Use of Prewetted Solid Materials for Roadway Anti-Icing

Synthesis Report

CLEAR ROADS

research for winter highway maintenance

CTC & Associates LLC

Project CR17-S2
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Acknowledgments

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16. Abstract

Anti-icing (also known as "pre-treating") is the winter road maintenance practice of applying a liquid or solid material intended to depress the freezing point of water in order to prevent winter storm precipitate from bonding to roadway pavement. Anti-icing may be performed hours (or even days) before a winter storm event begins; it can also be performed after ice or snow begins to fall in order to keep pavements as clear of ice and snow as possible. Salt [sodium chloride] brine and other chloride liquids are widely used for anti-icing. Historically, materials other than liquids, such as dry and prewetted salt/solids, have also been used by winter maintenance agencies for anti-icing.

This Clear Roads synthesis project sought to learn how and the extent to which agencies use prewetted salts/solids for anti-icing, the conditions under which they are used, their effectiveness, cost-effectiveness and agencies' response to environmental concerns about anti-icing salt use. The investigation included a national survey of state department of transportation winter maintenance experts that gathered information about materials used for anti-icing, including reasons why materials were selected, how they were prepared and applied, and their effectiveness, with particular focus on the use of prewetted solids. The results of a literature search supplemented the survey findings.

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Table of Contents

Tables

Figures

Executive Summary

Anti-icing (also known as "pre-treating") is the winter road maintenance practice of applying a liquid or solid material intended to depress the freezing point of water in order to prevent winter storm precipitate from bonding to roadway pavement. Anti-icing may be performed hours (or even days) before a winter storm event begins. It can also be performed after ice or snow begins to fall in order to keep pavements as clear of ice and snow as possible. Salt [sodium chloride] brine and other chloride liquids are widely used for anti-icing. Historically, materials other than liquids, such as dry and prewetted salt and other solids, have also been used by winter maintenance agencies for anti-icing operations.

This Clear Roads synthesis project sought to learn how and the extent to which agencies use prewetted salts/solids for anti-icing, the conditions under which they are used, their effectiveness, cost-effectiveness and agencies' response to environmental concerns about anti-icing salt use.

Through a survey of the 36 Clear Roads member agencies and others reached via AASHTO's Snow & Ice Listserv, this synthesis gathered information about materials used for anti-icing, including reasons why materials were selected, how they were prepared and applied and their effectiveness, with particular focus on the use of prewetted solids. Respondents from 33 state agencies participated in the survey, with four states—Kentucky, Minnesota, North Dakota and Washington State—submitting complete surveys from multiple respondents. One participant from a private company as well as one international representative resulted in a total of 40 survey respondents. The survey results are presented in this synthesis; the results of a literature search supplement the survey findings.

Survey Respondents

Respondents are listed below:

- Alaska
- Arizona
- Colorado
- Connecticut
- Delaware
- Idaho
- Illinois
- Indiana
- Iowa
- Kansas
- Kentucky—2 respondents:
  - Transportation Cabinet Director
  - Snow & Ice Program Coordinator
- Maine
- Maryland
- Massachusetts
- Michigan
- Minnesota—3 respondents:
  - MnDOT-Statewide
  - MnDOT-District 7
  - MN-Ottertail County
- Montana
- New Hampshire
- New York State
- North Dakota—2 respondents:
  - Transportation Engineer
  - District Engineer
- Ohio
- Oregon
- Ontario, Canada
- Pennsylvania
- Rhode Island
- South Dakota
- Texas
- Utah
- Vermont
- Virginia
- Washington State—2 respondents:
  - Maintenance Supervisor
  - Maintenance Manager
- West Virginia
- Wisconsin
- Wyoming
- WVB Partners

The survey included 18 questions divided into three sections:

- Overview of anti-icing practices
- Environmental concerns
- Wrap-up/links

Documents with links provided by respondents are described in **Related Resources** following the survey details. Resources from respondents not accessible online are presented in appendices.

Overview of Anti-icing Practices

The primary section of the survey asked participants seven questions about materials and methods agencies use for anti-icing. The first question asked whether their agency uses anti-icing methods before storms. One participant indicated they did not (Minnesota Ottertail County). The remaining 39 participants completed the rest of the survey.

Materials Used: What and Why

The next question asked about the materials respondents use for anti-icing, with the option of choosing more than one material from among these materials: liquid brine, other chloride salt liquids, non-chloride liquids, pre-wetted salts/solids, dry salts/solids and other materials (which they were asked to specify). The following question asked why they used the materials they did, with the option to choose more than one among five reasons listed. Comments were encouraged.

What Materials Used

The three most frequently used materials for anti-icing were **liquid brine**, **other chloride salt liquids** and **prewetted solids**. All 38 respondents indicated they use liquid brine in anti-icing. Twenty-four respondents (about 63 percent) indicated they also use liquids of other chloride salts, such as calcium chloride or magnesium chloride. Fourteen (about 36 percent) respondents reported they also use prewetted salt/solids for anti-icing. Four (about 10.5 percent) listed other materials and three (about 8 percent) reported the use of dry solids for anti-icing in some situations. Three (about 8 percent) reported that they also use non-chloride liquids.

Table 2.1 presents the range of anti-icing materials and which agencies use them.

Why Materials Used

Eighteen respondents (46 percent) reported that they use the material they do because their equipment is set up for it, it is the most cost effective and they also consider it the most effective anti-icing material. Equipment compatibility was chosen by two states (Michigan and West Virginia). Two states (Idaho and North Dakota 2) reported that cost-effectiveness was the reason. Maine's respondent reported that it uses the material it does solely because it is the most effective anti-icing material. Many respondents chose a combination of reasons, though the three primary reasons overall were effectiveness, cost-effectiveness and existing equipment configurations.

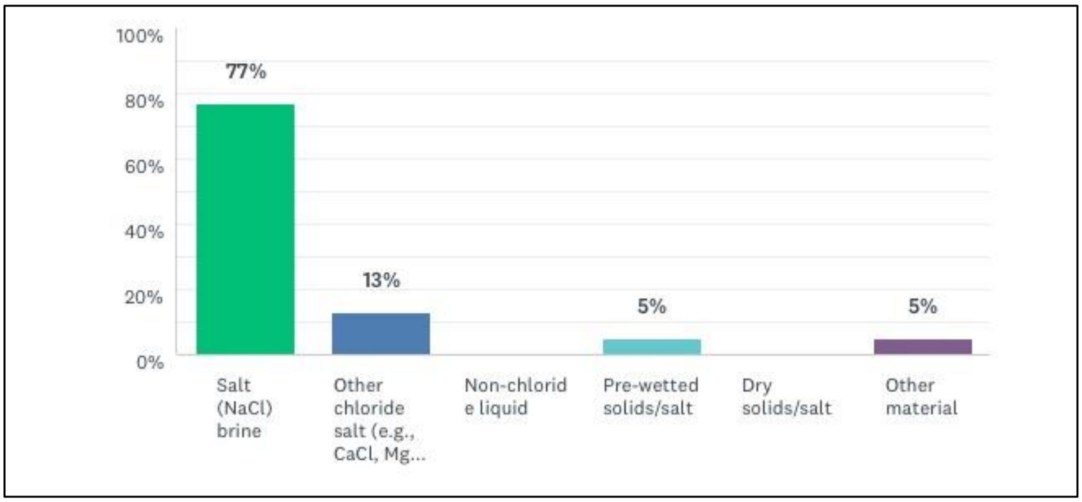
Table 2.2 presents reasons why individual agencies use the materials they indicated in the previous question.

Most Effective and Most Cost-Effective Materials

Most Effective

The next two questions examined which anti-icing materials respondents considered the most effective and the most cost-effective. Liquid brine was by far considered the most effective anti-icing material: 30 respondents (77 percent) chose it. Five respondents (12 percent) chose "other chloride salt liquids." Two respondents (Idaho and Washington State 2) indicated that they considered "prewetted salt/solids" as the most effective anti-icing material (5 percent). Two other respondents chose "other materials" as most effective (Illinois and New Hampshire; 5 percent). Comments included discussions of what materials may be used effectively below 15 degrees F.

Most Effective Anti-icing Materials



Most Cost-Effective

Thirty-four of 39 respondents (87 percent) considered liquid brine to be the most cost-effective anti-icing material. Three respondents (Alaska, Oregon and Washington State 2; about 8 percent) chose "other chloride salt liquids." Only one respondent (Washington State 2) selected "prewetted salt/solids" as the most cost-effective material. One respondent chose "other material" as most cost-effective (New Hampshire) and described the material as "80/20 blend of brine and MgCl." Wisconsin's respondent offered a summary comment that conveyed the gist of many others: "If conditions are ideal, salt brine is the most effective and economical for anti-icing, by far. When conditions are not ideal, other additives and products may be necessary to achieve similar results."

Table 2.4 and Figure 2.2 present information respondents provided to this question.

Liquids Used for Prewetting

The next two questions examined the practice of anti-icing with prewetted solids: first, which liquids are used to prewet solids? Second, what is the ratio of liquid to solid when anti-icing with prewetted solids?

Which Liquids

Twenty-four of 39 participants (62 percent) answered this question. Fifteen participants (33 percent) did not answer this question. Sixteen of the 24 answering reported using liquid brine to prewet anti-icing solids. Six chose "other liquid." Two respondents (Arizona and Connecticut) reported using liquid MgCl to prewet anti-icing salt/solids.

Table 2.5 shows which liquids respondents use to prewet solids.

Liquid to Solid Ratio

Twenty-two of 39 participants (about 56 percent) responded to the question asking the ratio of liquid to solid that organizations use for anti-icing with a prewetted salt/solid. Eleven indicated they used nine to twelve gallons per ton. Four reported using five to eight gallons per ton, while three indicated they use more: 13–16 gallons per ton of solid material. Idaho's respondent noted that if MgCl is used rather than liquid brine, the amount of liquid used is less. Three more respondents offered other ratios. The table below shows respondents' choices.

Ratio of Liquid to Solid: Prewetting Salt/Solids for Anti-icing

Liquid/Solid Ratio	State/Other Respondents	Total Respondents
5–8 gal/ton	Maine, New York State, North Dakota 1, Wyoming	4
9–12 gal/ton	Connecticut, Delaware, Illinois, Indiana, Iowa, MnDOT-Statewide, Pennsylvania, Rhode Island, South Dakota, Washington State 1, West Virginia	11
13–16 gal/ton	Idaho, Utah, Washington State 2	3
Other ratio	Arizona, Montana, Oregon	3

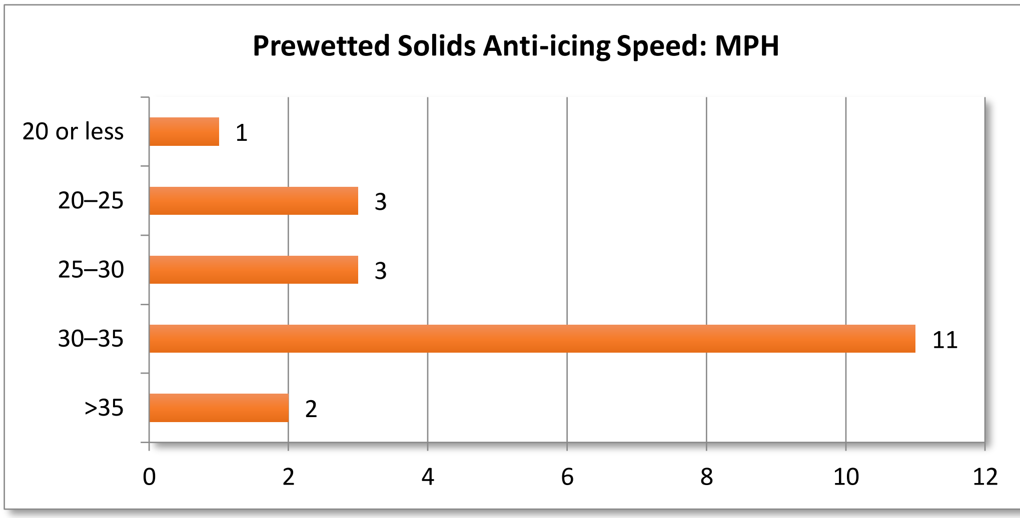
Five respondents indicated that they do not use prewetted solids for anti-icing, joining twelve others who skipped this question (17 of 39, about 44 percent).

Speed and Application Rates

The next survey question asked about the speed at which materials are applied, the rate of application of materials in pounds per lane mile, and the rate of application of dry solids, if that material is used for anti-icing. Twenty of the 39 participants responded to the prewetted solids speed and rate questions.

Speed

The majority of respondents (11 of 20) reported applying prewetted solids at a rate of 30–35 miles per hour. Two ran at higher speeds, while seven respondents reported application at speeds below 30 miles per hour. One reported application speed of 20 miles per hour or slower. The chart below graphically illustrates the range of application speeds among 20 respondents.



Application Rates
Twenty respondents supplied application rates of prewetted salt/solids for anti-icing. The amount applied ranged from 100 to 500 pounds per lane mile. Eight respondents reported applying 100–200 pounds per lane mile, while three apply less and nine apply more. Several respondents commented that the application rate depends upon the air/pavement temperatures.

Table 2.8 presents application rates provided by respondents to this question.

Application Rates of Dry Solids for Anti-icing
Eight respondents (about 20.5 percent) answered this question about application rates for dry solids used for anti-icing. Three respondents (Idaho, Illinois and Washington State 2) reported they apply between 100 and 150 pounds of dry solids per lane mile. Two respondents (Oregon and Pennsylvania) reported using up to 200 pound per lane mile. Two others (Indiana and West Virginia) indicated they use 250 to 350 pounds per lane mile. Ontario, Canada's respondent reported a range with a top limit exceeding 350 pounds of dry solids per lane mile for anti-icing.

Figure 2.7 graphically illustrates solid anti-icing application rates.

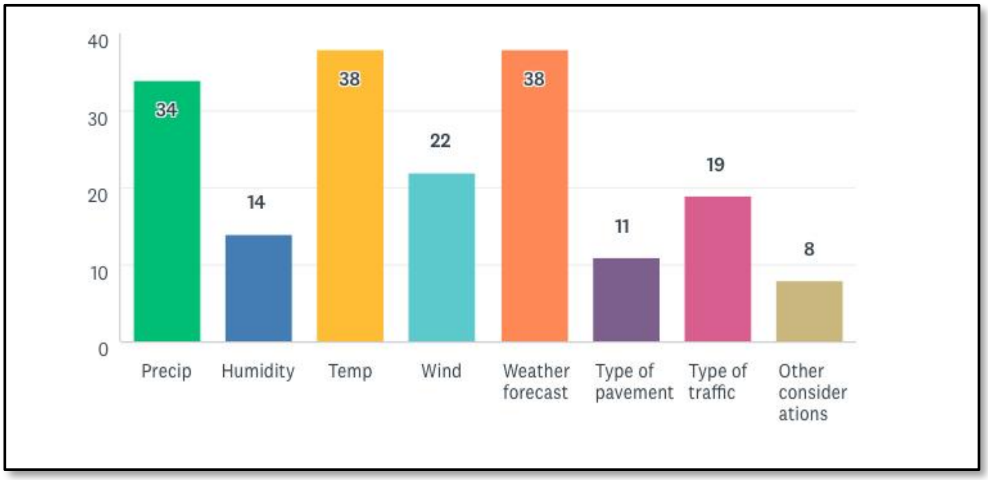
Factors Considered in Deciding to Anti-ice

Question 11 of the survey addressed the factors that winter road maintenance professionals must consider in deciding whether and when to anti-ice roadways. All 39 respondents participated in this question. The question offered a range of seven factors, plus an "Other" option, to select as influential in deciding to anti-ice roadways:

- Temperature
- Weather Forecast
- Precipitation
- Wind
- Type of Traffic
- Humidity
- Type of Pavement
- Other Conditions

The factors were ranked through respondents' participation in this survey question. Temperature and Weather Forecast were equally weighted: 38 of 39 respondents (97 percent) rated one or the other as most important in deciding to anti-ice. The type of precipitation was a close second concern with 34 respondents (87 percent) choosing it. These factors and the remaining four are ranked as illustrated in the chart below.

