine DOT: Comparing Different Approaches to the Same Storm** on page 6.

State, National and International Research

No research focusing specifically on use of abrasives or deicing agents at very low temperatures was identified, but this section includes a sampling of recent research on identifying blends of deicing agents that are versatile and cost-effective. This section also provides citations to several recent studies addressing control of blowing and drifting snow.

State Practices

Use of Abrasives

Many agencies have acted to minimize sand use in recent years because of concerns about its effectiveness and its impacts on the environment. But the agencies we spoke with agreed that sand has its place in very cold temperatures, even on high-volume roadways.

- **Cost-effectiveness:** Maine DOT examined the approaches of several different locations along an Interstate highway to a January 2011 snowstorm that hit during very low temperatures. Staff found that applying sand prewetted with a 70/30 blend of salt brine and Ice B'Gone (a proprietary magnesium chloride blend) was the most cost-effective approach. See page 6 of this report.

- **Prewetting abrasives:** Several agencies prewet sand with deicing agents. One staff member at Ontario MTO said that prewetting sand helps it stick to the roadway and reduces the number of applications needed; another stated that spreading prewetted sand on a snowpacked road tends to break up the snowpack in a way that makes it more difficult to drive on.

Innovations

The **hot-water sand spreader** was developed in Europe and used successfully there, and has been tested in recent years by the Ontario Ministry of Transportation. The spreader discharges sand mixed with water that has been heated to 95 C [203 F], a technique that is designed to cause the sand to stay on the road for an extended time.

Max Perchanok of Ontario MTO reports that his agency's initial assessments of the technology were favorable, but that in the winter of 2010-2011, the agency carried out traction monitoring that did not demonstrate much improvement over conventional sanding. Perchanok noted that the road does continue to appear brown where the sand was deposited, and said staff theorized that the sand could be staining the snow but not staying in place.

Perchanok still thinks the hot-water sander concept is sound, and he isn't sure yet what his agency's next step will be. The agency is exploring using the same grade of sand that has achieved successful results in the sander in Europe, and is evaluating the methodology of the traction monitoring performed this year.

The sander is manufactured in Sweden by Falköping, and is distributed in Ontario by Gin-Cor Industries (see http://www.gincor.com/index.php?page=test-2). More information on the hot-water sander is available in these documents:

> **Product brochure:**
> http://www.friggeraker.se/gb/userfiles/images/FRIGG_LTFV_GB_100210_LR.pdf
> *Excerpt:* "Sand mixed with 95 C hot water creates an anti-skid surface that freezes onto the road. The ice-bound sand provides excellent friction over a long period of time."
>
> **"Making Sand Last: MTO Tests Hot-Water Sander,"** Ontario MTO *Road Talk,* Summer 2008.
> http://www.mto.gov.on.ca/english/transtek/roadtalk/rt14-2/#a5
> This article describes Ontario's initial experiences with the technology.
>
> **"Sustainable Winter Sanding with Pre-wetting,"** Max Perchanok et. al, 2010 Annual Conference of the Transportation Association of Canada
> http://www.tac-atc.ca/english/resourcecentre/readingroom/conference/conf2010/docs/m1/perchanok.pdf
> This paper provides a primer on the hot-water sander technology.
>
> **"Implementation of New Sanding Method in Norway,"** Torgeir Vaa, *Transportation Research Circular E-C063, Sixth International Symposium on Snow Removal and Ice Control Technology,* pages 473-486, June 2004
> http://onlinepubs.trb.org/onlinepubs/circulars/ec063.pdf
> This paper gives an in-depth description of Norway's first several years using the hot-water sander and refining its development.
>
> **"Winter Friction Project in Norway**," Jon Dahlen, Torgeir Vaa, *Transportation Research Record: Journal of the Transportation Research Board,* No. 1741, pages 34-41, 2001
> Abstract: http://trid.trb.org/view.aspx?id=688954
> This paper describes the initial development of the hot-water sander as part of Norway's Winter Friction Project in the late 1990s.

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Use of Deicing Agents

Several agencies discussed the use of calcium chloride, magnesium chloride or deicers made from alcohol or agricultural byproducts. The hot-water salt spreader provides another possibility for using salt at lower temperatures.

Calcium chloride vs. magnesium chloride:

- One region of Manitoba avoids using calcium chloride products in very low temperatures; their experience is that these products do not dry fully, but instead create an ice film that can make the pavement slippery. They use only salt brine for prewetting. This region has also experienced problems with liquid anti-icing agents being tracked onto its roads from neighboring jurisdictions and then becoming slippery.
- Concerning direct liquid application, one region of Ontario says that in general, MgCl is more effective than CaCl, which is more likely to have refreeze problems. Staff feels that the CaCl "burns hotter and faster," and that while its initial reaction is quicker, it gets used up faster than MgCl. This may require crews to go out with the next load of salt sooner. This region uses about a 29% dilution for both deicing agents.

