Center for Advanced Multimodal Mobility Solutions and Education

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Developing Friction Data to Support the Optimal Use of Pre-Wet Deicing Salt for Enhanced Winter Mobility

Final Report

by

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DISCLAIMER

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EXCUTIVE SUMMARY

Applying prewet deicers during winter storms is a cost-effective strategy to improve deicer performance. Prewet deicers have a small amount of liquid product applied to solid salt or salt/sand which helps activate the ice melting and penetration and significantly reduces bounce and scatter. Prewetting keeps the product on the road and improves the ability of plows to removed compacted snow and ice. While many agencies use prewet deicers, there is not enough reliable data to determine optimal prewetting rates or product type.

This research presents the results of an in-depth survey of the pacific northwest (Oregon, Washington, Alaska and Idaho) on prewetting practices and laboratory tests that quantified the ice melting, frictional behavior and reduction in snow–pavement bond strength of salt prewet with various liquid deicers and prewetting rates. Ice melting tests are an accepted method to gauge basic chemical performance, but do not adequately predict field performance. More sophisticated laboratory tests on asphalt pavement with realistic snow and representative trafficking motion and forces were conducted. Whereas ice melting tests require unrealistically high application rates (over 1000 pounds per lane mile (lb/lm)), the snow/traffic/friction tests were conducted with reasonable application rates (250 lb/lm).

For the ice melting tests, pre-wetted salt worked better than dry salt at 1,000 lb/LM at 25°F and 2,000 lb/LM at 15°F. The biggest different observed between the types of liquid used for pre-wetting were at 25°F 1,000 lb/LM tests. At the colder temperature of 15°F the pre-wetting liquids worked similarly and each better than dry salt. Considering all temperatures and application rates the ranked order of liquids from best to worst are: $CaCl_2$, Grape blend, Beet blend, 23% NaCl, $MgCl_2$. For the snow–traffic–plowing–friction tests, pre-wetting reduced the snow–pavement bond compared to dry salt and control tests (no deicer application). The highest friction after plowing was observed with the dry salt test, although this experiment did not mimic the bounce and scatter that would be expected during application by material spreaders. The best-performing pre-wetting liquid with respect to friction was NaCl and with respect to snow–pavement bond was beet-modified salt brine.

The laboratory tests confirmed that pre-wetting liquid-to-solid application rates in the range of 8–16 gal/ton are reasonable for increasing the speed and total ice melting capacity of solid salt. Furthermore, prewetting significantly reduces the snow–pavement bond, but does not seem to increase friction more than dry salt. One key limitation of the laboratory tests conducted was that bounce and scatter from realistic application speeds was not included. Thus field tests are critical for expanding the knowledge and identifying specific best practices of pre-wetting. Specific road types and data that should be collected during field operational tests are provided.

Chapter 1. Introduction

1.1 Problem Statement

Research is currently lacking for agencies 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. Deicing salts are often selected by DOTs and municipalities as essential tools for maintaining roads during winter conditions because of their ability to break the bond of snow/ice to pavement and effectively restore a safe driving surface. The relative performance of the many products available on the market is a key factor in selection. Salt (sodium chloride), commonly understood to be the most affordable deicer, can exhibit significant improvement by pre-wetting with deicer solutions which are more powerful freezing point depressants. Pre-wetting refers to the application of liquid products, such as brines, to solid material (primarily salt, abrasives or a combination of these) at the truck just before the pre-wet material hits the road. Pre-wetting, in combination with optimal vehicle speeds, reduces the bounce and scatter loss that causes dry material to disperse beyond its desired location. Pre-wetting can also help activate the ice melting, penetration and undercutting mechanisms that help break up snowpack for subsequent mechanical removal. However, limited data is available to support the optimal use of pre-wet deicing salts for enhanced winter mobility under various road weather scenarios.

While field tests would provide the most realistic environment with proper scale and concentration considerations, they are more expensive and fail to provide highly reproducible combinations of air/pavement temperatures, snow precipitation, solar radiation, etc. As such, groundwork in the laboratory (well-controlled conditions) is needed to support the decisions related to the practices of pre-wetting salt and subsequent deicing. Currently only a few standard laboratory tests for deicers are available, and the most widely known are the three tests developed during the Strategic Highway Research Program (SHRP) and published in the Handbook of Test Methods for Evaluating Chemical Deicers (Chappelow et al. 1992). These performance-based tests measure ice melting, penetration and undercutting of deicers, all of which are limited by the use of small sample size, the lack of control in humidity and ultraviolet light, and the absence of traffic.

1.2 Objectives

The objectives of this CAMMSE project are: (1) to investigate in the laboratory the effects of pre-wetting product type, pre-wetting ratio, and application rate of pre-wet deicing salt on the friction performance of deiced asphalt pavement under typical weather conditions in the Pacific Northwest region; and (2) to develop a plan for field operational tests (FOTs) designed to validate or calibrate the laboratory findings and to guide the appropriate use of pre- wet deicing salt for enhanced winter movements of passengers and freight. This scope is directly relevant to the **CAMMSE theme** of "*Developing Data Modeling and Analytical Tools to Optimize Passenger and Freight Movements*". The Federal Highway Administration (FHWA) has estimated that "over 70 percent of the nation's roads are located in snowy regions…and nearly 70 percent of the U.S. population lives in these regions" (Figure 1).

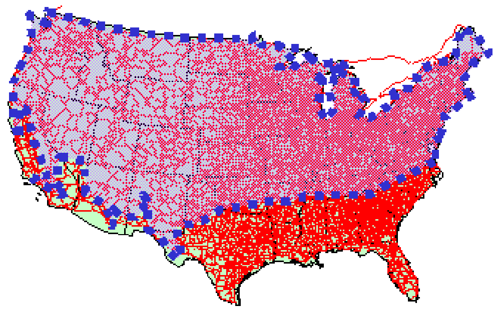

Figure 1: US areas affected by snow and ice (FHWA 2017)

1.3 Contributions

To accomplish these objectives, several tasks have been undertaken.