Factors in Determining to Anti-ice



Conditions that Preclude Anti-icing

Survey question 12 asked participants which conditions would cause them to decide not to anti-ice roadways. It was a free response question that allowed the widest range of responses, yet there was a strong agreement among respondents about some conditions. The majority of the 37 respondents who participated included one or two weather scenarios that would cause them to decide not to apply anti-icers to roadways:

- Extremely cold pavement/air temperatures
- Storms that begin as moderate to heavy rain

Eight respondents mentioned two other weather conditions that could affect their anti-icing decisions;

- Temperatures above 38–40 degrees and/or high humidity
- Strong winds

Three respondents noted that residual salt on the pavement is a condition pointing to a decision to avoid anti-icing.

Table 2.10 presents respondents' selected conditions that would point to refraining from anti-icing.

Environmental Concerns

The last four questions of the survey considered environmental concerns about anti-icing, including changes agencies may have made in response to existing or potential future federal or state regulations.

Questions also examined procedures in place to control application and measure chemical usage throughout the winter maintenance season.

Changes Made in Response to Regulation

The majority of respondents—29, about 76 percent—reported that their agencies had not made any changes in their anti-icing procedures. Nine respondents (24 percent) indicated that they had made changes and briefly described them. Their descriptions are included in the survey details. One survey participant did not respond to this question.

Controlling Bounce and Scatter

Respondents reported overwhelmingly that their agencies make efforts to limit the bounce and scatter of anti-icing materials (35 or 39, 90 percent). Four respondents reported that they do not have methods to control bounce and scatter.

The respondents who participated in this question offered many descriptions and comments about their agencies' techniques. The comments indicated that respondents discussed methods to reduce bounce and scatter of solid materials for *any* purpose—anti-icing *and* deicing—rather than only for anti-icing.

The following strategies were considered effective in limiting bounce and scatter for *any operation* using solid materials:

- Prewetting solids
- Reducing speeds
- Reducing spinner speeds (low or off) or using chutes to apply solids closer to the road

Table 2.11 shows the methods respondents employ to reduce bounce and scatter of materials.

Extensive respondent comments are included in the survey details.

Records of Materials Dispensed

The final two questions queried participants about how agencies address environmental concerns through control of the amount of material dispensed and how they keep accurate records of materials they apply to roadways. Thirty-eight of 39 respondents (about 97.4 percent). Thirteen respondents reported they use ground application controllers. Nine also mentioned global positioning systems with automatic vehicle locating (GPS/AVL).

Five respondents indicated that their agencies use software programs that assist in materials management or a Maintenance Decision Support System (MDSS) that assists in determining best strategies for road treatment. Nine respondents mentioned operator logs; eight use in-house systems and programs to keep track of material usage. Some agencies reported using more than one method of keeping records.

Respondents from Illinois and Virginia reported that they do not record exactly where anti-icing materials are applied. Alaska's respondent did not respond to this question.

Table 2.12 presents respondents' methods of keeping records of materials dispensed.

Applicator Control

The final question asked participants if their agencies used applicator control to dispense anti-icing materials. Thirty-eight of 39 participants (97.4 percent) reported that they did use applicator control for anti-icing. Among these, 36 respondents offered information about their equipment (respondents from Alaska and Connecticut did not). The respondent from Illinois indicated the agency did not use applicator control for anti-icing.

Responses revealed that while many agencies use controllers from one manufacturer, such as Force America or Cirus, many use controllers from two or three different manufacturers. Respondents offered a range of comments about their fleets.

Table 2.13 shows the brands of applicator controllers respondents use in dispensing anti-icing materials to roadways.

Wrap-up

The survey concluded with two additional opportunities for respondents to include links to documents and further information, as well as closing comments about the agency anti-icing procedures.

Two respondents from Idaho and Maine mentioned guidelines in their survey answers that are included in a Clear Roads manual. Respondents from Connecticut, New York State, Ohio, Vermont and Wisconsin provided links to documents relevant to their anti-icing operations and general winter road maintenance. These resources are listed with descriptions in Related Resources following the presentation of the last question in Survey Details. Documents not available online were provided by respondents from Pennsylvania and Wisconsin, presented in Appendices B and C.

Conclusion

The purpose of this synthesis was to learn whether and to what extent winter road maintenance organizations—state agencies and others—use prewetted salt/solids for anti-icing operations. In addition, it sought to learn conditions under which this procedure is used, its effectiveness, cost-effectiveness, and agencies' responses to environmental concerns regarding anti-icing salt use.

While many respondents participated in questions regarding how they would use prewetted salts/solids in such a procedure—perhaps treating prewetted salt/solids as another tool in the winter road maintenance toolbox—half and often more than half reported that they would not use prewetted salt/solids for anti-icing. Instead, the majority opted for liquid brine or other anti-icing liquid applications. Only two respondents of 39 considered prewetted salt/solids as "most effective" in anti-icing, while only one considered it the "most cost-effective" among all other choices. Those who reported using prewetted salt/solids provided information about types of liquids and ratios used to prewet that will assist those who may choose to try this anti-icing procedure.

Participants provided detailed and instructive responses to questions regarding the factors and conditions that would point toward a decision to anti-ice. Further, the query about when they would refrain from anti-icing also elicited detailed and illuminating responses and comments. Responses to questions about vehicle speed and application rates reveal a wide range of practices.

Concern about environmental effects of salt showed up in the extent to which agencies work to reduce bounce and scatter of materials on the roadway. While bounce and scatter is an environmental concern, it is also an economical issue. Thus, while the majority of respondents reported that they had not changed their procedures in response to current or potentially future state or federal regulation, 90 percent of respondents applied methods to limit bounce and scatter of solid materials applied to winter roadways.

Questions about control of application and record-keeping of materials dispensed showed that most respondents' organizations used equipment that is intended to control application. Record-keeping methods across respondents vary in technological sophistication; however, every respondent reported a record-keeping regimen was in place.

While this study suggests that prewetted salt/solids for anti-icing are used to a very limited extent, it remains a tool in the winter road maintenance toolbox. In addition, the responses gathered for this synthesis contribute a wealth of information about agency anti-icing practices overall. A comment from the Wisconsin respondent seems both pragmatic and flexible: "If conditions are ideal, salt brine is the most effective and economical for anti-icing, by far. When conditions are not ideal, other additives and products may be necessary to achieve similar results."

1 Introduction

Anti-icing (also known as “pre-treating”) is the winter road maintenance practice of applying a liquid or solid material intended to depress the freezing point of water in order to prevent winter storm precipitate from bonding to roadway pavement. Anti-icing may be performed hours (or even days) before a winter storm event begins; it can also be performed after ice or snow begins to fall in order to keep pavements as clear of ice and snow as possible. Salt [sodium chloride] brine and other chloride liquids are widely used for anti-icing. Historically, materials other than liquids, such as dry and prewetted salt/solids, have also been used by winter maintenance agencies for anti-icing.

This synthesis project sought to learn how and the extent to which state agencies use prewetted salts/solids for anti-icing, the conditions under which they are used, their effectiveness, cost-effectiveness and agencies’ response to environmental concerns about anti-icing salt use. The investigation included a national survey of state department of transportation winter maintenance experts. It gathered information about materials used for anti-icing, including reasons why materials were selected, how they were prepared and applied as well as their effectiveness. The particular focus was on the use of prewetted solids. The results of a literature search supplemented the survey findings.

2 Survey of Practice

2.1 Overview

An online survey was distributed to the Clear Roads member state representatives and also posted on AASHTO’s Snow & Ice Listserv. It gathered information about the use of prewetted solids for anti-icing for winter road maintenance, including agency practices and perceptions. Thirty-three states responded to the survey, with four states—Kentucky, Minnesota, North Dakota and Washington State—submitting completed surveys from multiple respondents. In addition, the Snow & Ice Listserv posting resulted in one international response and one from a private American company, for a total of 40 responses. Respondents are listed below:

- Alaska
- Arizona
- Colorado
- Connecticut
- Delaware
- Idaho
- Illinois
- Indiana
- Iowa
- Kansas
- Kentucky (2)
  - Transportation Cabinet Director
  - Snow & Ice Program Coordinator
- Maine
- Maryland
- Massachusetts
- Michigan
- Minnesota (3)
  - MnDOT-Statewide
  - MnDOT-District 7
  - MN-Ottertail County
- Montana
- New Hampshire
- New York State
- North Dakota (2)
  - Transportation Engineer
  - District Engineer
- Ohio
- Oregon
- Ontario, Canada
- Pennsylvania
- Rhode Island
- South Dakota
- Texas
- Utah
- Vermont
- Virginia
- Washington State (2)
  - Maintenance Supervisor
  - Maintenance Manager
- West Virginia
- Wisconsin
- Wyoming
- WVB Partners

The survey included 18 questions divided into three sections:

- Overview of anti-icing practices
- Environmental concerns
- Wrap-up/links

Respondents' links and related information are presented after the survey question summary in **Related Resources.**

The full text of the survey questions appears in **Appendix A**. Complete survey responses are available as an Excel file from the Clear Roads administrator.

2.2 Overview of Anti-icing Practices

The first section of the survey asked respondents seven questions about the materials and methods their agency uses for anti-icing. *Anti-icing* was defined as the application of a material to the roadway in advance of a snow/ice event—while the pavement is still bare—to prevent or mitigate the frozen precipitate bonding to the pavement.

The first question asked respondents whether their agency uses anti-icing methods before storms. Only one respondent from Minnesota (Ottertail County) indicated that anti-icing was not used. The remaining 39 respondents went on to complete the rest of the survey.

The respondent from Montana noted that the state practices a "just-in-time" strategy whereby they endeavor to get material to the pavement in the short time before it is covered with ice or snow as a storm begins. The respondent was concerned that this "just-in-time" practice might not be considered "anti-icing." For the purposes of this report, the definition of "anti-icing" as the practice of applying material to the roads before a storm includes Montana's practice, since this synthesis is concerned with what winter maintenance agencies apply to road pavement *before freezing rain, ice or snow can bond to it*, regardless of how far (or close) in advance of the storm that application occurs. Montana's responses are included among the 39 survey responses examined here.

2.2.1 Materials Used: What and Why

The next two questions asked about the materials respondents use for anti-icing, with the option to choose one or more materials from among liquid brine, other chloride salt liquids, non-chloride liquids, prewetted salts/solids, dry salts/solids, and other materials (which they could specify). The next associated question asked *why* they use the materials they indicated, with the option to choose one or more among five reasons listed. A comment option was also offered for each question.

Table 2.1 Materials Used for Anti-icing

Materials Used for Anti-Icing	State/Other Respondents	Total Respondents
Liquid brine	Alaska, Arizona, Colorado, Connecticut, Delaware, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky 1, Kentucky 2, Maine, Maryland, Massachusetts, Michigan, MnDOT-Statewide, MnDOT-District 7, Montana, New Hampshire, New York State, North Dakota 1, North Dakota 2, Ohio, Ontario (Canada), Pennsylvania, Rhode Island, South Dakota, Texas, Utah, Vermont, Virginia, Washington State 1, Washington State 2, West Virginia, Wisconsin, WVB Partners, Wyoming	38
Other chloride salt liquid	Alaska, Arizona, Colorado, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky 1, Massachusetts, MnDOT-Statewide, MnDOT-District 7, Montana, New Hampshire, New York State, Ontario (Canada), Rhode Island, Utah, Vermont, Virginia, Washington State 1, Washington State 2, West Virginia, Wisconsin	24
Non-chloride liquid	Kansas, MnDOT-Statewide, Ontario (Canada)	3
Prewetted salt/solids	Connecticut, Idaho, Illinois, Indiana, Kansas, MnDOT-Statewide, Montana, Ontario (Canada), Oregon, Rhode Island, Utah, Washington State 1, Washington State 2, West Virginia	14
Dry salts/solids	MnDOT-Statewide, Ontario (Canada), West Virginia	3
Other material	Ohio, Ontario (Canada), Wisconsin, WVB Partners	4

In answering the question about what materials they use for anti-icing, thirty-eight respondents (all respondents except Oregon) indicated that they use liquid brine as one anti-icing material. Twenty-four respondents (about 63 percent) indicated that they also use liquids of other chloride salts, such as calcium chloride or magnesium chloride. Fourteen respondents (about 36 percent) indicated that they also use prewetted salt/solids for anti-icing. Four respondents (about 10.5 percent) listed other materials they also use for anti-icing (Ohio, Ontario, Wisconsin, WVB Partners). Three respondents (about 8 percent) included that they use dry solids for anti-icing in some situations (MnDOT-Statewide, Ontario, West Virginia). Three respondents indicated that they also use non-chloride liquids (Kansas, MnDOT-Statewide, Ontario). Thus, respondents reported that the three most frequently used materials for anti-icing were liquid brine, other chloride salt liquids and prewetted solids.

Many respondents included comments further explaining their choices of anti-icing materials.

Alaska	*We are continuing refining our processes for better results.*
Idaho	*Depending upon the location and the equipment available, we may use prewetted salt or liquid deicers.*

Maine	*[Salt brine is] more forgiving and doesn't get slimy like calcium chloride or magnesium chloride.*
MnDOT-Statewide	*[We are] going to more liquids.*
Ontario, Canada	*We use a combination of equipment and products to provide the most effective operation based on the vast climatic needs across the province.*
Washington State 1	*Typically we accomplish pre-treatment through the use of liquid application; however, we have at least one region that has been experimenting with prewet solid applications.*

Eighteen respondents (46 percent) reported using the materials they do for anti-icing because their equipment is set up for this material, it is the most cost-effective and they also consider it the most effective anti-icing material. Respondents from two states (Michigan and West Virginia) indicated that the material they use was chosen due to equipment compatibility alone, while two others (Idaho and North Dakota 2) reported that their choice was based only upon cost-effectiveness. The respondent from Maine reported that the agency uses the material it does solely because it is the most effective anti-icing material. Choosing none of the listed reasons, the respondent from Ontario instead commented that a wide variety of materials is used across the large Canadian province.

Other combinations of reasons for particular material use were evident among choices from ten other respondents (see Table 2.2 below). Three respondents from Indiana, MnDOT-District 7 and Virginia reported that cost and effectiveness of an anti-icing material were most important to them. Those from Connecticut, Maryland and Oregon indicated that their equipment and a material's cost-effectiveness determined their choices. New Hampshire, Pennsylvania, Rhode Island and Wyoming's respondents reported choosing an anti-icing material based upon their equipment and the material's effectiveness. One respondent from Kentucky noted that the agency was "not able to store liquids." Alaska's respondent added that the agency is "considering changing equipment and methods."

Table 2.2 Reasons Selected Anti-icing Material Is Used

KEY
1. Our equipment is set up for this method 2. Most cost-effective method 3. Most effective method
4. Cannot store liquids 5. Considering changing our equipment

State/Other Respondents	1	2	3	4	5
Arizona, Colorado, Delaware, Illinois, Iowa, Kansas, Kentucky 2, Massachusetts, Montana, New Hampshire, New York State, North Dakota 1, Ohio, South Dakota, Texas, Utah, Vermont, Washington State 1, Washington State 2, WVB Partners	X	X	X		
Kentucky 1	X	X	X	X	
Alaska, Minnesota DOT-Statewide	X	X	X		X
Indiana, MnDOT-District 7, Virginia	X	X			
Connecticut, Maryland, Oregon		X	X		
New Hampshire, Pennsylvania, Rhode Island, Wyoming	X		X		

KEY 1. Our equipment is set up for this method 2. Most cost-effective method 3. Most effective method 4. Cannot store liquids 5. Considering changing our equipment					
State/Other Respondents	**1**	**2**	**3**	**4**	**5**
Michigan, West Virginia	**X**				
Idaho, North Dakota 2		**X**			
Maine			**X**		

2.2.2 Most Effective and Most Cost-Effective Materials

The next two questions asked respondents which anti-icing material they considered to be the most effective and which was the most cost-effective. Liquid brine was reported overwhelmingly as the most effective anti-icing material, with 30 (77 percent) respondents choosing it. Five respondents (12 percent) chose "other chloride salt liquids" (Alaska, Kansas, Oregon, Vermont and Washington State 1), two respondents (5 percent) from Idaho and Washington State 2 chose "prewetted salt/solids." Two others (Illinois and New Hampshire) chose "other materials." (Table 2.3 presents selections below.)