Other deicing agents:

- Manitoba is experimenting with other deicing agents in an effort to be environmentally sensitive. One is an alcohol byproduct produced by the nearby Crown Royal plant. To date, it seems to be effective, but one minor comment is that the product is black, and can temporarily make vehicles appear dirty. Manitoba is also experimenting with deicing agents made from sugar beet byproducts.

Direct liquid or slurry applications:

- In moderately low temperatures, one Ontario MTO staff person noted that a vendor recommended using a direct liquid application (DLA) to burn through a thin layer of ice on the roadways, or to treat refreezing that has occurred in the wheelpaths. Another staff person stated that the agency's guidelines for contractors indicate that DLA should only be used as an anti-icing treatment.
- When roads are packed with snow and ice at temperatures of 0 to 10 F, crews in Alberta may go out with a load of salt mixed with a small percentage of sand, plus a very heavy application of liquid deicer (MgCl or CaCl) in an effort to melt the ice on the roadway. They note that this approach carries the risk of refreezing, and the deicing agents may be diluted by drifting snow.

Innovations

Following Norway's success with the hot-water sand spreader, the Norwegian Public Roads Administration tested the use of hot water as an alternative prewetting liquid for salt. Two documents describe this testing:

> "Prewetting Salt with Hot Water," K.R. Lysbakken, R. Stotterud, *PIARC XII International Winter Roads Congress,* 2006
> Abstract: http://trid.trb.org/view.aspx?type=MO&id=907401
> This paper describes results of preliminary tests conducted during the winter of 2003-2004, which found that prewetting salt with hot water had a more rapid effect as a deicer than prewetting salt with brine, and that it provided a higher friction level. As an anti-icing medium, the tests showed no significant difference between the two methods.
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> "Current Report on New Salting Method," *Nordic* newsletter, No. 1, 2007
> http://www.nordicroads.com/website/index.asp?pageID=126
> This article describes the success of the method and notes that future tests will include an evaluation of "the consequences for traffic and temperature limits for salting."

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Plowing
Two challenges associated with very cold temperatures are breaking up packed snow and removing thin layers of ice. Agencies' approaches included:

- **Level of service:** Two staff at Ontario MTO mentioned that the agency's level of service guidelines, which allow the lowest-volume roads to remain in a snowpacked state unless temperatures allow them to be cleared, allow the agency to set realistic goals and meet them. Ontario's Level of Service guidelines are available in a 2009 Clear Roads Transportation Synthesis Report at http://www.clearroads.org/downloads/tsrlevelsofservice.pdf (see page 241 of the PDF).
- **Scarifying or ice chipping blades** were mentioned by Ontario MTO as a tool that may be used occasionally by some contractors to break up snowpack.
    - A scarifying blade was part of the Multiple Blade Snowplow Project carried out by five Clear Roads member states; see page 9 of the final report at http://www.clearroads.org/downloads/Multiple-Blade-Snowplow-Project-Final%20Report_1-6-11.pdf. An excerpt: "The scarifying blade included on the prototypes tested in Indiana, Ohio and Wisconsin received a less enthusiastic response from operators, who conveyed concerns about blade wear and a preference for underbody scrapers in removing hardpack."

Controlling Blowing and Drifting Snow
Snow that blows and drifts onto the roadway in very cold temperatures can create a thin layer of ice if the pavement temperature rises slightly. The agencies we spoke with mentioned several methods for preventing blowing and drifting:

- **Snow fences:** Several agencies have had success controlling blowing and drifting by installing snow fences in locations where this is an issue. These include wooden, perforated plastic, and living snow fences.
- **Snow ridges:** Manitoba law allows contractors for the ministry of transportation to install snow fences on private property as needed to control drifting on adjacent roadways. Practice has recently turned to constructing snow ridges instead, which don't require driving steel pegs into cold ground or removing them in spring. Alberta constructs snow ridges as well.
- **Highway design:** In Manitoba and Ontario, the highway design process includes evaluating the potential for drifting and striving to avoid designs that are likely to lead to drifting.
- **Plowing techniques:** When possible, Manitoba and Alberta crews plow highway shoulders so that any drifting snow has farther to travel to reach the roadway.
- **RWIS:** Alberta uses weather forecast data to determine when drifting is likely to conclude, and begins treatment with deicing agents after this time.