Task 1: Planning for the laboratory investigation—a literature review and survey of Pacific Northwest states' winter maintenance practitioners were conducted. The survey was distributed within the states of Washington, Idaho, Oregon and Alaska to assess this region's pre-wetting practices, insights and experiences. Specific information sought included type of solid and liquid pre-wetting products commonly used, the typical range of pre-wetting ratio (liquid deicer to solid salt), the typical application rates or guidelines for application rates of pre-wet deicing salts, and the typical road weather scenarios of interest to the snow/ice control practitioners in the region. Success stories or lessons learned was also requested.

Task 2: Laboratory investigation—Two types of laboratory tests were conducted 1) ice melting tests and 2) snow–pavement bond and friction tests with snow and traffic simulation. The ice melting tests included multiple pre-wet liquids, pre-wet application rates and temperatures to narrow down the pre-wetting tests conducted with more realistic winter storm parameters. More sophisticated laboratory tests were conducted with select pre-wetting liquids and pre-wetting ratios using asphalt pavement samples, snow and traffic to measure the effect of pre-wetting on the snow–pavement bond and friction of the plowed pavement.

Task 3: Data analysis and design of FOTs—Comparative and statistical analyses were conducted and potential correlations between the two types of laboratory tests were explored. The design of the FOTs includes specific measurements that should be made and targeted winter storm scenarios.

Task 4: Final report and technology transfer—This final report was written and submitted to CAMMSE UTC and a student poster was presented at the 1st annual CAMMSE Research Symposium on July 22, 2018 in Charlotte, North Carolina.

1.4 Report Overview

The remainder of this report is organized as follows: Chapter 2 presents a synthesis of the state-of-the-art and state-of-the-practice literature on pre-wetting. Chapter 3 provides the results of the survey. Chapter 4 describes the laboratory test methods, results and data analysis. Chapter 5 provides details of the recommended FOTs. Finally, Chapter 6 concludes this report with a summary of findings and a discussion of the directions for future research.

Chapter 2. Synthesis of Literature

2.1 Introduction

This chapter provides a review and synthesis of the state-of-the-art and state-of-the-practice literature on pre-wetting deicers. This should give a clear picture of the current situation in pre-wetting, including laboratory and field test findings, as well as gaps in scientific rational for various practices.

2.2 Benefits of Pre-Wetting

Best practices of winter traction material application are implemented to apply the right type and amount of materials in the right place at the right time for winter maintenance activities. Pre-wetted solids tend to have less material loss from the pavement via bounce and scatter (Shi and O'Keefe, 2005; Cui and Shi, 2015). Pre-wetting is most commonly done with on-board equipment by spraying the solid or mixing liquid with solid just before it is spread on the road. Less common alternatives include purchasing manufactured pre-wet materials, pre-wetting at the stockpile (more commonly referred to as pre-treating instead of pre-wetting), or pre-wetting as spreader trucks are loaded (also a version of pre-treating). Prewetting at rates of 8-30 gallons of liquid chemical per ton of sand or other abrasives has proven effective (Kummer, 2005). The wet material stays on the surface longer, bounces less (due to greater "staying power"), and resists traffic action. To minimize bounce and-scatter, the suggested application rate for pre-wetting is 10-12 gallon per ton (Blackburn et al., 2004). When there is rain before the snow events or there is snow at 32°F, pre-wetting is not needed (Roosevelt, 1997). Gerbino-Bevins (2011) found pre-wetted salt works quicker, at lower temperatures, and at reduced application rates, improving the effectiveness of deicing. Prewetting accelerates the dissolution of solid chemicals and enhances its melting action (Transportation Association of Canada 2003). Relative to dry salt, pre-wetted salt (with 10-mm or smaller particles) has been proven to be better retained on dry roads and its spreading leads to less wasted salt and quicker deicing effect (Burtwell 2004). When the pavement temperature drops below -12ºC (10 ºF), the use of salt would no longer be effective and roadway agencies thus utilize other chemicals either alone or as pre-wetting agent to enhance the performance of salt (Ohio DOT, 2011) or apply abrasives to provide a traction layer on pavement. Dahlen and Vaa (2001) found that "by using heated materials or adding warm water to the sand it is possible to maintain a friction level above the standard, even after the passage of 2,000 vehicles". NCHRP Report 577 provided guidelines for the selection of snow and ice control materials to mitigate environmental impacts and recommends pre-wetting over dry solid application (Levelton Consultants, 2007). Pre-wetting abrasives can reduce abrasives applications by 50% (Williams, 2003). Clearly a significant body of literature exists supporting pre-wetting practices. Key knowledge also exists in the actual "down on the ground" experiences of a multitude of practitioners.

2.3 Pre-Wetting Equipment

Pre-wetting systems are typically available with either tailgate mount or hopper-side mount tanks. Pre-wetting equipment can involve a variety of wet liquid delivery systems and spreader configurations. Some systems rely on electric pumps and others use hydraulic pumps. Additional factors include nozzle selection, optimum pressure, screen size, hose diameter and flow meter design. New on-vehicle tools (e.g., zero velocity spreaders, modified spinners, and other delivery mechanisms) facilitate precise and effective applications of both solid and liquid materials. An example with side-mounted liquid tanks along a V-box solid spreader is shown in Figure 2 (left). Nantung (2001) evaluated the use of a zero-velocity deicer spreader to determine their effectiveness for the Indiana DOT (Figure 2, right). The primary benefit of the system was viewed to be the more accurate placement of material, producing significant potential for cost savings. Sharrock (2002) discussed the Ohio DOT's experience with zero-velocity spreaders and salt brine. Observed benefits included a decrease in salt consumption (up to 70% less used) while achieving bare pavement in half the time required using other methods. Additionally, zero-velocity spreaders allowed roads to be treated at speeds of 40 to 50 miles per hour while keeping up to 90% of the granular salt material on the road surface in the wheel tracks where it is most effective. Hoppers configured to allow the snowplow to carry and spread both liquid and granular materials in different amounts are becoming popular, especially in areas sensitive to certain materials. The Minnesota DOT developed a spreader control that used on-vehicle friction sensors to automatically adjust a zero-velocity spreader (Erdogan et al., 2010). The controller that was developed was found to adequately apply granular materials up to speeds of 25 mph.