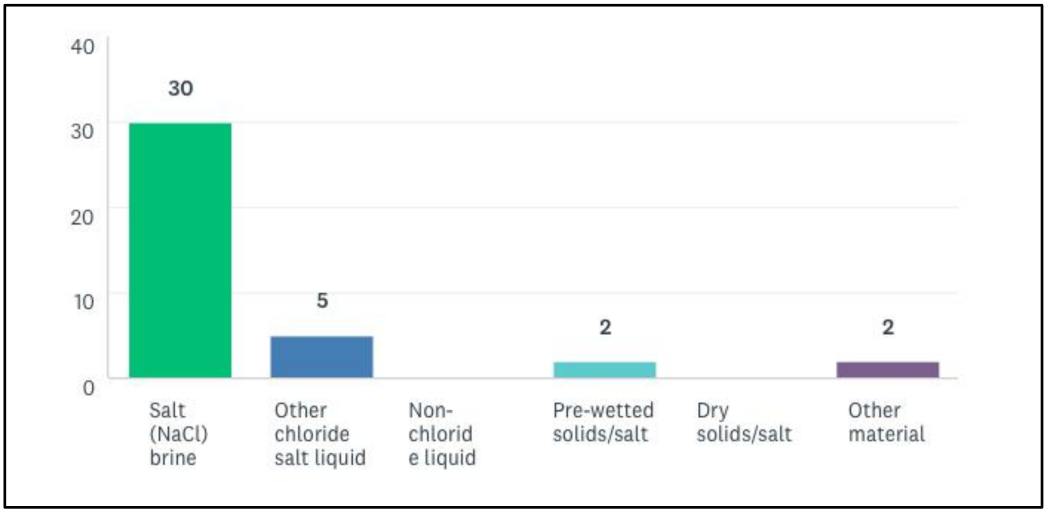
Table 2.3 Most Effective Anti-icing Material

Most Effective Anti-icing Material	State/Other Respondents	Total Respondents
Liquid brine	Arizona, Colorado, Connecticut, Delaware, Indiana, Iowa, Kansas, Kentucky 1, Kentucky 2, Maine, Maryland, Massachusetts, Michigan, Minnesota, Montana, New York State, North Dakota 1, North Dakota 2, Ohio, Ontario (Canada), Pennsylvania, Rhode Island, South Dakota, Texas, Utah, Virginia, West Virginia, Wisconsin, WVB Partners, Wyoming	30
Other chloride salt liquid	Alaska, Kansas, Oregon, Vermont, Washington State 1	5
Prewetted salt/solids	Idaho, Washington State 2	2
Other material	Illinois*, New Hampshire	2

The respondent from Idaho, who indicated "prewetted salt/solids" as most effective also expanded upon the selection with this comment: "We do not standardize on the anti-icing product as each District makes their own determination based on available products at each location. For anti-icing, we use both liquid salt brine and liquid MgCl as well as prewetted granular salt."

As explanation for the choice of "other material," the respondent from Illinois commented that a solution of 60 percent brine, 20 percent calcium chloride liquid and 20 percent beet juice "has shown good results." Six other respondents qualified their choices of liquid brine or other liquids with discussions of anti-icer material decisions being made dependent upon conditions. Solid salt and liquid brine cannot be effectively used as an anti-icer or deicer below 15 degrees Fahrenheit. Consequently respondents in those areas that experience winter temperatures below 15 degrees must use materials other than variations of NaCl to depress the freezing point of winter precipitation. Figure 2.1 presents responses graphically below.

Figure 2.1 Most Effective Anti-icing Material



The question of cost-effectiveness produced a range of different responses. Eighty-seven percent of respondents (34 of 39) considered liquid brine to be the most cost-effective anti-icing material. Respondents from Alaska, Oregon and Washington State 1 (about 8 percent) chose “other chloride salt liquid.” Only the respondent from Washington State 2 selected “prewetted salt/solids” as the most cost effective material (about 3 percent), while New Hampshire’s respondent explained the choice of “other material” as an “80/20 blend of brine and MgCl.”

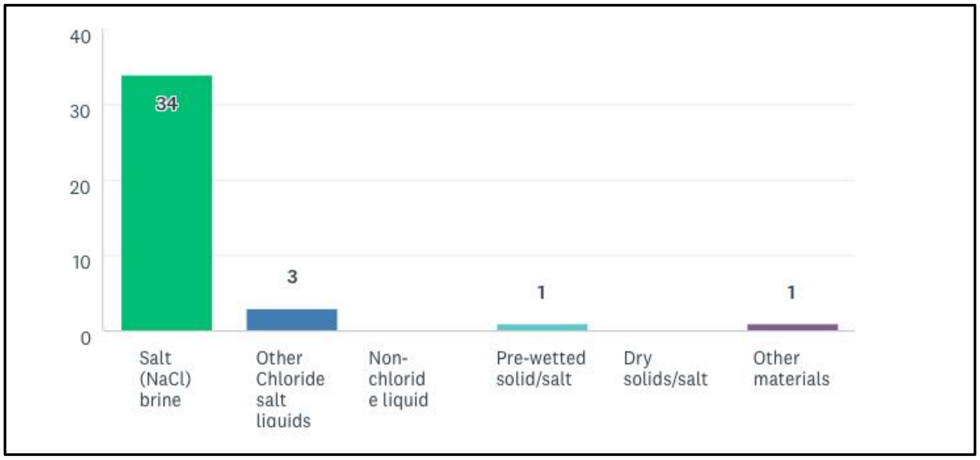
Table 2.4 Most Cost-Effective Anti-icing Material

Most Cost-Effective Anti-icing Material	State/Other Respondents	Total Respondents
Liquid brine	Arizona, Colorado, Connecticut, Delaware, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky 1, Kentucky 2, Maine, Maryland, Massachusetts, Michigan, MnDOT-Statewide, MnDOT-District 7, Montana, New York State, North Dakota 1, North Dakota 2, Ohio, Ontario (Canada), Pennsylvania, Rhode Island, South Dakota, Texas, Utah, Vermont, Virginia, West Virginia, Wisconsin, WVB Partners, Wyoming	34
Other chloride salt liquid	Alaska, Oregon, Washington State 1	3
Prewetted salt/solids	Washington State 2	1
Other material	New Hampshire	1

Idaho’s respondent added that liquid brine was chosen as least expensive, but “depending upon temperature, it may not be used.” Massachusetts’ respondent offered that “salt brine is 20% the cost of

30% liquid [magnesium chloride] (.16 – .17¢ versus .86¢/gal.).” New Hampshire’s respondent again noted that the agency uses an “80/20 blend of liquid brine and MgCl” and chose it as the most cost-effective material.

Figure 2.2 Most Cost-Effective Anti-icing Material



The respondent from Wisconsin offered a comment that seemed to encompass the gist of many others: “If conditions are ideal, salt brine is the most effective and economical for anti-icing, by far. When conditions are not ideal, other additives and products may be necessary to achieve similar goals.”

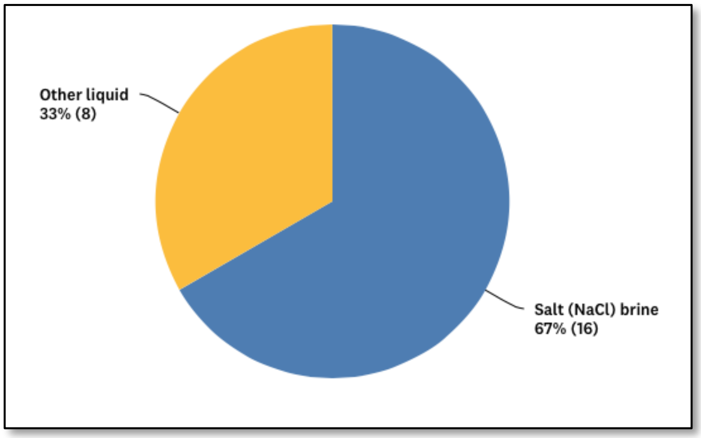
2.2.3 Liquids Used for Prewetting

The next question sought to determine which liquids respondents’ agencies used to prewet solids—among those respondents who may use prewetted salt/solids for anti-icing. Twenty-four respondents (62 percent) answered this question. Fifteen respondents (38 percent) did not answer this question. Sixteen respondents (about 67 percent of those who responded) reported using liquid brine to pre-wet anti-icing solids. Six respondents chose “other liquid,” and two respondents (Arizona and Connecticut) indicated that they use liquid MgCl to prewet anti-icing salt/solids. Nine respondents also commented on their selection.

Table 2.5 Liquid for Prewetting Anti-icing Solids
(24 respondents)

Liquid for Prewetting Anti-icing Solids	State/Other Respondents	Total Respondents
Liquid brine	Delaware, Idaho, Illinois, Indiana, Iowa, Kansas, MNDOT-Statewide, Montana, North Dakota 1, North Dakota 2, Pennsylvania, Rhode Island, South Dakota, Washington State 1, West Virginia, Wyoming	16
Other liquid	New York State, Ontario (Canada), Oregon, Utah, Vermont, Washington State 2	6
Other material	Arizona (MgCl), Connecticut (MgCl)	2

Figure 2.3 Liquid for Prewetting Anti-icing Solids



The respondents who indicate they use "other liquids" listed magnesium chloride and calcium chloride liquids in their comments. Many use a blend of salt brine and MgCl or CaCl liquid, depending upon the temperature and the needs of districts across each state. A few agencies use salt brine until the temperature drops to 20 degrees—a point below which NaCl becomes ineffective as a freeze point depressant, and then use a blend (adding MgCl or CaCl liquid) or use straight MgCl liquid.

2.2.4 Ratio of Liquid to Solid

Twenty-two participants responded to the question asking the ratio of liquid to solid organizations used for anti-icing with a prewetted solid. Eleven (50 percent) indicated that they used nine to twelve gallons per ton of solid material. Four respondents (Maine, New York State, North Dakota 1 and Wyoming) reported using five to eight gallons, while three others (Idaho, Utah and Washington State 2) indicated that they use more liquid: 13–16 gallons per ton of solid material. Idaho's respondent added that this amount refers to the use of salt brine; if MgCl liquid is used instead, the volume is nine to twelve gallons per ton of solid. Three more respondents (Arizona, Montana and Oregon) offered other ratios.

Arizona's respondent specified 8–15 gallons (MgCl liquid) per ton of solid. Oregon's respondent reported the agency uses 10–20 gallons (MgCl liquid) per ton of solid. Montana's respondent commented that five to eight gallons of MgCl liquid or nine to twelve gallons of salt brine is used to prewet a 10% salt/sand mixture used on pavement just before roads are affected by incoming storms, adding, "We seldom use straight salt, but it is prewet the same way." Montana's also respondent mentioned this 10% salt/sand mixture as "our primary tool" in several comments throughout the survey.

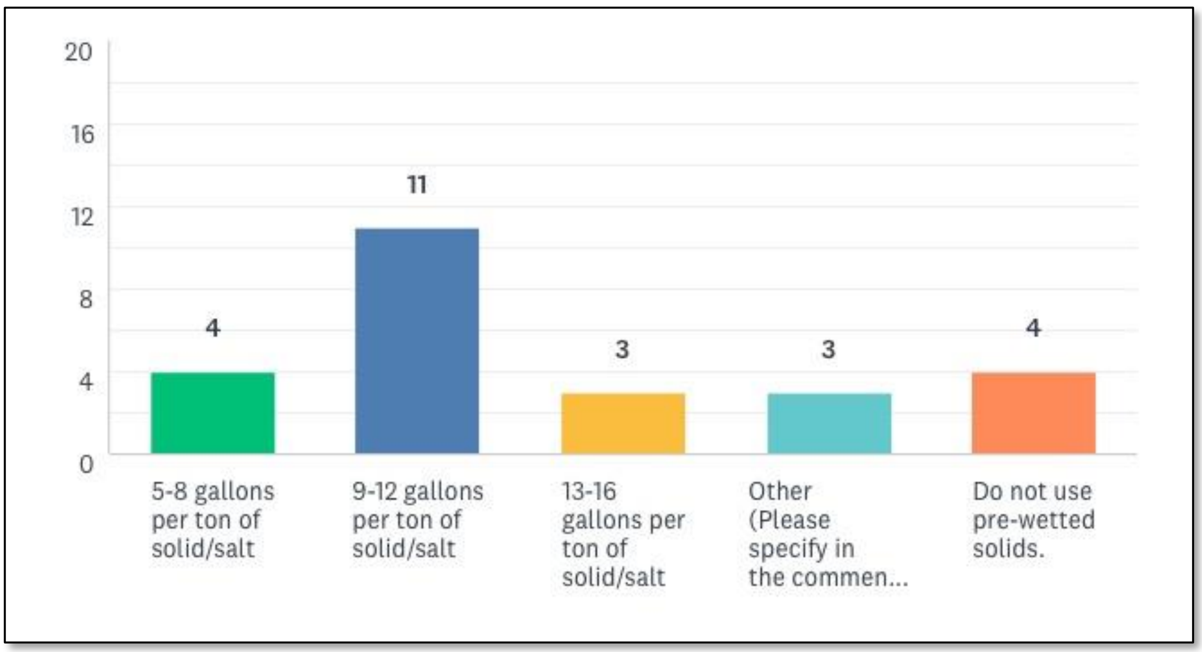
Five respondents indicated that they do not use prewetted solids for anti-icing, joining twelve others who skipped the question altogether.

Table 2.6 Ratio of Liquid/Solid: Prewetting for Anti-icing

Liquid/Solid Ratio	State/Other Respondents	Total Respondents
5–8 gal/ton	Maine, New York State, North Dakota 1, Wyoming	4
9–12 gal/ton	Connecticut, Delaware, Illinois, Indiana, Iowa, MnDOT-Statewide, Pennsylvania, Rhode Island, South Dakota, Washington State 1, West Virginia	11
13–16 gal/ton	Idaho, Utah, Washington State 2	3
Other ratio	Arizona, Montana, Oregon	3

Figure 2.4 below illustrates the liquid/solid ratios graphically with numbers of respondents indicated.

Figure 2.4 Ratio of Liquid/Solid: Prewetting for Anti-icing



2.2.5 Speed and Application Rates

The next survey questions addressed the speed at which prewetted solids are applied, the rate of application of material in pounds per lane mile, as well as the rate of application of dry solids, if that material is used for anti-icing. Twenty survey participants responded to the prewetted solids speed and rate question. As shown in the chart below, the majority of respondents (11 of 20) reported applying prewetted solids at a speed of 30–35 miles per hour. Two ran at a higher speed, while seven respondents indicated they applied prewetted solids at speed ranges below 30 miles per hour. One reported speed of 20 mph or slower. Table 2.7 shows the application speed of each respondent state.