Snow Storage
Plowed snow placed very close to the roadway can contribute to blowing and drifting. Two techniques for mitigating this problem were mentioned:

- **In-traffic truck loading:** In areas of Manitoba where snow storage is limited, crews use two trucks in tandem to remove snow that needs to be hauled away from the roadway. A grader throws snow into a truck while both vehicles are moving in traffic, with the truck that is being loaded with snow driving in the traffic lane so that no lane closures are needed.
- **Highway design:** Manitoba's highway design process considers the need for snow storage adjacent to the roadway.

Maine DOT: Comparing Different Approaches to the Same Storm

Maine DOT recently examined the approaches of several different locations to treating an Interstate highway during a low-temperature January 2011 snowstorm that lasted about 7 to 8 hours. The agency found that applying prewetted sand was the most cost-effective approach. Three approaches used at different locations were:

- **Delayed sand application** (*most cost-effective*): The storm began at 6:30 a.m. with an air temperature of 3 F and a pavement temperature of 1 F, at which time the snow was blowing off the road. Around 9 a.m. the pavement temperature rose to 6-7 F and the roads began to glaze over. The road was treated with 10 cubic yards of sand per truck, which was effective in giving vehicles traction until the pavement warmed up to 10 F. At that point the road was treated at 400 pounds of salt per lane mile prewetted with a 70/30 blend of salt brine and Ice B'Gone (a proprietary blend of MgCl). This cleared the road.
- **Three applications of salt** (*effective, but more expensive*): This location is further south, and the storm began at 5:10 a.m. The roads were treated early at 300 pounds of salt per lane mile prewetted with an Ice B'Gone blend. At around 8 a.m., a couple of cars slid off the road, and crews put out a second application of salt at 600 pounds per lane mile. A third application (400 pounds per lane mile) later cleared the road. Around 1 inch of snow fell during the storm.
- **Salt early, then sand** (*salt was ineffective*): This location is adjacent to the one that used the "delayed sand application" approach. The storm began at 6:30 a.m., which was earlier than expected, and snowfall was heavier than expected. Air temperature was around 2 F and pavement temperature was 0 F. Snow blew off the road until around 8:30 a.m., when salt was applied. Later, 45 cubic yards of sand was applied, which provided traction until the temperatures rose to 10 F and salt could be applied to clear the road. Asked what they would do differently next time, this location reported that applying salt at 8:30 a.m. had no positive effect, and could have had a negative effect, noting "It was too cold for salt; we should have started with sand."

State, National and International Research

Of the subtopics discussed above, two have been the subject of several recent research projects: use of deicing agents and controlling blowing and drifting snow.

Use of Deicing Agents

We did not identify any research that specifically focused on innovative uses of deicing agents at very low temperatures. Most recent research on deicing agents has tended to focus on minimizing impacts on the environment and transportation structures. A few projects have also addressed the use of blends of deicing agents, especially salt brine blended with another agent, with a eye toward identifying cost-effective, versatile blends. A sampling of these projects is included below.

"Properties of Mixed Winter Roadway Chemicals," Maine DOT; expected completion date August 2011
Abstract: http://trid.trb.org/view.aspx?id=976377
This project will collect and verify laboratory data on the performance of commonly used deicing agents and blends, including sodium chloride, calcium chloride, magnesium chloride, calcium magnesium acetate, potassium acetate and additives intended to reduce corrosion. We spoke with Brian Burne of Maine DOT, who said that the agency is aiming to identify versatile blends that can be used in locations that have only one liquid tank.

Contact: Brian Burne, Maine DOT, (207) 624-3571, Brian.Burne@maine.gov.

"Chloride Cocktail: Department in Illinois Finds Good Results Mixing Their Own Deicer/Anti-Icer," *Roads and Bridges,* Vol. 44, No. 8, pages 50-52, August 2006
http://www.roadsbridges.com/Chloride-Cocktail-article7214
This article describes the development and use of blended anti-icing and deicing agents by Iowa DOT and by McHenry County (Ill.) Division of Transportation. The agencies sought to find a mixture of brine and liquid calcium chloride that would be suitable for all conditions, and they identified a successful mixture that included 85 percent brine, 10 percent De-ice, and 5 percent calcium chloride, dubbed "Supermix." An excerpt:

> Supermix was first tried in late December 2004. It was used in only two trucks initially and was applied directly to the salt in the auger at a rate of 10 gal per ton. Positive results soon had the mix in every truck

prewetting at the same 10-gal-per-ton rate. In the anti-icing units the mixture was applied to the pavement at a rate of 40 gal per lane-mile. Initial results had the operators excited about its performance. It seemed to work well in all temperatures and had a dark color that was easy to see. It seemed to last, which resulted in less re-treatment. Not one operator claimed to experience re-freeze, which the division had seen using straight calcium. The residual effect, especially in anti-icing, seemed to be excellent. The product seemed to work well in all conditions.