Figure 2: An on-board pre-wetting system (right) and Zero Velocity Dispensing Unit (left);.

2.4 Pre-Wetting Laboratory and Field Studies

In theory, only a sufficient amount of liquid to wet every particle of a dry chemical is required for pre-wetting. The actual rate to achieve this wetting will vary with the particle size distribution, but 8–12 gallons of liquid per ton of solid is fairly common. Several agencies use higher pre-wetting rates, perhaps to improve salt activation or reduce corrosion. Laboratory tests have been conducted by Zhang et al. (2018), Koefod (2018), Alger & Haase (2006), and Luker et al. (2004). Field tests have been conducted by Kaur (2018), Usman et al (2018), Chebot et al. (2015), Michigan DOT (2012), Vaa (2004a and 2004b), and Larrimore et al. (1979).

Table 1: Summary of Pre-Wetting Laboratory Tests

Lab Test Conditions	Significant Findings	Reference
Ice, solid salt, pre-equilibrated diluted brines in reaction vessel in recirculating temperature-controlled bath, with and without mixing. Samples removed at time intervals to measure concentration. Calculate ice melting and salt dissolution.	$CaCl_2$ and $MgCl_2$pre-wetting brines melted ice faster than NaCl pre-wetting brine; $CaCl_2$ was slightly faster than $MgCl_2$. $CaCl_2$ ice melting rate was less dependent on mixing than NaCl.	Koefod (2017)
SHRP Ice Melting Tests run in triplicate at 15, 20, 25°F using No.4–No.8 solid salt pre-wetted with 5 different liquids at 6, 8 and 10 gal/ton	No observed ice melting benefit by increasing pre-wetting weight from 6–10 gal/ton, although at 15°F and 10 gal/ton dry salt performed worse than pre-wetted salt. At many other temperatures and pre-wetting rates dry salt performed as well as pre-wetted salt.	Alger & Haase (2006)
"Snow" collected from Zamboni and compacted onto asphalt samples exposed to periodic trafficking with manually operated trailer tire with 750 lb vertical force. Friction measurements collected at 25-pass intervals. Tests at temperatures of 30, 23, and 14°F with 4, 8, and 12 gal/ton pre-wetting with water and six commercial liquid deicers.	Pre-wetting was more beneficial at colder temperatures. Water was an ineffective pre-wetting liquid. Melting and friction increased with increasing pre-wetting rates. "No single deicer and salt mixture performed best at all temperatures."	Luker et al. (2004)

Table 2: Summary of Field Pre-Wetting Studies

Field Test Conditions	Significant Findings	Reference
Three sections of Ontario highway treated at 5%, 10% and 20% pre-wetting ratios (10, 20, and 40 gal/ton, respectively) during 2016–17 winter season	Pre-wetting at 40 gal/ton resulted in higher friction and lower overall material application. Pre-wetting at 20 and 40 gal/ton had 11% and 15% friction improvements than 10 gal/ton. Pre-wetting at 20 gal/ton used 13% more salt and 22% less sand and pre-wetting at 40 gal/ton used 19% less salt and 35% less sand than 10 gal/ton.	Kaur (2018)
Two sections of Ontario highway treated with dry (1000 lb/LM) vs pre-wetted sand (1000, 850 and 700 lb/LM). Data collected included friction trailer, optical friction, dashcam images, traffic volume, weather.	At same application rate (1000 lb/LM) pre-wet sand had better friction improvement (187% average) than dry sand. 700 lb/LM pre-wet sand had poorer friction than 1000 lb/LM dry sand. Mixed results when comparing 850 pre-wet sand to 1000 lb/LM dry sand, but generally comparable and with less overall sand usage.	Usman et al. (2018)
Evaluated Epoke (pre-wet capable spreader) compared to Caltrans existing V-box (solid only spreader)	Caltrans will modernize their fleet and capabilities, but needs to do field testing to quantify pre-wetting benefit to use of sand vs salt.	Chebot et al. (2015)
Quantified and observed bounce and scatter of dry vs pre-wet salt (8 gal/ton of blended $CaCl_2$, ag byproduct and corrosion inhibitor) applied to bare pavement (during no-snow conditions) at varying vehicle speeds (25, 35, 45 mph) with rear cross conveyor vs Y-chute by vacuuming grids of salt	Truck speed most critical parameter – target retention nearly double at 25 mph than 35 mph. Pre-wet salt performed better than dry salt at all vehicle speeds. Best performer: 25 mph, cross conveyor with pre-wet salt. Worst performer: 45 mph, Y-chute delivery with dry salt	Michigan DOT (2012)
Pre-wet sand with hot water (195–205°F) at about 30% by weight. Measured friction with two variable-slip wheel continuous friction devices	Satisfactory friction for up to 7 days on roads with AADT 1,000–1,500 with warm wetted sand. Dry sand ineffective after 50 vehicle passes; warm wetted sand effective after more than 2,000 vehicles	Vaa (2004a)
Compared NaCl vs $MgCl_2$ as pre-wetting liquid to solid salt at pre-wetting ratio of 70% salt to 30% liquid by weight. Two roads in Oslo used for testing throughout 2 winter seasons,	Road section with $MgCl_2$ used more overall salt than NaCl road section. Friction results were mostly inconclusive except at low temperatures (below 14°F) where	Vaa (2004b)

both 4-lane/2-direction; one road used NaCl the other road $MgCl_2$. Measured friction with Roar Mark 1 friction trailer for some storms.	$MgCl_2$ road section generally had better friction than NaCl road section.	
Provided a review of field and laboratory studies. Field tests were in Clayton County, Iowa and 8 districts in Michigan.	Overall salt reduction of 25–50% is possible by pre-wetting. Rock salt may be effectively used if pre-wet with $CaCl_2$ liquid as low as 0°F, but claims of salt pre-wet with $CaCl_2$ down to -20°F are not practical.	Larrimore et al. (1979)

2.5 Summary

A review and synthesis of current pre-wetting practices indicates a lack of systematic laboratory and field studies have been conducted. Current practices seem to be primarily based on agency trial-and-error or observations.