Figure 2.5 Overview Prewetted Solids Anti-icing Speed: MPH

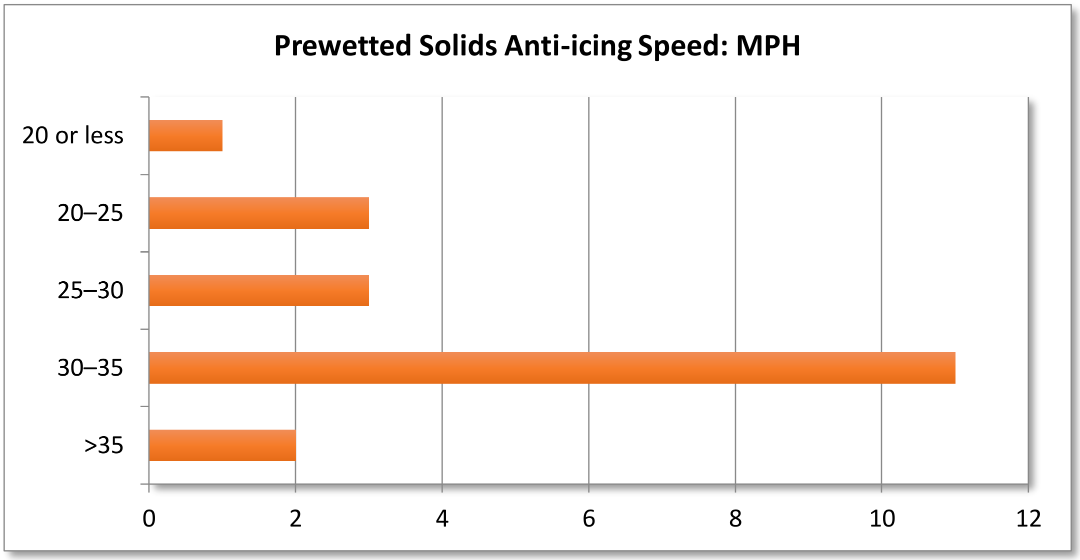


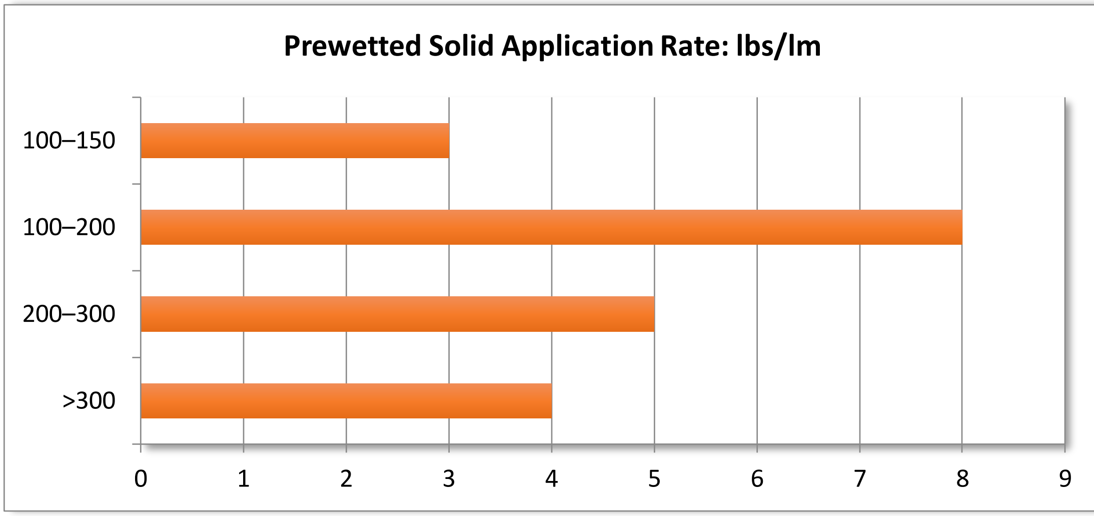
Table 2.7 Prewetted Solids Anti-icing Speed Respondent Details: MPH

Speed MPH	State/Other Respondents	Total Respondents
20 mph or less	MnDOT-Statewide (20 mph or less)	1
20–25 mph	Connecticut (20–30), Kansas (25), Washington State 2 (20–25)	3
25–30 mph	Idaho (25–35), Ontario, Canada (27), Oregon (30 or less)	3
30–35 mph	Delaware (35), Illinois (30–35), Indiana (35), Iowa (25–35), Montana (30–35), South Dakota (32), Utah (35 freeway/25 non-highway), Washington State 1 (<35), West Virginia (35)	11
>35 mph	Arizona (35–45), Pennsylvania (25–45)	2

Application rates for prewetted solid were provided by twenty respondents. The range of pounds of prewetted solid material per lane mile applied was very wide, from 100 to 500 pounds. The chart below shows the general range of application among states, with eight respondents (40 percent) applying 100–200 pounds per lane mile, while three (15 percent) apply less and nine (45 percent) apply more.

Several respondents commented that application rates depend upon air/pavement temperature, precipitation type and other factors. It is instructive to note that the wide ranges of amount of material applied and the range of speeds arise from the wide range of winter conditions that winter road maintenance workers face in keeping roadways passable and safe.

Figure 2.6 Prewetted Solid Application Rate: lbs/lm
(20 Respondents)



The table below shows application rates for individual respondents.

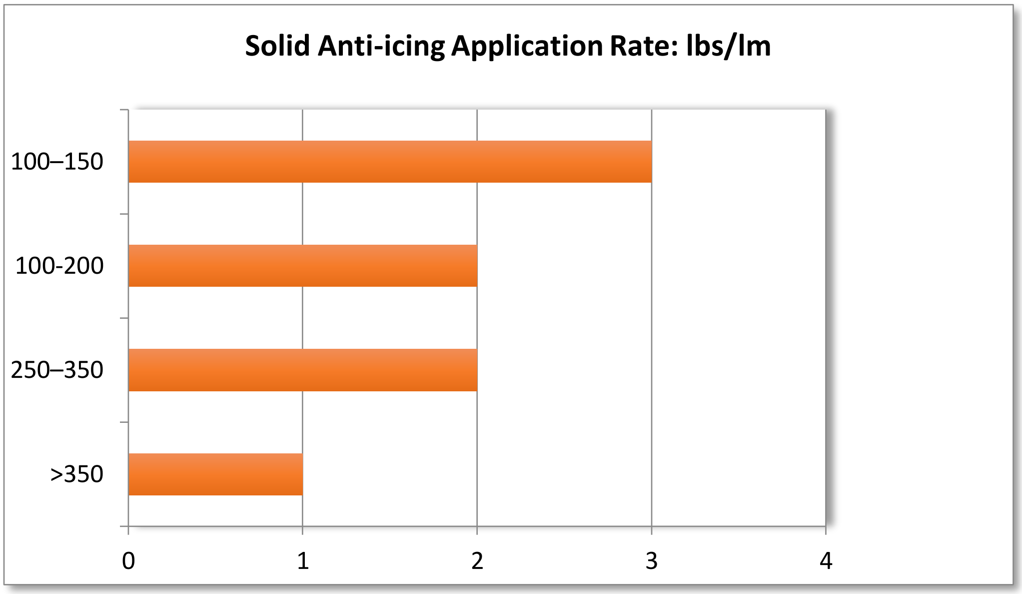
Table 2.8 Prewetted Solid Application Rate Respondent Details: lbs/lm
(20 Respondents)

Application Rate: lbs/lm	State/Other Respondents	Total Respondents
100–150 lbs/lm	Illinois (100–150), Iowa (100–150), Washington State 2 (100–150)	3
100–200 lbs/lm	Connecticut (200), Idaho (100+), Kansas (200), Montana (150–200 salt), New York State (200), Oregon (100–200), Pennsylvania (200), Washington State 1 (200)	8
200–300 lbs/lm	Arizona (100–300), Delaware (300), Indiana (250), Ontario, Canada (220-286), Utah (300 average)	5
>300 lbs/lm	MnDOT-Statewide (100–500), South Dakota (50–500), West Virginia (250–500), Wyoming (450)	4

The next question asked about the application rate of *dry* solid materials to pavement for anti-icing. Eight agencies provided answers to this question. The chart below shows the broad range of use. Three of the eight respondents (Idaho, Illinois and Washington State 2) indicated that they applied between 100 and 150 pounds per lane mile. Two respondents (Oregon and Pennsylvania) reported using up to 200 pounds per lane mile. Two respondents (Indiana and West Virginia) indicated the use of 250 to 350 pounds per lane mile. One respondent (Ontario, Canada) reported applying a range in which the top limit exceeded 350 pounds of dry solids per lane mile for anti-icing.

There are many tools that winter road maintenance agencies use for anti-icing. These eight respondents' agencies include solid materials as one tool that can be used for anti-icing pavement should conditions warrant it.

Figure 2.7 Solid Anti-icing Application Rate: lbs/lm
(Eight Respondents)

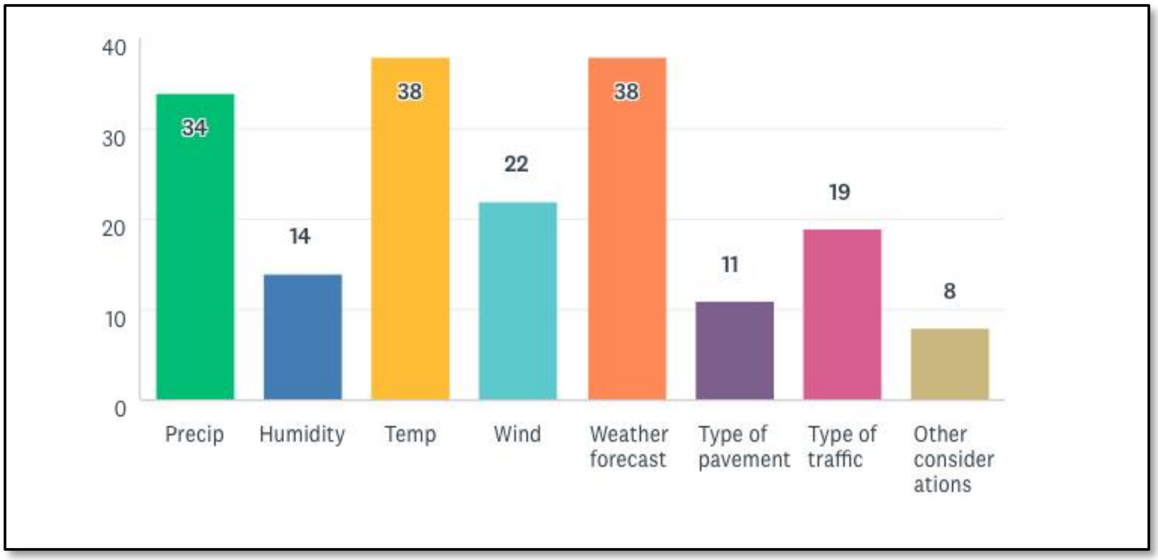


2.2.6 Factors Considered in Decision to Anti-ice

Question 11 of the survey addressed the many factors that winter road maintenance professionals must consider in deciding whether and when to apply anti-icing materials to a roadway. All 39 respondents participated in this survey question and many offered additional comments. Participants were offered a range of factors from which to select, with the option of choosing as many as they considered applicable. The chart below graphically shows respondents choices.

Thirty-eight of 39 respondents (97 percent) reported that temperature and the weather forecast were both equally important factors to consider in determining whether to anti-ice. The kind of incoming precipitation (rain, ice or snow) was a close second concern, with 34 respondents (87 percent) choosing it. Wind was an important consideration for 22 respondents (56 percent); 19 indicated that the type of traffic on the roadways was also a factor to take into account (about 49 percent). The level of humidity and the type of pavement were factors included by 14 and 11 respondents, respectively (36 percent and 28 percent). Indiana's respondent elaborated by noting that "pavement temperature" was a factor.

Figure 2.8 Factors Considered in Determining to Anti-ice
(38 Respondents)



The "Other" category was chosen by eight respondents, with seven offering comments. Arizona's respondent noted that the condition of bridge decks was a factor. Idaho's respondent commented that "surface state is a major factor in determining the final application rate." Montana's respondent added that "time of day" and "cycle times" were factors in determining what actions to take. New York's respondent reported that the "amount of residual salt remaining on the road from previous applications" was another piece of information that determines anti-icing actions. Ohio's respondent comment examined the incoming storm: "What type of precipitation is the storm going to start with? [If rain], we will not apply liquid anti-icers prior to the storm." A respondent from Washington State mentioned "dew point" as a concern. Pennsylvania's respondent revealed that the agency has a decision tree tool it uses to assist in determining when/whether to anti-ice (this document is available in Appendix B).

Seven factors that responding agencies consider in determining when/whether to anti-ice were prioritized through their responses to this survey question. Temperature and Weather Forecast were equally weighted.

- Temperature and Weather Forecast
- Precipitation
- Wind
- Type of Traffic
- Humidity
- Type of Pavement
- Other Conditions

These factors, which were selections offered by the survey question, are shown with respondents' choices in Table 2.9 below.

Table 2.9 Factors Considered in Determining When to Anti-ice
(38 Respondents)

Factors Considered	State/Other Respondents	Total Respondents
Temperature	Alaska, Arizona, Colorado, Connecticut, Delaware, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky 1, Kentucky 2, Maine, Maryland, Massachusetts, Michigan, MnDOT-Statewide, Montana, New Hampshire, New York State, North Dakota 1, North Dakota 2, Ohio, Ontario (Canada), Oregon, Pennsylvania, Rhode Island, South Dakota, Texas, Utah, Vermont, Virginia, Washington State 1, Washington State 2, West Virginia, Wisconsin, WVB Partners, Wyoming	38
Weather Forecast	Alaska, Arizona, Colorado, Connecticut, Delaware, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky 1, Kentucky 2, Maine, Maryland, Massachusetts, Michigan, MnDOT-Statewide, MnDOT-District 7, Montana, New Hampshire, New York State, North Dakota 1, North Dakota 2, Ohio, Ontario (Canada), Oregon, Pennsylvania, Rhode Island, South Dakota, Texas, Utah, Vermont, Virginia, Washington State 1, Washington State 2, West Virginia, Wisconsin, WVB Partners	38
Precipitation	Alaska, Arizona, Colorado, Delaware, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky 1, Kentucky 2, Maine, Maryland, Massachusetts, MnDOT-Statewide, Montana, New York State, North Dakota 1, North Dakota 2, Ohio, Ontario (Canada), Oregon, Pennsylvania, Rhode Island, South Dakota, Texas, Utah, Vermont, Virginia, Washington State 1, Washington State 2, West Virginia, Wisconsin, WVB Partners	34
Wind	Alaska, Arizona, Colorado, Illinois, Indiana, Iowa, Kansas, Maine, Massachusetts, MnDOT-Statewide, Montana, North Dakota 1, Ohio, Ontario (Canada), Oregon, South Dakota, Utah, Virginia, West Virginia, Wisconsin, WVB Partners, Wyoming	22
Type of Traffic	Alaska, Arizona, Colorado, Idaho, Indiana, Iowa, Maine, Massachusetts, MnDOT-Statewide, Montana, North Dakota 2, Oregon, Pennsylvania, South Dakota, Texas, Utah, Vermont, Virginia, Washington State 1	19
Humidity	Alaska, Arizona, Idaho, Illinois, Maine, Massachusetts, MnDOT-Statewide, Montana, New York State, Oregon, Utah, Virginia, Wisconsin, WVB Partners	14
Type of Pavement	Indiana, Iowa, Massachusetts, MnDOT-Statewide, Montana, North Dakota 1, Oregon, Rhode Island, South Dakota, Texas, Utah	11
Other	Arizona, Idaho, Montana, New York State, Ohio, Pennsylvania, Virginia, Washington State 2	8

2.2.7 Conditions that Preclude Anti-icing

Survey question 12 asked participants which conditions would cause them to decide not to anti-ice roadways. It was a free response question that allowed the widest range of responses, yet there was a strong agreement among respondents about some conditions. The majority of the 37 (about 95 percent) respondents who participated included one or two weather scenarios that would cause them to decide not to apply anti-icers to roadways:

- Extremely cold pavement/air temperatures
- Storms that begin as moderate to heavy rain

Eight respondents mentioned two other weather conditions that could affect their anti-icing decisions;

- Temperatures above 38–40 degrees and/or high humidity
- Strong winds

Three respondents noted that residual salt on the pavement would be a factor in their decision to anti-ice.