In anti-icing operations, Supermix was not applied below 15° pavement temperatures despite the possibility that it may work at lower temperatures. While in prewetting applications, it seemed to work well at pavement temperatures down to 2°F. It was determined that antifoam was needed during loading. The 100-gal tanks were now being loaded in 45 seconds compared to 4 to 5 minutes. At these increased volumes, foaming was taking place. Another unforeseen benefit was the overall reduction in calcium chloride use.

While switching between products, the MCDOT annually used about 23,000 gal of calcium per season. That number was reduced to 2,704 gal the first year of using Supermix at 5% calcium.

"Effectiveness of Using Organic By-Products in Decreasing the Freezing Point of Chemical Solutions,"
M.A. Alkoka, K. Kandil, *New Challenges for Winter Road Service: XIth International Winter Road Congress,*
9 pages, 2002
Abstract: http://trid.trb.org/view.aspx?id=709240
The objective of this paper was to determine the freezing point and a working temperature for a deicing agent named Magic, a mix of organic by-products from agriculture industries blended with liquid magnesium chloride, and also to study its effect, at different ratios, on lowering the freezing point of sodium chloride brine solution. A comparison between the effect of the product on a sodium chloride brine solution and the effect of a magnesium chloride solution on lowering the freezing point of the sodium chloride brine solution was also conducted.

Controlling Blowing and Drifting Snow

"Optimization of Snow Drifting Mitigation and Control Methods for Iowa Conditions," Iowa DOT. Initiated in November 2010; expected completion date April 2012
Project description: http://rip.trb.org/browse/dproject.asp?n=27349
This project's goal is to design passive snow-control measures for Iowa roadways that minimize or eliminate impacts from drifting snow. Researchers will focus on cost-effective solutions that can be tailored for Iowa's weather and road conditions. Project results will directly benefit several ongoing initiatives sponsored by Iowa DOT, including the Cooperative Snow Fence Program, by providing specific design recommendations for snow fences installed in rights of way.

Control of Blowing Snow Using SnowMan (Snow Management): User Manual, New York State DOT, 2008
https://www.nysdot.gov/divisions/engineering/technical-services/trans-r-and-d-repository/C-01-67_user%20manual.pdf
This project developed and deployed a software application named SnowMan (for Snow Management) to run within NYSDOT's MicroStation-based CAD environment to assist highway designers and maintenance users in the design of passive control measures. It incorporates current knowledge regarding snow transport and deposition, evaluating roadway cross sections for drift susceptibility, design of passive and living snow fences, and earthwork modification for reducing drifting.

The developers' manual is available at https://www.nysdot.gov/divisions/engineering/technical-services/trans-r-and-d-repository/C-01-67_developers%20manual.pdf

"Effect of Blowing Snow and Snow Fences on Pavement Temperature and Ice Formation," Ronald D. Tabler, *Transportation Research Circular E-C063, Sixth International Symposium on Snow Removal and Ice Control Technology,* page 401, June 2004
http://onlinepubs.trb.org/onlinepubs/circulars/ec063.pdf
Previous research found that the majority of winter crashes in Wyoming were found to be associated with icy road conditions, and that blowing snow was the dominant cause of icy roads in wind-exposed areas. This paper shows that the melting of blowing snow constitutes a major heat sink and that areas protected by snow fences can be 10 or more degrees F warmer than adjacent unprotected roadway. These quantitative measurements explain the dramatic effect of snow fences on road surface conditions that have been previously reported, and they provide a compelling argument for mitigating blowing snow with roadside vegetation as well as fences.

Surface Transportation Weather and Snow Removal and Ice Control Technology, Transportation Research Circular E-C126, TRB, June 2008
http://onlinepubs.trb.org/onlinepubs/circulars/ec126.pdf
These conference proceedings contain three papers on blowing and drifting snow:

- "The Physical Nature and Prediction of Blowing Snow Within the Roadway Environment," Benjamin W. Hershey and Leon F. Osborne, Jr., page 381
- "Geospatial Variability of Roadway Vegetation and Blowing Snow," Scott S. Kroeber, Damon M. Grabow, and Leon F. Osborne, Jr., page 393
- "Spatial Modeling for Evaluation and Remediation of Snow Drifting on Ontario Highways," Max S. Perchanok, Steve McArdle, Patrick Grover, and Aleksey Naumov, page 403