Chapter 3. Survey of Pacific Northwest States

3.1 Introduction

A survey of Pacific Northwest State Departments of Transportation was conducted to assess local pre-wetting practices within states. The online survey received 31 responses, distributed among Washington, Oregon, Idaho and Alaska as shown in Figure 3.

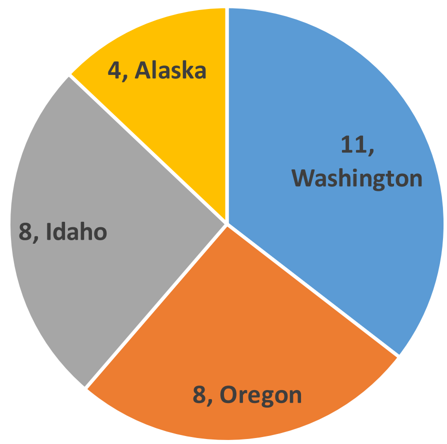

Figure 3: Number of survey responses from each state

The rest of this chapter includes the results obtained regarding pre-wetting materials and application rates.

3.2 Pre-Wetting Materials

Pacific northwest states tend to use salt and sand, as well as salt/sand blends throughout the winter depending on temperatures, local budgets and regulations. The number of respondents (shown in parentheses) using the following types of solid material are:

- salt only (12)
- sand only (4)
- sand/salt separately or blended depending on storm (19)

The ratio of sand/salt blends used varies from 20:1 to keep sand from clumping to 1:1 by volume. The number of responses for each blending ratio provided was:

- 20:1 (1)
- 6:1 (1)
- 5:1 (4)
- 3:1 (3)
- 2:1 (2)
- 1:1 (3)

The liquid products used for pre-wetting include NaCl (8 reponses), $MgCl_2$ (14 responses) and $CaCl_2$ (2 responses).

3.3 Pre-Wetting Application Rates

Pre-wetting liquid-to-solid application rates are typically expressed as gallons of liquid per ton of solid material (gal/ton). The most common application rate is 10–12 gal/ton, used by almost half of the respondents. However, almost a third use more than 15 gal/ton.

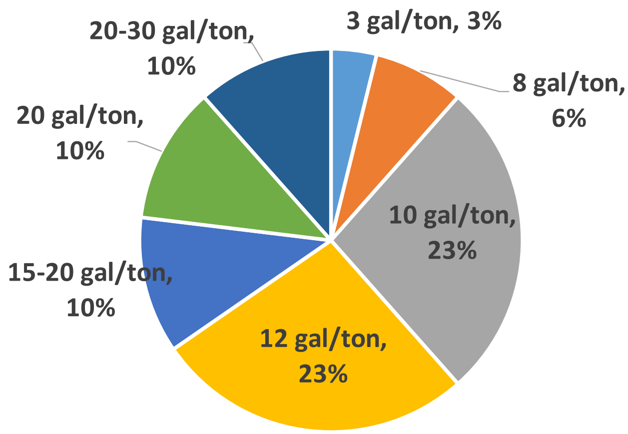

Figure 4: Pre-wetting liquid-to-solid application rates reported by respondents.

When asked if all material is pre-wetted before applying on roads or if sometimes dry salt, sand or salt/sand mix was applied the responses were fairly mixed with 16 always pre-wetting and 14 sometimes pre-wetting.

Application rates of pre-wetted material during a winter storm depend on pavement temperature and snowfall. The specific responses to the question of "What are your typical road application rates (for example 250 pounds per lane mile) for pre-wetted material? For what temperatures and snowfall amounts?" are shown in .

Table 3: Responses to Pre-wetted Material Road Application Rates (typos corrected without notation)

• 150/200 lb/lane mile. Temps at or below freezing with light snow.
• varies with the storm and temps .
• 250 28 degrees light snow fall
• snow---temperature 16 to 20 -- 250 lbs • frost and black ice --- temperature 26 to 30 -- 250 lbs • This based on a lap time it could be more if your lap time is longer
• 400 salt • 800 mixed
• 100-125 pounds per lane with 10-20 gallons, this is once the Rd. is bare and wet to maintain. 32–20°F with little to no snowfall. • 150 pounds per lane with 10-20 gallons 32–15°F with light snowfall. • 200 pounds per lane with 20 gallons 32–15°F with moderate - Heavy snowfall. • 100- 150 pounds per lane with 20-30 gallons 32–20°F with no snow but heavy frost
• Frost, Black Ice and Freezing fog 100 to 150 pounds per lane mile.