Table 2.10 Conditions Precluding Anti-icing
(37 Respondents)

Condition	State/Other Respondents	Total Respondents
Extremely Cold Pavement/Air Temp	Alaska, Connecticut, Delaware, Kansas, Kentucky 1, Kentucky 2, Maryland, Michigan, MnDOT-Statewide, New Hampshire, New York State, North Dakota 1, Ohio, Ontario (Canada), Oregon, Pennsylvania, Rhode Island, South Dakota, Utah, Washington State 2, West Virginia, Wisconsin, WVB Partners	23
Storms Beginning as Moderate to Heavy Rain	Arizona, Colorado, Delaware, Idaho, Illinois, Kansas, Kentucky 1, Kentucky 2, Maryland, Massachusetts, MnDOT-District 7, New York State, Ohio, Oregon, Pennsylvania, Rhode Island, South Dakota, Utah, West Virginia, Wisconsin	20
Temperatures <38–40 Degrees F/ High Humidity	Arizona, Michigan, New York State, Oregon, Utah, Washington State 1, Wisconsin, WVB Partners (humidity)	8
Strong Winds	Colorado, Kansas, MnDOT-Statewide, North Dakota 1, Ontario (Canada), South Dakota, Wisconsin, Wyoming	8
Residual Salt	Indiana, New York State, Pennsylvania, Wisconsin	4

Twenty-three respondents indicated that they would not anti-ice if pavement and/or air temperature were extremely cold. Twenty respondents reported that anti-icing materials would not be applied if a storm begins as moderate to heavy rain. Eight respondents mentioned rising temperatures and/or high humidity as a condition that would preclude anti-icing, while eight mentioned high winds as a condition in would pre-empt anti-icing operations. Residual salt on the pavement was mentioned by three respondents as a condition in which they would not anti-ice.

Many respondents added more specific details describing the conditions in which they would refrain from anti-icing or about their general anti-icing protocols.

One of North Dakota's respondents noted they anti-ice before *most storm events* unless it is too cold. Conversely, Vermont's respondent noted that anti-icing is *not done* in "most situations, as there have been [many] complaints regarding anti-icing," and the agency does it "only in special situations." Montana's respondent noted that the agency does not anti-ice, *per se*, but tries to get materials to the road surface before it is covered. He noted "our strategy changes when the surface becomes snow-packed or [icy]."

Arizona's respondent noted "drift areas" as a condition that would cause the agency to avoid anti-icing, as well as temperatures "above 40 degrees F and 40% humidity." Ontario's respondent mentioned, "dry snow with high winds that blow off the road" and "very light snow" as weather conditions that would affect anti-icing operations. Rhode Island's respondents reported that "if the pavement is open grade friction course," they would not anti-ice. This respondent also stated, "We have found that liquids are not effective for anti-icing."

Low traffic counts" was a condition mentioned by South Dakota's respondent as one factor that would result in no anti-icing for a roadway. The Texas respondent indicated that no anti-icing would occur with a "favorable weather forecast." One of Washington State's respondents expressed a list of concerns, reporting that anti-icing would not occur with an "uncertain forecast, temperatures rising, where chemical slipperiness is a concern, where cost outweighs benefit."

Wisconsin's respondent provided a detailed list of conditions that would preclude anti-icing:

1. If rain is predicted before the snow or frost.
2. If there is enough salt residue from the previous storm.
3. If it is too cold (below 15 degrees).
4. If the dew point is 3 degrees below air [temperature] or less.
5. If the relative humidity is over 70%.
6. If the pavement is wet.
7. If the wind is more than 15 [mph] and there is loose snow that could blow on pavement.
8. If there is not enough time for the brine to dry before the pavement [temperature] falls below 15 degrees.

The respondent representing WVB Partners added, "sub-freezing temperatures and if below 32 degrees and within 2 degrees of dew point." Wyoming's respondent specified "strong winds over 30 mph" as a condition in which the agency would not anti-ice roadways. Participants from Iowa and Virginia did not respond to this question.

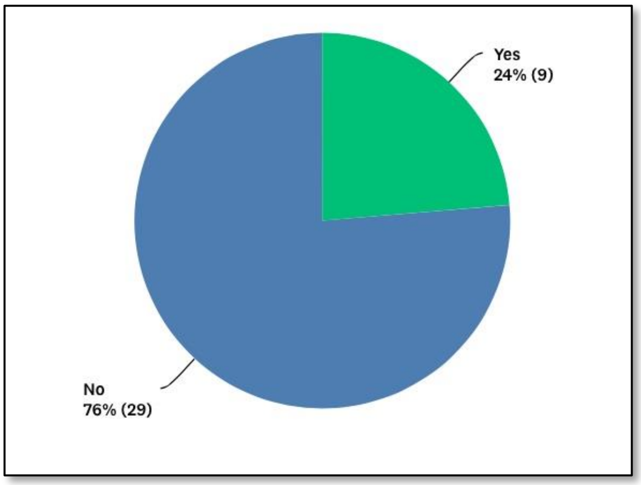
2.3 Environmental Concerns

The final four survey questions addressed environmental concerns about anti-icing, including changes agencies may have made in response to existing or potential future federal and state regulations, as well as procedures in place to control and measure roadway chemical usage throughout the winter maintenance season.

2.3.1 Changes Due to Regulation

The first question asked if agencies had made anti-icing procedural changes in response to federal or state regulations. The majority of respondents—29, about 76 percent—indicated that their agencies had *not* made any changes in their anti-icing procedures. Figure 2.9 graphically presents the breakdown.

Figure 2.9 Changes in Anti-Icing Procedures Due to Federal or State Regulations?



Nine respondents (24 percent) reported their agencies had made changes and briefly described them. One participant did not answer this question (Washington State 2).

Indiana reported that "some locations had modified plans." The respondent from Massachusetts noted that the state hires private contractors and demands that they present proof of annual calibration of liquid tankers and salt spreaders: "We need to be able to document the amount of salt, salt brine or liquid [magnesium chloride] we put down in any storm and/or season, particularly where there exist concerns about watershed impacts from anti-icing materials." The MnDOT-Statewide respondent reported that they are using less granular material and more liquids.

Montana's respondent described an agency that is very attentive to environmental concerns: "MDT [Montana Department of Transportation] has always had very high environmental concerns. We use very little salt comparatively. Chloride use is a hot topic for our legislature, and we have to justify our actions regularly. It has definitely become a point of emphasis in recent years." Similarly, the respondent from Ontario, Canada reported that the "MTO [Ministry of Transportation] has a Salt Management Plan and continues to research ways to undertake winter operations more effectively and [in ways that are] environmentally friendly."

The respondent from Pennsylvania noted that anti-icing is promoted "to reduce solid application rates." Rhode Island's respondent reported that the policies concerning salt usage in the state change with government administrations, and that they are "once again in an upward cycle due to the desire for black [and] wet roads faster and [longer] during [a weather] event."

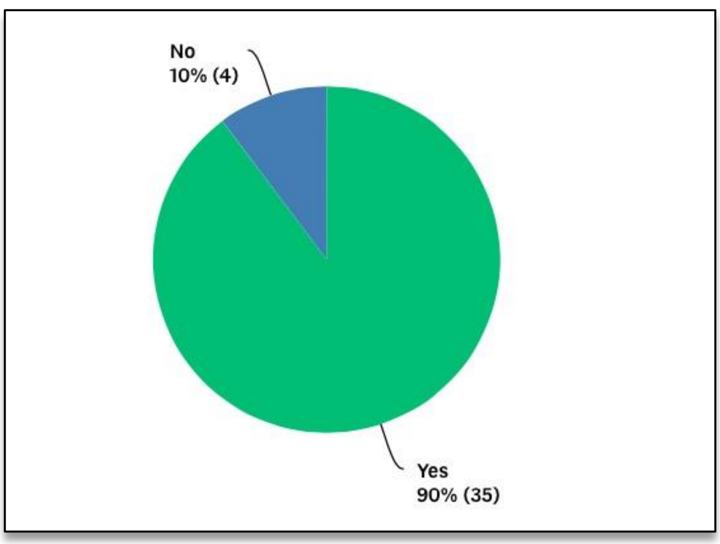
The South Dakota respondent reported that they use an MDSS—a Maintenance Decision Support System. This is a decision support tool that integrates road weather forecasts, maintenance best practices and other data to provide winter road maintenance professionals with recommendations for effective strategies. The respondent reported that MDSS "has allowed us to save on hours as well as materials."

The respondent from Utah noted, "we are moving towards using high performance magnesium chloride to replace regular magnesium chloride due to environmental and corrosion concerns."

2.3.2 Limiting Bounce and Scatter

The next question asked whether agencies used methods or techniques to reduce the bounce and scatter of anti-icing materials on roadways. Despite the preponderance of "No" answers to the previous question, respondents overwhelmingly reported that their agencies *do* try to limit bounce and scatter of anti-icing materials. Of the 39 participants who responded, 35 (90 percent) reported that they used techniques intended to limit bounce and scatter of anti-icing materials on roadways. Four respondents (10 percent) reported that they did not have methods to control it (Indiana, Kansas, Maryland and Wyoming).

Figure 2.10 Methods to Limit Bounce and Scatter of Anti-icing Materials: Y/N?



This question also asked respondents to describe methods used to reduce bounce and scatter of materials. The comments indicated that many participants responded to discuss their techniques for reducing bounce and scatter of solid materials for *any* purpose—anti-icing and deicing—not only for anti-icing. There was strong agreement among those who described their procedures. The following strategies were considered effective in limiting bounce and scatter for *any operation* using solid materials:

- Prewetting solids
- Reducing vehicle speeds
- Reducing spinner speeds (low or off) or using chutes to apply solids closer to the road

The table below details respondents' descriptions of agency methods to limit material bounce and scatter.

Table 2.11 Methods to Reduce Material Bounce and Scatter

Method	State/Other Respondents	Total Respondents
Prewetting Solids	Alaska, Arizona, Colorado, Connecticut, Delaware, Idaho, Illinois, Iowa, Kansas, Kentucky 1, Kentucky 2, Maine, Massachusetts, Michigan, MnDOT-Statewide, Montana, New Hampshire, New York State, North Dakota 1, North Dakota 2, Ohio, Ontario (Canada), Oregon, Pennsylvania, Rhode Island, Texas, Utah, Vermont, Washington State 1, Washington State 2, West Virginia, Wisconsin, WVB Partners	33
Reducing Vehicle Speeds	Alaska, Arizona, Delaware, Illinois, Maine, Michigan, MnDOT-Statewide, Montana, New York State, Ohio, Oregon, South Dakota, Texas, Utah, Washington State 1, West Virginia	16
Reducing Spinner Speeds + Spread	Alaska, Arizona, Delaware, Montana, Ohio, Oregon, Washington State 2, Washington State 2	8
Chutes/Application Close to Pavement	Michigan, MnDOT-Statewide, Wisconsin	3

Arizona's respondent added, "we also use AVL and limit the speed of the plow truck. We can reduce the speed of the spinner as well, which is related to the speed of the plow truck." Colorado's respondent noted that they use pre-wetting of solids to "help reduce scatter and bounce, but it isn't used for anti-icing." In Idaho, the respondent reported that "we restrict operators to applying to a single lane only for granular products and require/encourage the use of pre-wetting material to try and keep the granular product on the roadway surface." Illinois reports "reduced application speed to 30-35mph."

Indiana reported that the agency is "working to improve SOPs [standard operating procedures]." Both respondents from Kentucky indicated that liquid calcium chloride is applied to rock salt "at the spinner."

Maine's respondent reported, "for during storm application, reduced speeds and pre-wetting." Massachusetts' respondent wrote, "We mandate pre-wetting of 8-10 gallons of liquid mag or brine per ton of rock salt." The respondent from Michigan relayed that the state "did a salt bounce and scatter study and changed a lot. They are [to] reduce speed to twenty five while applying material, pre wetting the material and putting the material out close to the road."

In New York State, the respondent reported that “application speed [is} not to exceed 35 mph,” and ground speed control application units are used. North Dakota’s respondent reported, “we use slurry spreaders and pre-wet systems to reduce bounce and scatter.” Oregon’s respondent noted that beyond pre-wetting and reducing application speeds, they are also “lowering spinner heights, adding spinner shields, apply with spinner setting at low/off. “

In Texas, the respondent reported “pre-wetting and combination with sand and aggregate materials. Also, lower speeds when applying to bridge structures." Utah’s respondent indicated that “pre-wetting the salt with water, sodium chloride brine, magnesium chloride brine, or calcium chloride brine helps reduce scatter as does keeping the speeds down to 35mph for freeways and 25mph for surface streets (non-freeways).” Vermont pre-wets “granular salt with salt brine, blend or MgCl additive.” Virginia’s respondent noted that “for normal spread—*not anti-icing*—we use prewetting at [the] spinner with CaCl.”

The Washington State 1 respondent was somewhat circumspect in how effectively the agency limits material bounce and scatter: "In theory, yes, [we control bounce and scatter] through the use of pre-wet and speed reduction, although we suspect 12 [gallons per ton] is too low to be entirely effective, and we know through the use of AVL that we have applications that are being applied at much too high [speeds]." The Washington State 2 respondent also noted the use of "side spinners in conjunction with travel speed" and mentioned that spinner patterns are adjusted.

The West Virginia respondent noted that in addition to limiting speed and pre-wetting materials, "[calibrating the] spreader. [Adjusting] gate and flap settings" would help reduce bounce and scatter of materials. Wisconsin's respondent noted, "some of our counties use a low chute rather than a spinner to prevent bounce." The respondent from WVB Partners noted particularly that "in *de-icing mode*, we prewet all solid salt."

2.3.3 Record-Keeping and Application Control

The final two questions continued the inquiry into how agencies address environmental concerns through control of the amount of anti-icing material dispensed and how they keep accurate records of materials applied.

Record-Keeping

The question, “What methods does your agency use to keep accurate records of amounts of anti-icing materials applied to roadways” yielded the responses from 38 respondents (Alaska's respondents chose not to complete this question). Thirteen agencies mentioned their use ground control application equipment; nine also mentioned global positioning systems with automatic vehicle locating (GPS/AVL). This system is capable of recording and transmitting a wide range of information about vehicles’ activities in the field, such as location, speed, application of materials (weight) and other information, depending upon the types of sensors used on board.

Five agencies reported use of programs that assist in materials management (maintenance management systems). Montana's respondent described their system: "We have a Maintenance Management System that we use to record all our material use. Each driver reports their use daily. They typically get the amounts for a calibrated operating system on the truck." MnDOT's two respondents both noted the use of Maintenance Decision Support Systems (MDSS), which assist in determining the best strategies for road treatment taking into account conditions, materials, equipment, road qualities and more. The North Dakota1 respondent recounted, "our districts input usage into our Maintenance Equipment Tracking System (METS)."

Nine agencies reported they record operator logs of materials used, while methods employed by eight other agencies include in-house systems and programs to keep track of material usage.

Respondents from Illinois and Virginia reported that they do not record exactly where anti-icing materials are applied. Alaska did not provide an answer.

Table 2.12 below shows individual responses. Note that as the table illustrates, some agencies reported using more than one record-keeping method.

Table 2.12 Record-Keeping Methods for Anti-icing Materials Applied to Roadways

Record-keeping Method	State/Other Respondents	Total Respondents
Spreader Controllers	Delaware, Iowa, Kentucky 1, Maine, Maryland, Massachusetts, New York State (all vehicles), North Dakota, Ontario (Canada), Rhode Island, Washington State 2, West Virginia, WVB Partners	13
GPS/AVL	Arizona, Idaho, Michigan, MnDOT-District 7, New York State (on some vehicles), Ontario (Canada), Pennsylvania (on board tracking system), Utah, Washington State 1	9
MDSS or Similar	Idaho, MnDOT-Statewide, MnDOT-District 7, North Dakota 1 (Maintenance Equipment Tracking System METS), South Dakota	5
Operator Logs	Arizona (TAPER logs), Connecticut, Kansas, New Hampshire, North Dakota 2 (load count), Ontario (Canada), Oregon, Wisconsin (weekly county reports), Wyoming	9
Other	• Colorado (SAP and work orders) • Indiana (WMS: Warehouse Management System) • Kentucky 2 (in-house program) • Montana (Maintenance Management System) • Ohio (load/bucket counts; visual inspection) • South Dakota (in-house performance measure) • Texas (Maintenance Management System/Agile Assets) • Vermont (activity tracking program—hope to transition to AVL)	8
Do not record road application	Illinois (limited tracking of liquids), Virginia	2

Applicator Controllers

The final question in this section asked if winter maintenance organizations used applicator control to dispense anti-icing materials. Thirty-eight of 39 respondents reported that they did use applicator control for anti-icing. Thirty-six offered information about their equipment (respondents from Alaska and Connecticut did not). The respondent from Illinois reported the agency did not use applicator control for anti-icing.