• Light snow 33° to 15° 100 to 100 to 250 pounds per lane mile. • Moderate snow 32° to 15° 150 to 250 pounds per lane mile. • Heavy Snow 32° to 15° 200 to 350 Pounds per lane mile. • Freezing rain 32° to 15° 200 to 400 Pounds per lane mile. • Below 15° Apply abrasives.
• 150 to 250 lbs. lane mile salt Above 20°F ice, frost, pre treat snow event & after snow stops falling. • Salt sand mix, typical 300 to 400 lbs. per lane mile and up to 800 if necessary. Below 20°F or during snow event when snow has compacted on surface and traction is immediately needed. This is most common during heavy snowfall on the west side of the state. • Future forecast also plays a part in determining prescriptions.
• 200 to 300 lbs of salt prewet with 15 gallons of brine per ton.
• We follow the clear roads matrix. Everything is based off surface temperatures and what type of moisture you’re getting.
• We refer to the "Clear Roads Matrix"
• 200 lb. salt to peel compact • 800 lb. sand for traction during storms
• 450 LBS/ mile 20 degrees and higher at 1 inch /hr. 2 hour lap time.
• On average, 150 to 200 lbs/ lane mile and 10 gal/ ton for pre-wet. This is for temps ranging from 25° to 34° and ranging from black ice to a couple inches of snow.
• 100 to 400 lbs. per lane mile, very seldom do we use the higher rates. You can not melt a snow storm.
• Pre wet only for cold temps with high winds.
• 200 lbs per lane mile
• 300#/ LM for rock salt. 500#/LM for sand • We apply brine directly to the road surface down to +10°F. Salt down to +5°F and sand down to -30°F.
• 50 - 250 lbs at20° - 35°F
• The Max rate is 300 per lane mile, the average use is about 225 lb of salt per lane mile. Sometimes pre wet sometime not depends on the moister content of the Snow/ Road surface. 32° to 15°F, snow amounts 2 in per hour of snow.
• 150-300
• 200 / 30 and below
• 200 pounds per lane mile for light snow fall and temperatures no less than 18 degrees.
• 100-200 lbs per lane mile depending on forecast and temps
• 100 pounds per lane mile
• 100 to 200 lbs per lane mile

3.4 Summary

Pre-wetting is commonly performed by Pacific Northwest state DOTs with 10–12 gal/ton being the most common liquid-to-solid application rate. Pre-wet material road application rates vary from 100 – 450 lb/LM for salt and up to 800 lb/LM for sand, depending on temperature and snowfall intensity

Chapter 4. Laboratory Testing

4.1 Introduction

Initial laboratory tests were conducted to assess the ice melting behavior of pre-wet deicers with a variety of liquid-to-solid and pre-wet solid application rates at temperatures of 25° and 15°F. Select pre-wet deicers were then tested with more sophisticated laboratory tests on asphalt pavement with realistic snow and representative trafficking motion and forces.

4.2 Ice Melting Tests

Ice melting tests were conducted in substantial accordance to SHRP standard test methods in a walk-in environmental chamber. Ice samples were made in 5.5-inch diameter Petri dishes with 48.5 ml deionized water and frozen at the test temperature (25 and 15°F). Solid salt was donated by WSDOT with the grain size distribution shown in Figure 5. Samples of dry salt were prepared to mimic the gradation as shown in Table 4 for both 1,000 lb/LM and 2,000 lb/LM application rates. Liquid deicer was applied to solid salt samples with a micropipette and stirred for 15 seconds before applying the pre-wet salt to the ice sample. Melted ice was collected by titling the ice sample and using a syringe to capture brine at the edge and from within pockets of melted ice. Collected brine was returned to the ice after recording the volume at 15-minute intervals. Liquid-to-solid application rates were 8 and 16 gal/ton, corresponding to 39 and 79, and 79 and 158 µl for the 1.18 and 2.36 g salt samples, respectively. The liquid deicers used for pre-wetting the solid salt were:

- 23.3% sodium chloride, specific gravity 1.179 at 60°F
- 32% calcium chloride, specific gravity 1.314 at 70°F
- 30% magnesium chloride, specific gravity 1.26 at 60°F
- 80/20 by volume blend of 23.3% NaCl brine (80 ml) with beet juice (20 ml); beet juice provided by WYDOT
- 97/3 by mass blend of 23.3% NaCl brine (97 g) with concord grape-based additive (3 g) formulated for specific temperatures (slightly different formula for 25°F and 15°F), details of concord grape-based additive available in Honarvar Nazari (2018).

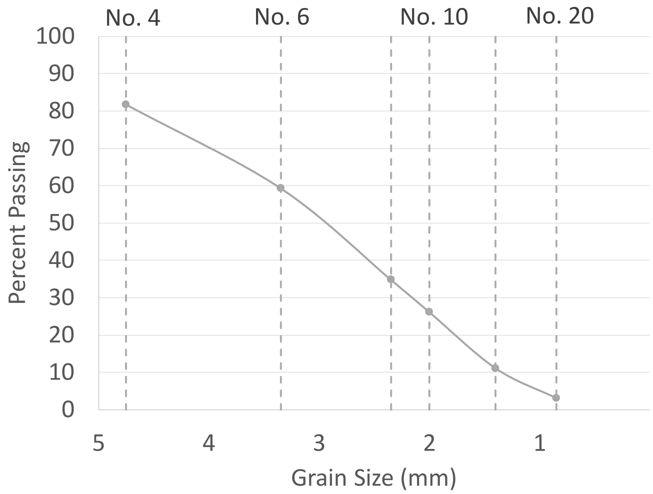

Figure 5: Grain size distribution of air-dried WSDOT solid salt

Table 4: Salt Samples for Ice Melting Tests

Sieve Size (pass – retained)	Mass (g) for 1,000 lb/LM	Mass (g) for 2,000 lb/LM
4 – 6	0.323	0.647
6 – 8	0.354	0.708
8 – 10	0.126	0.251
10 minus	0.377	0.754
Total	1.180	2.360

Ice melting test results for sample measurements during the 60-minute test are presented in Figure 6–Figure 8. A summary of all results at the terminal 60-minute measurement is shown in Figure 9. Pre-wetted salt worked better than dry salt at 1,000 lb/LM at 25°F and 2,000 lb/LM at 15°F. The biggest different observed between the types of liquid used for pre-wetting were at 25°F 1,000 lb/LM tests. At the colder temperature of 15°F the pre-wetting liquids worked similarly and each better than dry salt. Considering all temperatures and application rates the ranked order of liquids from best to worst are: $CaCl_2$, Grape blend, Beet blend, 23% NaCl, Dry*, $MgCl_2$, although in a field test dry salt would likely perform the worse because of bounce and scatter, which was not simulated in the laboratory.

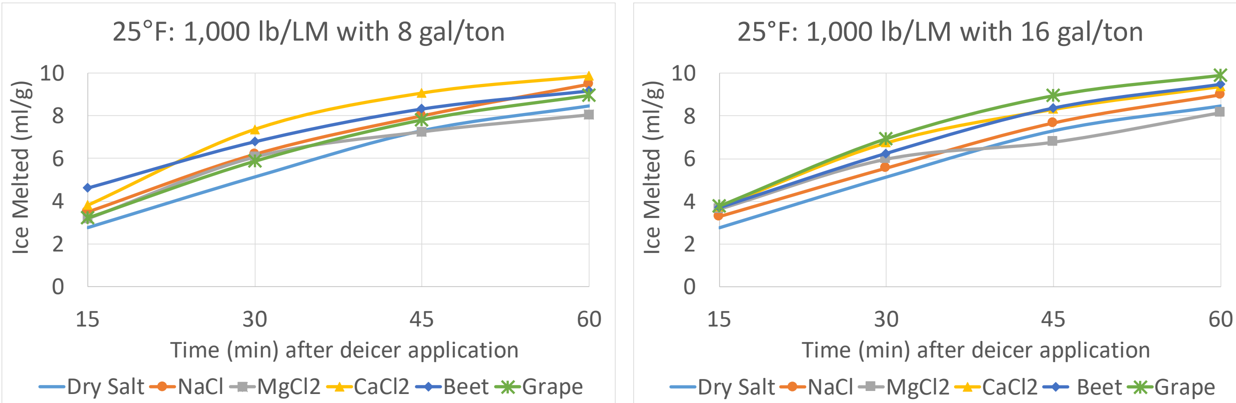

Figure 6: Ice melting test results at 25°F for 1,000 lb/LM application at 8 gal/ton (left) and 16 gal/ton (right)

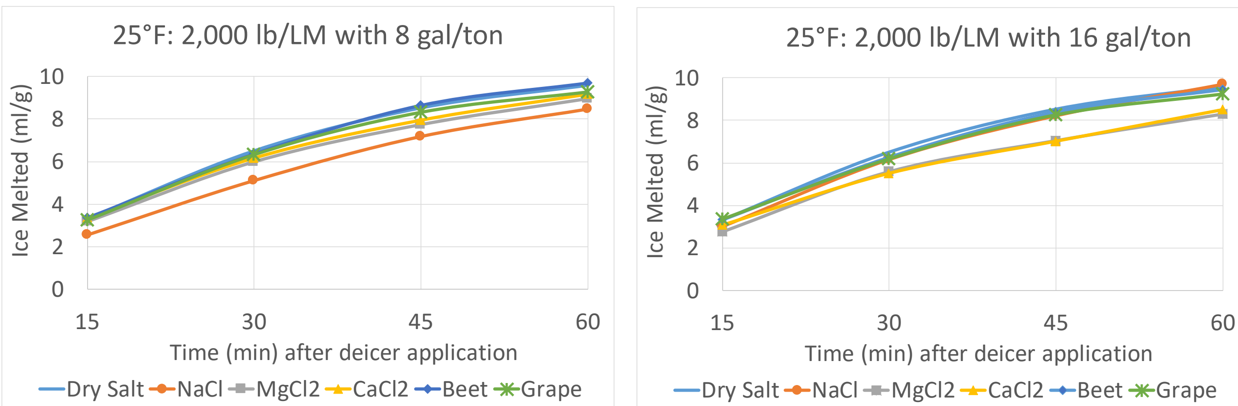

Figure 7: Ice melting test results at 25°F for 2,000 lb/LM application at 8 gal/ton (left) and 16 gal/ton (right)

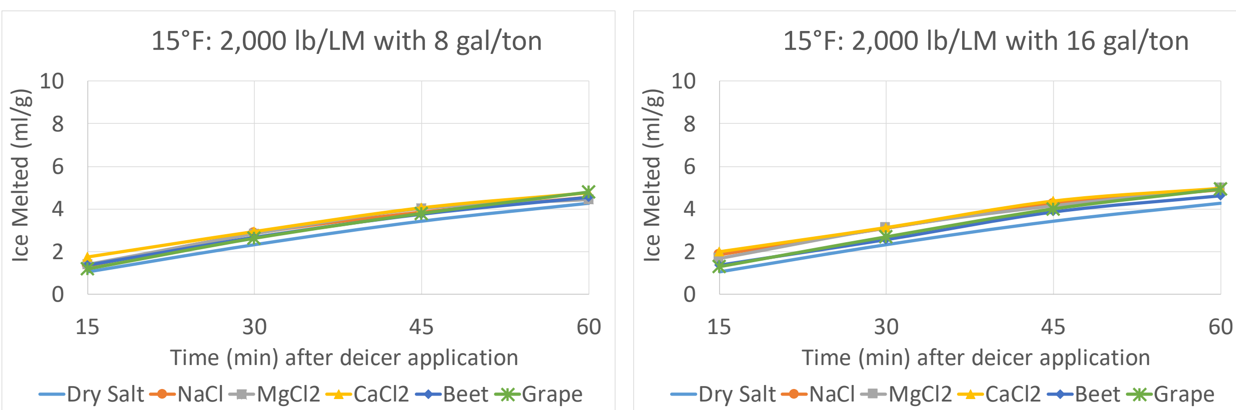

Figure 8: Ice melting test results at 15°F for 2,000 lb/LM application at 8 gal/ton (left) and 16 gal/ton (right)