The table below details participant's' responses about their agency's applicator controller(s) used to regulate anti-icing materials.

Table 2.13 Applicator Controllers Used to Regulate Anti-Icing Materials

Applicator Controllers	State/Other Respondents
Cirus	Colorado, Delaware, Idaho, Indiana, Iowa, Kansas, Kentucky 1, Maine, Massachusetts, Montana, Oregon, Vermont
Dickey-John	Arizona, Kentucky 1, Kentucky 2, Michigan, New York State, Vermont, West Virginia
Force America	Arizona, Indiana, Kansas, Kentucky 1, North Dakota 1 (6100), North Dakota 2, Ohio, Oregon, South Dakota (5100/6100), Utah, Washington State 1, Washington State 2 (5100/6100), WVB Partners (5100), Wyoming
Other Controllers	• Arizona (Vartech for liquids) • Indiana (Muncie) • MnDOT-District 7 (Control Point) • New Hampshire (Rex Roth CS 440 & 550) • New York State (Control Point, Flex 4, ICS2000) • Ohio (Muncie, Penqwyn, Certified Power) • Oregon (Parker IQAN MC2/MD3, Raven) • Pennsylvania (GL 400) • Rhode Island (Rex Roth) • Vermont (Certified Power) • West Virginia (GL 400, Freedom XDS)
Other Equipment	Arizona (lift gate settings), MnDOT-Statewide (flow meters and pumps), Virginia (various: ground speed, radar & GPS)

Responses to this question revealed that while many agencies use controllers from one manufacturer, such as Force America or Cirus, many use controllers from two or three different companies (for example, New York State, Ohio and Oregon). Respondents from Maryland and Massachusetts described their agencies' use of contractors, and, thus, the presence of a wide range of manufacturers' equipment maintaining winter roadways. Maryland's respondent explained: "[There is] no specific controller used on [in our] all-contract fleet. [Our] contract specifies a ground speed controlled system to regulate the gallons per lane mile to the traveling speed."

"[We have] mostly Cirus in MassDOT vehicles, although not exclusively," noted the Massachusetts respondent. He explained further, "With our own equipment we maintain a very limited portion of our owned roadways, depending upon hired equipment very heavily. It seems that 65% of our hired spreaders utilize Certified Power closed-loop controllers. We are considering requiring a single brand (such as Cirus) because it is the easiest controller for us to couple [to a modem in order to] receive salt distribution rate and location information (among other parameters) from our own and hired equipment.

Ontario, Canada's respondent reported, "all spreaders have electronic controllers." South Dakota's respondent added to the information about the agency's Force America 5100/6100 controller usage that for anti-icing the controller is "set to Direct Application."

Both Vermont's and West Virginia's respondents thought there might still be Dickey-John controllers in their agencies' fleets. Wisconsin's respondent did not know which applicator controllers are used in the state. (Wisconsin's winter road maintenance is orchestrated at the county level, rather than directly through a centralized agency office.)

2.4 Wrap-up

The survey concluded with two additional opportunities for respondents to include links to documents and further information about other resources, as well as closing comments about agency anti-icing procedures.

2.4.1 Links and Documents

Respondents from Connecticut, New York State, Ohio, Vermont and Wisconsin provided links to documents relevant to their anti-icing operations and general winter road maintenance. These are listed with descriptions in **2.5 Related Resources** directly following this section. Documents not available online were also provided by respondents from Pennsylvania and Wisconsin. These are presented in Appendices B and C.

2.4.2 Closing Comments

Five respondents offered final comments (edited for clarity):

> **Colorado**: **"**We have yearly driver refreshers. Equipment is recalibrated yearly or when the driver feels it needs to be checked. We [also] have 24-hour OJT [on-the-job training] drive time [and] simulations everyone must run through once a year."
>
> **Kansas**: We only use prewetted salt for anti-icing when the conditions warrant it. We mostly just pretreat with brine.
>
> **Montana**: "MDT does NOT typically pre-treat roads. We have a "just in time" policy that says we won't treat the road until the event has begun. Anti-icing to us is when we are able to get material to the road surface."
>
> **Ohio**: I would have liked to see how many people were using slurry units to anti-ice their roads. We have some Epokes and a Schmidt spreader, but none of them are true slurry generators.
>
> **Vermont**: We strive to ensure material is placed prior to pack/ice forming on the road with either a salt residual, anti-icing in some areas or ensuring we are out immediately when snow starts.

2.5 Related Resources

Six respondents referenced publications or offered links to anti-icing and related winter road maintenance documents they use in their operations.

Respondents from **Idaho** and **Maine** referred in their survey responses to anti-icing information that can be found in the manual below:

Manual of Best Management Practices for Road Salt in Winter Maintenance. Wilfrid Nixon and R. Mark DeVries, Clear Roads, November 2015, http://clearroads.org/wp-content/uploads/dlm_uploads/0537_2015-Clear-Roads-Best-Practice-Guide-WEB.pdf.

> A product of a previous comprehensive research study on road salt management and information needs in the field, this manual is an accessible road salt management handbook for snowplow operators and supervisors. It covers procurement, storage, application and emergency management. The chart covering vehicle speeds and salt application rates appears on page 26. Page 46 is an Anti-icing Decision Tree.

Idaho's respondent also referenced pages 16–20 of the **Clear Roads Study Establishing Effective Salt and Anti-icing Application Rates** from February 2015 listed on page 36 in the Literature Search.

Connecticut's respondent offered the following report that addresses winter road treatments in Connecticut and their corrosive effects:

Winter Highway Maintenance Operations: Connecticut, James Mahoney, Eric Jackson, Donald Larsen, Timothy Vadas, Kay Wille, Scott Zinke, Connecticut Transportation Institute and UConn, July 2015, http://ctcase.org/reports/WinterHighway2015/winter-highway-2015.pdf

> *From the abstract*: [This study is] an analysis of corrosive effects of chemical road treatments, [and is intended to] determine the cost of corrosion created by road treatments, and to provide an evaluation of alternative techniques and products, such as, but not limited to, rust inhibitors, with a comparison of cost and effectiveness. [. . .] While use of chloride-based deicing chemicals for winter highway maintenance has raised concerns regarding impacts on vehicles, infrastructure and the environment, alternative products also have environmental, corrosion and expense impacts. Although corrosion inhibitors are available for use with deicers, evidence of their effectiveness in the field based on literature reviewed was not found. Research is needed to confirm their effectiveness before considering use. Further, CTDOT's participation in national initiatives, and ongoing communication with neighboring states, municipalities, and other stakeholders should continue and be strengthened to help balance the competing factors by using the most effective practices.

New York State's respondent offered the state DOT's snow and ice guidelines:

New York State Department of Transportation Highway Maintenance Guidelines: Snow and Ice Control, Operations Division, Office of Transportation Maintenance, April 2006, revised January 2012. https://www.dot.ny.gov/divisions/operating/oom/transportation-maintenance/repository/NYS_SI_Manual_Apr2006_RevJan2012.pdf

This comprehensive manual offers information covering all aspects of New York State's preparation and implementation of its winter road maintenance equipment, materials and workforce. Section 5.1000 covers "Preparation for Snow and Ice Control." Sections on "Snow Control" and "Ice Control" follow with detailed data addressing such factors as vehicle speeds and maintenance actions associated with hourly snowfall rates.

Ohio's respondent offered a link to a one-page document presenting the DOT's guidelines for pre-treatment:
Ohio Department of Transportation Snow & Ice Pre-Treatment Guidelines, undated. http://www.dot.state.oh.us/Divisions/Operations/Maintenance/SnowandIce/Snow and Ice Best Practices/Pre-treatment Guidlines.pdf.

Vermont's respondent offered a link to the state's snow and ice control plan:

Vermont Agency of Transportation Snow and Ice Control Plan for State and Interstate Highways, September 2017, http://vtrans.vermont.gov/sites/aot/files/documents/Snow_Ice Control Plan 2017 FINAL DRAFT.PDF.
From the plan:

> **Anti-icing** - For anti-icing with salt brine, the application rates per lane mile may vary when pavement temperatures *during the storm* are anticipated to be 15 degrees F or greater. Application will generally occur on designated routes 6 to 8 hours prior to the projected start of the storm, however, up to 12 hours may be permissible based on timing of the storm. Anti-icing may also be used to spot treat bridge decks and other problem areas located on any priority corridor whenever weather forecasts indicate the possibility of glazing. When anti-icing the roads with a blend, application rates may be cut back. Due to concerns associated with proper timing and effectiveness of anti-icing activities, as well as a desire to reduce salt usage, we reserve anti-icing for very special circumstances.
>
> **Pre-wetting** - Pre-wetting is the application of liquids onto solid materials. In general, salt brine shall normally be used when the pavement temperatures are above approximately 15 degrees F and chemical additive or blend shall be used when below. Pre-wetting is the preferred and typical liquid application method. Pre-wetting allows the salt to work immediately and reduces the loss of salt to "scatter and bounce" where up to 30% of the dry salt can be lost to the side of the road and ditches.

Wisconsin's respondent offered a link to the agency's anti-icing table:

Highway Maintenance Manual: Anti-Icing Guidelines, Wisconsin Department of Transportation Bureau of Highway Maintenance, January 2012, http://wisconsindot.gov/Documents/doing-bus/local-gov/hwy-mnt/mntc-manual/chapter06/06-20-20.pdf.

This chart includes guidelines for application rates for liquids and prewetted salt for each of four "Predicted Precipitation Event[s]": Frost or Black Ice, Sleet, Freezing Rain, Light Snow (<1/2 in/hr) and Moderate of Heavy Snow (>1/2 in/hr). Application rates for five location types are included in the chart.

3 Literature Search

- Related Resources
- Manuals and Guidance: State and National
- Environmental Concerns
- Research in Progress

3.1 Related Resources

Optimize Pre-Wetting for Sustainable Winter Road Maintenance, T. Usman, L. Fu, J. Kaur, M. Perchanok, H. McClinktock, TAC 2017: Investing in Transportation: Building Canada's Economy—2017 Conference and Exhibition of the Transportation Association of Canada, 2017, 18 pages, http://www.tac-atc.ca/sites/default/files/conf_papers/usmant_-sustainable_winter_road_maintenance.pdf

> *From the abstract.* This research presents the findings from a field study aiming at comparing the performance of different pre wet ratios using salt for their impacts on snow melting performance/friction of road surfaces under different weather conditions. The research was motivated by the question, whether or not more sustainability can be achieved by using higher ratios of pre wetting. Field tests were conducted on three sections of a provincial highway in Southwest Ontario in the winter season 2016/2017 comparing the performance of higher pre wet ratios (10% and 20%) compared to the 5% conventional figure. Using comparative analysis, results shows that use of pre-wet salt at both 10% and 20% improves road surface conditions by approximately 10% compared to the 5% pre wet rate whereas the difference between the performance of 10% and 20% pre wet rate is minimal.

Salt Brine Blending to Optimize Deicing, Anti-Icing Performance and Cost Effectiveness, Phase III, S. J. Druschel, Center for Transportation Research and Implementation, University of Minnesota, Mankato, November 2017, http://www.dot.state.mn.us/research/reports/2017/201745.pdf

This is a continuation of the previous two studies (2012, 2014 also listed in this section). Chapter 4, the **Anti-icing Persistence Study,** is on pages 87–109 (102–124 of the PDF). It presents and discusses methods and results of researchers' testing of many kinds of anti-icers on Minnesota highways.

> *From Chapter 4: Anti-Icing Persistence Study*: One technique of winter maintenance operations that has shown great promise is anti-icing, the prestorm placement of deicer brine to clear pavement done to limit or prevent formation of icing on a roadway. Whether due to windblown snow, ice fog, freezing rain, or simply wet snow becoming packed (Figure 17), anti-icing has been found to reduce formation and build up. However, winter maintenance operations have often found it difficult to mobilize the anti-icing application trucks, either because of labor shortages prior to a storm (resting crews before potential long shifts) or limited procurement of the anti-icing brine application equipment (Figure 18). Application of sodium chloride (rock salt) brine at typical rates between 10 and 30 gallons per lane mile (gal/LM) also provides a significant deicer material savings, as with a brine saturation of 23% concentration this rate calculates to 20 to 60 lb/LM, about 1/20th of the typical deicer application rate during a snow event. [. . .] **This study aims to further characterize and define the factors related to anti-icer and deicer persistence during traffic and precipitation events, to minimize loss of anti-icer and deicer material and maximize deicing performance.**

[Emphasis added.] The study was done on an elevated section of an active highway as an outdoor test facility, employing actual anti-icing on actual traffic with operational winter maintenance efforts unadjusted for research. Factors evaluated included: deicer application rate, time, temperature, precipitation, and traffic situation.

Clear Roads Study Establishing Effective Salt and Anti-icing Application Rates, Blackburn and Associates, February 2015, http://clearroads.org/wp-content/uploads/dlm_uploads/Summary-Report-of-Task-2-Findings.pdf

From the study: The ultimate goal of [this summary] is to refine and expand the recommended application rates in the National Cooperative Highway Research Program (NCHRP) Report 526 with a simple as possible approach considering pavement type, pavement temperature, adjusted dilution potential, and cycle time for a range of chemical types. The influence of weather patterns, storm type or scenarios, and site characteristics are to be treated as classifying elements in the recommended application rate tables. This summary report is divided into six main sections following introduction:

- Section 2 presents an overview of the liquid and solid chemicals used by the surveyed highway agencies.
- Section 3 provides a review of chemical application rate guidelines used by highway agencies.
- Section 4 describes the development of the updated application rate guidelines for NaCl.
- Section 5 describes the development of application rate guidelines for chemicals other than NaCl.
- Section 6 presents the results of an investigation into the relative cost of chemicals used in winter maintenance operations.
- Section 7 provides a summary of the activities and findings.

Salt Brine Blending to Optimize Deicing, Anti-Icing Performance and Cost Effectiveness, Phase II, S. J. Druschel, Center for Transportation Research and Implementation, University of Minnesota, Mankato, December 2014, http://www.dot.state.mn.us/research/TS/2014/201443.pdf

From the abstract: This report presents the evaluation of winter maintenance efforts, including applications of deicers and anti-icers and plowing, in parallel conditions on actual pavements to assess intuitions based on observations and anecdotal evidence. Parallel conditions eliminate the issue of test sections being in slightly different geographies. Four different aspects were evaluated in this effort:

- Anti-icer persistence, measured in response to actual traffic through drainage off defined roadway sections of an elevated highway;
- Deicer effectiveness, techniques and materials evaluated at two proximal facilities across six and three parallel treatment lanes of 1,000 feet length;
- Plow effectiveness, techniques and equipment evaluated at the same locations as the deicer effectiveness evaluation; and,
- Pavement study of anti-icer persistence in response to precipitation, performed using asphalt and Portland cement concrete pavements in a laboratory setting.

Results of this work indicate factor interaction such as truck traffic plus deicer use or roadway crosswind and deicer distribution may have significant impact on differences in winter maintenance performance and deicer efficiency.

Salt Brine Blending to Optimize Deicing and Anti-Icing Performance, S. J. Druschel, Center for Transportation Research and Implementation, University of Minnesota, Mankato, July 2012, http://www.dot.state.mn.us/research/documents/201220.pdf.