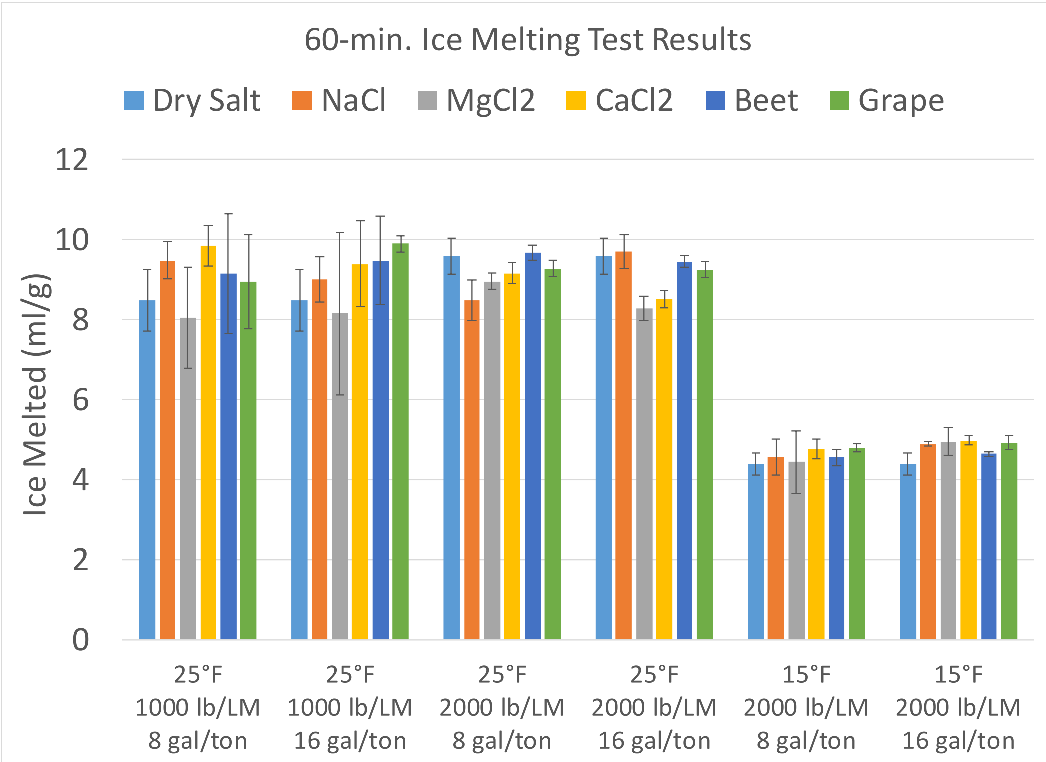

Figure 9: Summary of all ice melting test results with ± 1 standard deviation

4.3 Snow–Traffic–Plowing–Friction Tests

More sophisticated tests with snow, traffic, plowing and friction measurements were conducted to further compare the effect of pre-wetting in the laboratory. Tests were conducted at the Subzero Science and Engineering Research Facility at Montana State University. Snow is made at the facility and stored at 5°F and then equilibrated to the test temperature during sieving. 800 g of sieved snow (1 mm opening) is applied onto asphalt pavement samples and compacted for 5 minutes at 60 psi. Pre-wetted salt is uniformly distributed across the sample in a grid pattern with 2-in. spacing between rows and columns. Salt was sieved between the No. 4 and No. 6 sieve and combined with salt sieved between the No. 6 and No. 8 sieve to ensure 36 salt particles with a total weight of 2.13 g was isolated. This corresponds to an application rate of 250 lb/LM. Pre-wetting liquid was pipetted onto the salt and stirred for 15 seconds before applying to compacted snow. Pre-wetting liquid-to-solid application rate of 16 gal/ton using NaCl, grape-blended salt brine and beet juice-modified salt brine was investigated. 18 minutes after the last salt particle was placed on the snow, the sample was trafficked for 500 passes (equivalent to 250 vehicles) over about 12 minutes. Eight individual 2-in. square snow samples were isolated to measure the horizontal force required to shear the snow from the pavement. Static friction measurements were collected throughout the test beginning on clean, bare pavement, after snow compaction, after trafficking and after plowing. The sequence of steps during these tests are shown in Figure 10. More details about the snow-making, compaction and trafficking equipment is available in Akin et al. (2018).