From the abstract: This research evaluated the ice melt capacity and field performance factors of deicers and deicer blends and then developed a temperature-based cost model for comparing the relative field performance of the evaluated deicers and deicer blends. Both solid and liquid deicers were evaluated for both deicing and anti-icing methods.

Pages 122 to 129 (of the PDF) offer tables of cost-per-mile for various anti-icing materials.

"***Effectiveness of Anti-Icing Operations for Snow and Ice Control of Parking Lots and Sidewalks***," **S.M. Kamal Hossain, Liping Fu, Avalon J. Olesen,** *Canadian Journal of Civil Engineering*, **2014, 41(6): 523-530,** https://doi.org/10.1139/cjce-2013-0587.

From the abstract: This paper describes an empirical study aimed at investigating the performance of the anti-icing strategy for snow and ice control of parking lots and sidewalks. The research is motivated by the need to address several key questions concerning various operational decisions related to the anti-icing strategy, including its relative effectiveness under different weather and site conditions, treatment options, and optimal application rates. Extensive field tests were conducted under traffic controlled environment and variety of weather events using regular solid road salt, brine, and two other liquid alternatives. Data collected from these tests was used to analyze the performance of anti-icing operations such as friction level, bare pavement regain time, and the effects of various external factors such as pavement temperature and application rate. The research has concluded with findings that are directly applicable in real world winter maintenance practices.

Potential for Natural Brine for Anti-Icing and De-Icing, J. Kauser, M. Yusuf, Rowan University, New York State Department of Transportation, and Federal Highway Administration, September, 2012, https://www.dot.ny.gov/divisions/engineering/technical-services/trans-r-and-d-repository/C-06-07%20Final%20Report_Sept%202012.pdf.

From the abstract: This project focused on the feasibility of the use of natural brine for anti-icing and pre-wetting in Onondaga County, Syracuse, New York. A thorough literature review was conducted on the use of brine as an anti-icing and pre-wetting agent both in the United States and abroad. The review indicated that the use of brine as an anti-icing and pre-wetting agent has gained popularity in most of the Departments of Transportation (DOT) in the U.S. and abroad over the years. Studies indicate that decreased applications of anti-icing chemicals lead to significant savings in material costs, reduced use of abrasives (rock salt and sand), better road conditions, lower accident rates, better environmental protection and lower costs for winter road maintenance. Costs analyses indicated that natural brine applications costs were comparable to commercial brine applications in the Onondaga County region. Deicing materials and accident data analyses for the Village of Fayetteville, Onondaga County and the New York State DOT Onondaga East Residency office indicated that: (1) snow events are a significant contributor to winter road accidents; (2) frequency of accidents go up immediately after a heavy precipitation; and (3) number of accidents in the 2010-2011 winter season when brine was applied was less than when rock salt was applied (2009-2010 winter season) even though the precipitation was greater in the former case for I-81 and I-481.

"*Field Test of Organic Deicers as Prewetting and Anti-Icing Agents for Winter Road Maintenance*," Liping Fu, Raqib Omer, Chaozhe Jiang, included in ***Maintenance Services and Surface Weather*, February 2012**, Issue 2272, pp. 130–135, *Journal of the Transportation Research Board,* https://journals.sagepub.com/doi/abs/10.3141/2272-15.

From the abstract: Salts, in both solid and liquid forms, are used in winter road maintenance because of their effectiveness in breaking and preventing the bonding of snow and ice to road surfaces. Because of the detrimental effects of salt on infrastructure and the environment, many alternative materials are being tested for snow and ice control during winter. This paper summarizes the results of field tests that compared two beet molasses–based materials with regular salt and salt brine when used as prewetting and anti-icing agents. The performance comparison was based on more than 100 h[rs] of friction readings along with high-resolution image data collected over nine snow events. Application rates, test route, and comparison methodology along with experimental results, recommendations, and potential for future research are also presented.

Anti-icing and Pre-wetting: Improved Methods for Winter Highway Maintenance in North America, Xianming Shi, Katie O'Keefe, TRB 85th Annual Meeting Compendium of Papers, Report 06-2572, Transportation Research Board, Washington DC, 2006. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.563.7391&rep=rep1&type=pdf.

From the abstract: In recent years, anti-icing and pre-wetting practices have been gradually accepted and adopted by the North American highway agencies. One of the greatest challenges of implementing these practices has been the misunderstanding of the benefits and outcomes of their use. Members of the general public and organized groups such as trucking associations have been critical of these strategies, which may be a result of insufficient information, limited understanding and speculation. Therefore, research is needed to synthesize the information on these strategies in an objective manner. Through a project with the Pacific Northwest Snowfighters association, the Western Transportation Institute synthesized information obtained from a literature review and agency surveys on the advantages and disadvantages of anti-icing and pre-wetting for winter highway maintenance. Concerns discussed include: driver safety, human health, environmental stewardship, corrosion, costs, etc. The research indicates that compared with traditional methods for snow and ice control, anti-icing and pre-wetting lead to decreased applications of chemical products, reduced use of abrasives, decreased maintenance costs, improved roadway friction, and lower accident rates. **Anti-icing has been recognized as a pro-active approach to winter driver safety. Pre-wetting has shown to increase the performance of solid chemicals or abrasives and their longevity on the roadway surface, thereby reducing the amount of materials required.** [Emphasis added.] The information in this paper will benefit maintenance agencies and transportation officials who seek to fully understand the benefits derived from improved winter maintenance technologies, identify areas for improvement within their own jurisdiction, and learn about related experiences from other agencies.

Effectiveness of Pre-wetting Strategy for Snow and Ice Control on Highways, Rudolph Sooklall, Liping Fu, Max S. Perchanok, Transportation Association of Canada, 2006 (in *Transportation without Boundaries*, ISBN: 9781551872250; Order URL: http://worldcat.org/isbn/9781551872250.

From the abstract: This paper describes how maintaining clear pavement condition under a winter storms is critical to the safe and efficient flow of traffic in Canada. One of the principal snow and ice control methods is the application of salt. While salt remains to be the most cost-effective deicer for road maintenance, its excessive use may have a detrimental effect on the environment and highway infrastructure. Improved maintenance techniques such as pre-wetting and direct liquid application (DLA) have therefore gained increasing popularity as a means of reducing the quantity of salt used. Past research has indicated that, while pre-wetted salt generally outperforms dry salt for snow removal, its effectiveness depends on the types and proportion of pre-wetting agents used and the road weather conditions under which it is applied. **The primary objective of this research is therefore to investigate the effectiveness of different pre-wetting techniques under specific road weather conditions. The ultimate goal of this effort is to identify the optimal pre-wetting design (e.g. pre-wetting agent and ratio) for particular ranges of road weather conditions.** [Emphasis added.] Data collected by Ontario Ministry of Transportation (MTO) through a large-scale field experiment called De-icing/Anti-icing Response Treatment (DART) was used in this analysis. This data consisted of measurements on snow cover, weather and pavement conditions and treatment operations at 10-minute intervals over two winter seasons. The paper details an analysis of the snow melting trends on the test road under various road weather conditions and treatments, and summarizes the major findings related to the effects of pre-wetting chemical, pre-wetting ratio and application rate.

"Mixing It Up in the Fight Against Winter by Blending Liquid Ice Control Chemicals," Salt and Highway Deicing Newsletter, Vol. 43, No. 2 (Spring 2006).

This article highlights a blend of ice control chemicals used by McHenry County, Ill. Transportation Division staff set out to create a cost-effective liquid ice control product that performed well under various conditions and could be used for both prewetting and as a direct application for anti-icing. The product consists of 85 percent NaCl brine (23.3 percent solution), 5 percent CaCl2 (32 percent solution), 10 percent of a sugar beet syrup (55 percent solution), and a small amount of antifoaming agent. The liquid mix is used to prewet solid NaCl at a rate of 7 gallons per ton and performs satisfactorily at temperatures as low as 2° F.

"*The State of the States' Anti-Icing Technology*," R.W. Stidger, ***Better Roads**,* Vol. 72, Issue 4, April 2002, James Informational Media, Inc., Desplaines, IL, http://www.betterroads.com, order URL: http://worldcat.org/oclc/1519687.

From the abstract: This article describes various studies and applications of anti-icing technologies taking place through state departments of transportation. It relates experiences in Alaska, Colorado, Indiana, Iowa, Kansas, Kentucky, Maryland, Minnesota, Missouri, and Nebraska. Some of the challenges that are being tackled include: experimenting with ice-free roads, implementing anti-icing on a budget, preventing bond formation between the snow or frost and the pavement, and reducing salt use. Some of the solutions included: applying liquid magnesium chloride to a road prior to a storm in order to prevent ice bond from forming; creating brine-making systems using parts from local facilities; and, using zero-velocity spreaders and prewetting liquids such as salt brine in order to reduce both salt use and costs.

Application of Prewetted Snow and Ice Control Materials, A. Mergenmeier, Transportation Research Board, 1995, included in *Maintenance Management, Proceedings of the Seventh Maintenance Management Conference*, Orlando, Florida, July 18–21, 1994, Order URL: http://worldcat.org/isbn/0309061067.

From the abstract: Interest in the use of prewetting systems for the application of snow-and-ice-control materials is growing within the United States. This interest has been facilitated by activities in the Strategic Highway Research Program, the cooperative efforts between the Minnesota Department of Transportation and Scandinavian countries, the Federal Highway Administration study on anti-icing technology, and recent travel by U.S. maintenance engineers to Europe and Japan. Prewetting of snow-and-ice-control materials may be an important element in improving the efficiency and effectiveness of snow-and-ice-control processes. However, there is a need to evaluate the operational and economic impacts of prewetting systems on winter road maintenance activities. Once evaluated, prewetting systems for snow-and-ice-control materials could become an effective tool in a roadway agency's winter maintenance operation.

3.2 Manuals and Guidance: State and National

Clear Roads Training for Snowplow Operators and Supervisors, James Grothaus, Anne Johnson, University of Minnesota Center for Transportation Studies, 2017, contact Greg Waidley at greg.waidley@ctcandassociates.com for access.
This sequence of 22 PowerPoint modules with associated comprehensive instructional materials offers training in all areas of winter highway maintenance—equipment, materials, techniques— for snowplow operators and supervisors. The modules on anti-icing and freeze-point depression present up-to-date techniques and the underlying science.

MnDOT Anti-Icing Guide, Gary Peterson, Paul Keranen, Rod Pletan of EVS, Inc. for MnDOT, September 2010. http://www.dot.state.mn.us/maintenance/pdf/research/AntiIcingGuide8Full.pdf.
Combining the knowledge and experience of over 47 anti-icing experts across Minnesota's districts, this guide answers the what, why, when, where, how, and many more questions about anti-icing in Minnesota. It is a concise compendium of experience, knowledge and skill designed to be easily accessible and usable.

Anti-icing in Winter Maintenance Operations: Examination of Research and Survey of State Practice, MnDOT**,** Transportation Research Synthesis prepared by CTC and Associates, TRS 0902, May 2009, https://www.lrrb.org/pdf/trs0902.pdf.

This 2009 synthesis report presents similar materials—research and survey of state practice at the time—requested for this Clear Roads synthesis.

From the Introduction: Anti-icing, a proactive snow and ice control strategy that is sometimes practiced as the first line of defense in a winter maintenance operation, came into practice during the 1990s. As anti-icing is most commonly conducted, a small amount of liquid chemical is applied to the roadway or bridge deck prior to a storm to prevent ice from forming a bond with the surface.

The benefits of anti-icing are well documented in national studies and manuals, and in field tests conducted by various state departments of transportation, including Minnesota DOT. MnDOT is developing an anti-icing guide that will be incorporated into the department's existing winter training program. The guide will be used by front-line supervisors and managers to better manage their winter operations and by operators to assist them in effectively performing their snow and ice control duties. To prepare for development of the anti-icing guide, MnDOT asked us to review relevant research to identify existing anti-icing practices, field strategies and procedures, and application rates. We also reviewed 12 transportation agencies' anti-icing guidelines and procedures to identify current patterns of practice.

We conducted a broad review of the research related to anti-icing programs and identified seven key topic areas:

- National guidance
- Handbooks and manuals
- Best practices
- Product selection
- Anti-icing technology
- Prewetting
- Equipment

Snow and Ice Control: Guidelines for Materials and Methods, NCHRP Report #526, R.R. Blackburn, K.M. Bauer, D.E. Amsler, Sr., S.E. Boselly, A.D. McElroy, Midwest Research Institute of Kansas City, MO, 2004. http://www.trb.org/news/blurb_detail.asp?id=4355.

From NCHRP's "Impacts on Practice" presentation of Report 526: This guide helps agencies choose winter maintenance strategies to meet level-of-service objectives and pavement condition goals for different highway types—ensuring that materials are used cost-effectively and waste is minimized.

To create the guide, investigators conducted extensive fieldwork, working with 24 agencies to evaluate five combinations of snow removal tactics and anti-icing and deicing strategies.

The result was a set of detailed guidelines that gave state DOTs and local agencies a scientific methodology for addressing complex challenges, such as how to design a salt application rate to account for dilution caused by precipitation, traffic, and accumulated snow and ice on the road surface. The guidelines codified the experiences of field personnel across the country.
The report includes a step-by-step procedure that field supervisors can use to determine the best treatment plan for a variety of conditions. To make the guidelines even more accessible to field personnel, AASHTO incorporated portions of *Report 526* into its computer-based training modules on snow and ice control.

The five combinations of snow removal and anti-icing/deicing strategies studied over three winter seasons in various climates and traffic situations included these (*from the report):*

1. Anti-icing strategy with appropriate chemical forms (e.g., solids and prewetted solids) on lower-volume primary highways and local roads followed by a subsequent strategy of mechanical removal of snow and ice together with friction enhancement, if necessary.
2. Anti-icing strategy with appropriate chemical forms (e.g., solids, prewetted solids, and liquids) at selected highway locations such as hills, curves, intersections, grades, and selected bridge decks.
3. Anti-icing or deicing strategy with appropriate chemical forms on lower volume primary highways and local road systems.
4. Anti-icing strategy with liquid chemical applications on bridge decks to prevent preferential icing.
5. Mechanical snow and ice removal strategy with abrasives prewetted with liquid chemicals.

Anti-Icing Technology, Technical Transfer Brief, Illinois DOT, 1998, https://idot.illinois.gov/Assets/uploads/files/Transportation-System/Manuals-Guides-&-Handbooks/T2/FTB-3%20Anti-Icing%20Technology.pdf.

Although this short technical brief is 20 years old, it conveys information about anti-icing that is accepted today, and includes a discussion of the cost-savings (albeit in 1998 dollars) that anti-icing practices can realize.

Manual of Practice for an Effective Anti-Icing Program: A Guide for Highway Winter Maintenance Personnel, S. A. Ketcham, L. D. Minsk, R. R. Blackburn, E. J. Fleege, June 1996, U.S. Army Cold Regions Research and Engineering Laboratory, Federal Highway Administration, **Report/Paper Numbers:** FHWA-RD-95-20, http://www.fhwa.dot.gov/reports/mopeap/eapcov.htm.

From the abstract: Highway anti-icing is the snow and ice control practice of preventing the formation or development of bonded snow and ice by timely applications of a chemical freezing-point depressant. It provides a maintenance manager with two major capabilities: the capability for maintaining roads in the best conditions possible during a winter storm, and the capability to do so in an efficient manner. As a consequence, anti-icing has the potential to provide the benefit of increased traffic safety at the lowest cost. However, to achieve this benefit the maintenance manager must adopt a systematic approach to snow and ice control and must ensure that the performance of the operations is consistent with the objective of preventing the formation or development of bonded snow and ice. Such an approach requires use of considerable judgment in making decisions, requires the available information sources be utilized methodically and requires that the operations be anticipatory or prompt in nature. This manual provides information for successful implementation of an effective highway anti-icing program. It is written to guide the maintenance manager in developing a systematic and efficient practice for maintaining roads in the best conditions possible during a winter storm. It describes the significant factors that should be understood and must be addressed in an anti-icing program, with the recognition that the development of the program must be based on the specific needs of the site or region within its reach. The manual includes recommendations for anti-icing practices and guidance for conducting anti-icing operations during specific precipitation and weather events.

3.3 Environmental Concerns

Study of De-icing Salt Accumulation and Transport Through a Watershed, William Herb, Ben Janke, and Heinz Stefan, University of Minnesota, St. Anthony Falls Laboratory, December 2017, http://www.dot.state.mn.us/research/reports/2017/201750.pdf.

> *From the abstract*: The accumulation of chloride in surface waters and groundwater from road deicing and other sources is a growing problem in northern cities of the U.S., including the Minneapolis-St. Paul metro area. To inform mitigation efforts, the transport of chloride in surface waters of a metro-area watershed (Lake McCarrons) was studied in this project to characterize chloride transport by surface runoff, the residence time of chloride in surface water, and how variations in weather influence chloride transport and accumulation processes. Monitoring work over three winters showed that the residence time of chloride in small, sewered watersheds varied from 14 to 26 days, depending on winter weather conditions, with 37 to 63% of chloride applied as de-icers exported in snowmelt and rainfall surface runoff. In contrast, a monitored highway ditch exported less than 5% of chloride applied to the adjacent road. Stormwater detention ponds were found to act as temporary storage for chloride, with persistent layers of high chloride content at the bottom. Chloride monitoring data and runoff simulations were used to explore the possibility of snowmelt capture as a chloride pollution mitigation strategy. We found that capturing snowmelt runoff close to source areas (roads and parking lots) yields the highest chloride concentrations and removal potential.

Field Usage of Alternative Deicers for Snow and Ice Control, The Western Transportation Institute, Transportation Research Synthesis, Local Roads Research Board, MnDOT, September 2017, http://dot.state.mn.us/research/TRS/2017/TRS1706.pdf.

> *From the Introduction*: In the last two decades, potassium acetate (KAc), sodium acetate (NaAc), potassium formate (KFm), and sodium formate (NaFm) have gradually replaced urea as the freezing-point depressant in airport pavement deicing products (Shi 2008). (Urea imparts relatively large impacts on the environment. For this reason we will not include urea in this discussion of non-chloride deicers for use in roadway winter maintenance operations.) Additionally, the use of non-chloride based deicers and anti-icers have become more common in roadway winter maintenance operations due to the impacts that chloride based deicers exert on infrastructure and the environment. [. . .]This Transportation Research Synthesis (TRS) summarizes non-chloride based deicers available on the market at this time, including acetate, formate, glycol, and succinate based deicing products. This report explores their feasibility for use as alternatives to chloride based deicers, and identifies next steps to determine if a non-chloride based deicer is a viable option for implementation in winter maintenance operations by the Minnesota Department of Transportation (MnDOT) and local snow and ice removal providers.

Environmental Impacts of Chemicals for Snow and Ice Control: State of the Knowledge, Laura Fay, Xianming Shi, in *Water, Air & Soil Pollution*, June 2012, Volume 223, Issue 5, pp. 2751–2770, https://link.springer.com/article/10.1007/s11270-011-1064-6.

> *From the abstract*: As chemicals are widely used for snow and ice control of highway and airfield pavements or aircrafts, recent years have seen increased concerns over their potentially

detrimental effects on the surrounding environment. The abrasives used for winter operations on pavements are also a cause of environmental concerns. After some background information, this paper presents a review of the environmental impacts of chemicals used for snow and ice control, including those on: surface, ground, and drinking waters; soil; flora; and fauna. The paper provides a state-of-the-art survey of published work (with a focus on those in the last two decades) and examines mainly the impacts of abrasives, chlorides, acetates and formates, urea, glycols, and agro-based deicers. Finally, we conclude with a brief discussion of public perception of such impacts and best management practices (BMPs) to mitigate them.

Guidelines for the Selection of Snow and Ice Control Materials to Mitigate Environmental Impacts, NCHRP Report # 577, 2007, http://www.trb.org/Main/Blurbs/158876.aspx.

From the NCHRP "Paths to Practice" summary of Report #577: Every winter, transportation agencies apply large quantities of salt and other chemicals to roads to keep them clear of snow and ice. Rational decision-making guidelines were needed to help maintenance managers assess the properties of various materials and take steps to minimize their environmental effects.
To help meet this need, NCHRP conducted NCHRP Project 06-16 and produced NCHRP Report 577: **Guidelines for the Selection of Snow and Ice Control Materials to Mitigate Environmental Impacts** (www.trb.org/Main/Blurbs/158876.aspx). The report provides guidelines through an evaluation of cost, performance, and impacts on the environment and infrastructure. The project also produced a decision tool for selecting snow and ice control materials to suit the specific needs of any given highway agency (www.trb.org/NotesDocs/NCHRP06-16_MaterialSelectionWizard.zip). The software serves as a purchasing specification and as a quality assurance monitoring program that includes evaluation procedures and standard test methods.

3.4 Research in Progress

Developing Friction Data to Support the Optimal Use of Pre-wet Deicing Salt for Enhanced Winter Mobility, Shi, Xianming, Center for Advanced Multimodal Mobility Solutions and Education, University of North Carolina, Charlotte, **Start Date:** October 1, 2017, **Expected Completion Date:** September 30, 2018
Project Description: Currently agencies in North America do not have reliable data to analyze the effectiveness and efficiency of its pre-wetting salt operations in districts facing localized and diverse traffic and weather conditions. Research is much needed to understand the influence of pre-wetting product type, pre-wetting ratio, and application rate of pre-wet deicing salt on the friction performance of deiced asphalt pavements, so as to generate the data needed for optimizing the use of pre-wet deicing salts for enhanced winter mobility. This UTC project will address this knowledge gap by conducting a customized laboratory testing program to lay the groundwork and developing a plan for subsequent field operational tests (FOTs). The ultimate goal is to develop data needed to support the optimal decisions related to the practices of pre-wetting salt and subsequent deicing to improve the mobility and safety of multimodal transportation systems in a fiscally and environmentally responsible manner.

Appendix A: Survey Questions

Clear Roads Survey for Use of Prewetted Solid Materials for Roadway Anti-Icing

Members of the Clear Roads Winter Maintenance Pooled Fund are interested in learning about state practices concerning the use of prewetted solid materials for roadway anti-icing. We would very much appreciate your participation.

If answering certain questions requires expertise from other individuals at your agency, please forward this survey to those people. Multiple individuals at the same agency may respond to this survey, answering only those questions that apply to them. If you have any questions about this survey, please contact Sharon Van Sluijs at sharon.vansluijs@ctcandassociates.com; if you have questions about Clear Roads, contact Greg Waidley, at greg.waidley@ctcandassociates.com.

We would appreciate your responses by **Monday, April 16, 2018.**

Thank you.

* 1. (Required) Please provide your contact information.

Name:

Organization:

Title:

Email Address:

Phone Number:

* 2. (**Required**): Does your agency apply anti-icers in advance of winter storms to mitigate ice formation on roads? (Note: "anti-icing" refers to the application of materials to the roadway before a storm to prevent ice formation on the road surface.)

- Yes
- No (If your agency does not perform anti-icing, please indicate here and at the end of survey, please click **submit**.)

Comments

Overview of Anti-Icing Practices

3. What materials/methods does your agency use for anti-icing? (Please check all that apply.)

- [ ] Salt (NaCl) brine
- [ ] Other chloride salt liquid (e.g., CaCl, MgCl)
- [ ] Non-chloride liquid (Please specify below in the comment box)
- [ ] Pre-wetted solids/salt
- [ ] Dry solids/salt
- [ ] Other material (Please specify below in the comment box)

Comments

4. Why does your agency use the materials/methods it does for anti-icing? (Please check all that apply.)

- [ ] Our equipment is set up for this application.
- [ ] It is the most effective anti-icing method.
- [ ] It is the most cost-effective method.
- [ ] We are not able to store liquids.
- [ ] We are considering changing our equipment and methods.
- [ ] Other reasons (please explain in the comment box below)
- [ ] Don't know

Comments

5. Which material/method does your agency consider the most effective for anti-icing? (Choose one.)

- ○ Salt (NaCl) brine
- ○ Other chloride salt (e.g., CaCl, MgCl) liquid
- ○ Non-chloride liquid
- ○ Pre-wetted solids/salt
- ○ Dry solids/salt
- ○ Other material

Comments

6. Which material/method does your agency consider the most cost-effective for anti-icing? (Choose one.)

- ◯ Salt (NaCl) brine
- ◯ Other chloride salt (e.g., CaCl, MgCl) liquid
- ◯ Non-chloride liquid
- ◯ Pre-wetted solid/salt
- ◯ Dry solids/salt
- ◯ Other materials

Comments

7. If your agency uses pre-wetted solids for anti-icing, what do you use to pre-wet? (Choose one.)

- ◯ Water
- ◯ Salt (NaCl) brine
- ◯ Other liquid

Comment

8. If your agency uses pre-wetted solids for anti-icing, what ratio of liquid to solid do you use? (Choose one.)

- ◯ 5-8 gallons per ton of solid/salt
- ◯ 9-12 gallons per ton of solid/salt
- ◯ 13-16 gallons per ton of solid/salt
- ◯ Other (Please specify in the comment box below.)
- ◯ Do not use pre-wetted solids.

Comment

9. If your agency uses pre-wetted solids for anti-icing, what speed and application rates are used?

Speed at which material is applied:

Application rate:

Do not use pre-wetted solids

10. If your agency uses solid materials for anti-icing, what application rate is used?

11. Which factors does your agency consider when deciding to apply anti-icing materials? (Check all that apply.)

- ☐ Precipitation
- ☐ Humidity
- ☐ Temperature
- ☐ Wind
- ☐ Weather forecast
- ☐ Type of pavement
- ☐ Type of traffic
- ☐ Other considerations

Comments

12. Under what conditions does your agency refrain from anti-icing?

Environmental Concerns

13. Has your agency changed its anti-icing procedures in response to state or federal regulations arising from environmental concerns?

- ○ Yes
- ○ No

If yes, please describe when and how.

14. Does your agency use methods/techniques to limit bounce and scatter of material?

- Yes
- No

If yes, please specify the methods or techniques.

15. What methods does your agency use to keep accurate records of amounts of anti-icing materials applied to roadways?

16. Do you use an applicator controller to regulate the dispensing of anti-icing materials?

- Yes
- No

If yes, please specify the controller you use.
If no, please specify how the amount of material dispensed is controlled.

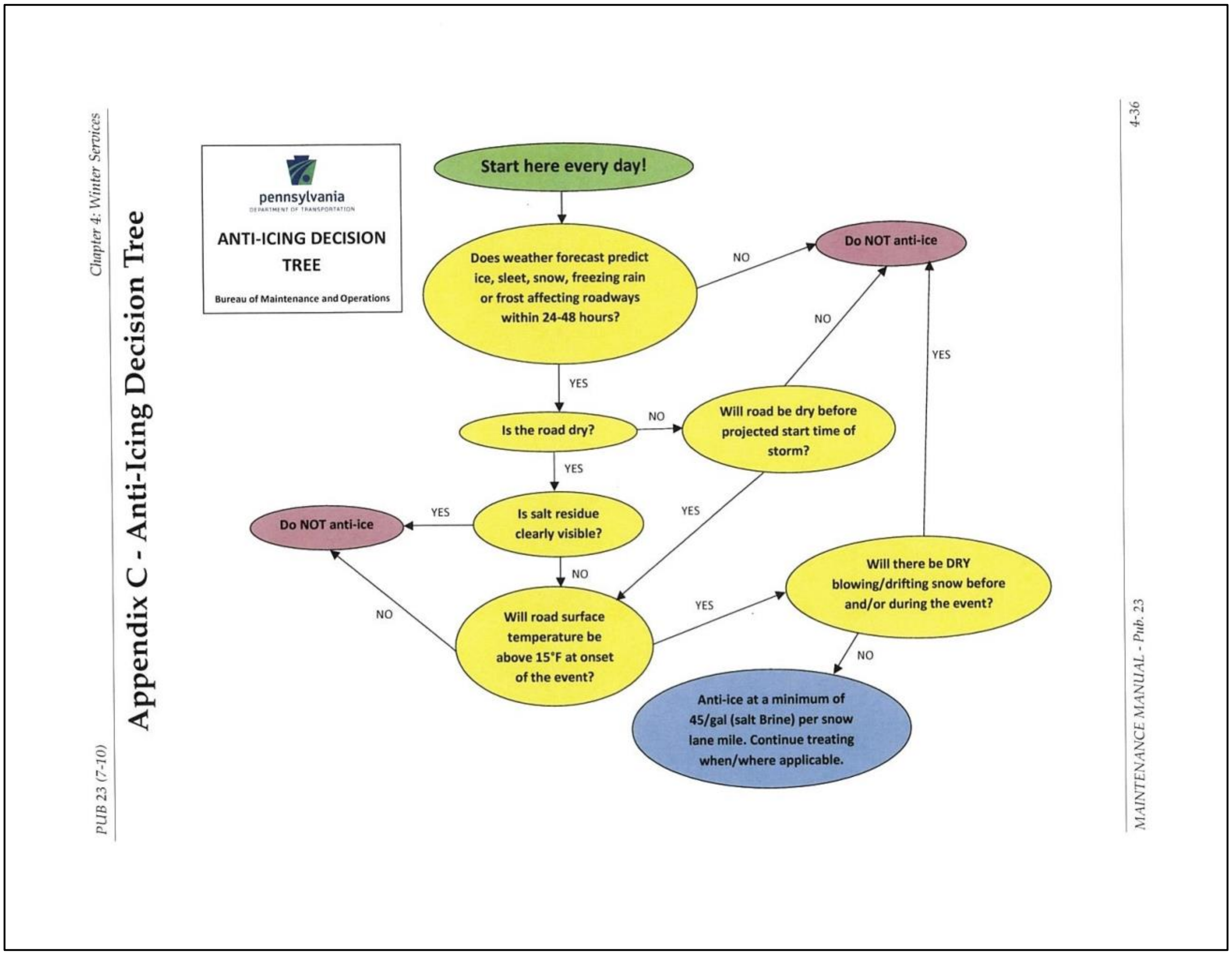
Wrap-up

17. Do you have anything more you would like to add to this survey?

18. Please include links to relevant documents here.

Thank you for completing this survey. We appreciate your contribution to this project.
Please click **Submit.**

Appendix B:
Pennsylvania DOT Anti-icing Decision Tree



Appendix C:
Wisconsin DOT Salt Brine Anti-icing Chart

Salt Brine Anti-Icing Application Decision Assessment

Each of the following criteria should be met before conducting Anti-Icing operations

1) Snow or frost is predicted within the next three working days.
2) Pavement is dry and absent of sufficient residual anti-icing materials
3) Pavement temperature 23 degrees or greater.
4) Sufficient time exists for pavement to dry before the pavement temperature falls below 20 degrees.
5) Relative humidity level less than 70% or dew point at least 3 degrees below the air temperature. (This ensures brine will dry relatively quickly and will not remain wet on the pavement.)
6) Winds less than 15 mph if loose snow is present.
7) Use of other materials such as calcium chloride, magnesium chloride or other commercial deicers require additional considerations. (Some products may attract moisture in high humidity events.)

Do Not Apply Anti-Icing Material if Rain is Predicted Before Snow, Frost, or Freezing Rain Events

Application Rate of Anti-Ice Materials (Salt Brine)

Frost: 20 – 30 gal/lane mile
Sleet: 20 – 30 gal/lane mile

Light Snow (< ½" hr): 30 – 40 gal/lane mile
Moderate or Heavy Snow (≥ ½" hr): 40 – 50 gal/lane mile
Freezing Rain: Application not recommended if rain is predicted prior to freezing rain event

Bureau of Highway Maintenance

Rev. Date 12/8/2014

CLEAR ROADS

research for winter highway maintenance

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