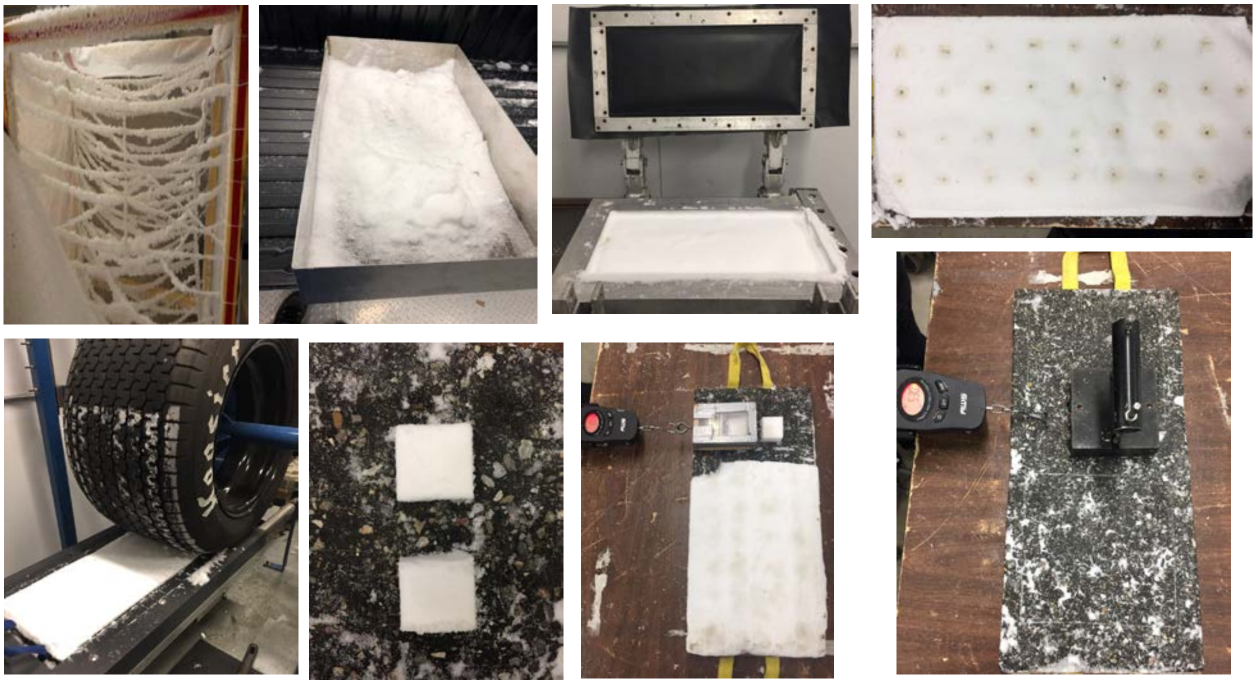

Figure 10: Sequence of steps during snow-traffic-plowing-friction tests.

Friction varied throughout the test beginning at 0.74 on clean, dry pavement. Average friction after snow compaction before deicer application was 0.26. After trafficking friction averaged 0.24. The friction after plowing varied greatly depending on deicer treatment, ranging from 0.2 to 0.63. Pre-wetting reduced the snow–pavement bond compared to dry salt and control tests with no deicer application, as shown in Figure 11. The highest friction after plowing was observed with the dry salt test, although this experiment did not mimic the bounce and scatter that would be expected during application by material spreaders. The best-performing pre-wetting liquid with respect to friction was NaCl and with respect to snow–pavement bond was beet-modified salt brine.

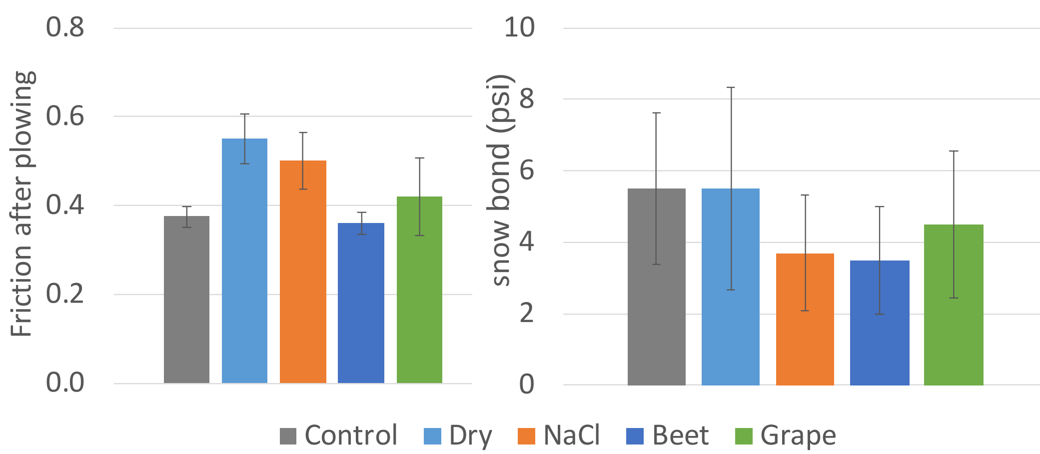

Figure 11: . Friction and snow–pavement bond for pavement #3; NaCl, Beet and Grape with 16 gal/ton prewet rate

Chapter 5. Recommended FOTs

5.1 Introduction

The laboratory tests confirmed that pre-wetting liquid-to-solid application rates in the range of 8–16 gal/ton are reasonable for increasing the speed and total ice melting capacity of solid salt. Furthermore, prewetting significantly reduces the snow–pavement bond, but does not seem to increase friction more than dry salt. One key limitation of the laboratory tests conducted was that bounce and scatter from realistic application speeds was not included – that is, it would be expected that in the field the quantity and density of pre-wet salt on compacted snow and ice would be significantly greater than dry salt, but the quantity and density of salt during the laboratory tests was the same for dry and pre-wet salt. Thus field tests are critical for expanding the knowledge and identifying specific best practices of pre-wetting. This chapter provides an overview of recommended field test locations, materials, winter storm scenarios and products that should be included, as well as recommended data collection parameters.

3.1.1. **FOT Parameters**

Three target performance parameters of pre-wetting should be considered in the experimental design. To evaluate the bounce-and-scatter reduction, the spread material should be vacuum collected from various grids on the pavements and weighed. The Michigan DOT bounce and scatter study (2012) serves as an excellent template in further evaluation of variables such as type of pre-wet chemicals, pre-wetting/application rates, methods of pre-wetting, spreader height, vehicle speed, etc. To evaluate the salt activation, digital photos along with on-board friction sensor readings will be used. Both an optical, non-contact friction sensor (e.g., Teconor RCM411, Lufft MARWIS, Vaisala DSC111, or Innovative Dynammics Mobile IceSight, etc.) and a rubber/tire contact friction device (e.g., Halliday Technologies RT3, ASFT T-5, or Neubert Aero Corp Dynamic Friction Tester, etc.) should be used. Both the spreader/pre-wetting equipment and these units should be calibrated at the beginning of each FOT. To evaluate the corrosion inhibition benefits of pre-wetting solid salts, pre-wet (vs. nominally dry) salt samples from the pavement should be collected sealed for subsequent laboratory evaluation of corrosivity.

3.1.2. **Pavements and Road Classification**

Asphalt and concrete pavements should be included in the field testing. Two types of asphalt pavements are recommended – traditional dense-graded pavement and an open-graded pavement (open graded friction course, ultrathin bonded wearing course, or porous asphalt). Concrete pavements and bridge decks should also be included. A range of traffic volumes should also be included, such as low-volume (<2,000 AADT), moderate (~6,000 AADT) and high-volume (>10,000 AADT) roads with straight segments and minimal intersections. Various posted speed limits should also be included, such as 25, 45 and 65 mph. Preliminary tests should be conducted in a parking lot to practice material application and sample collection.

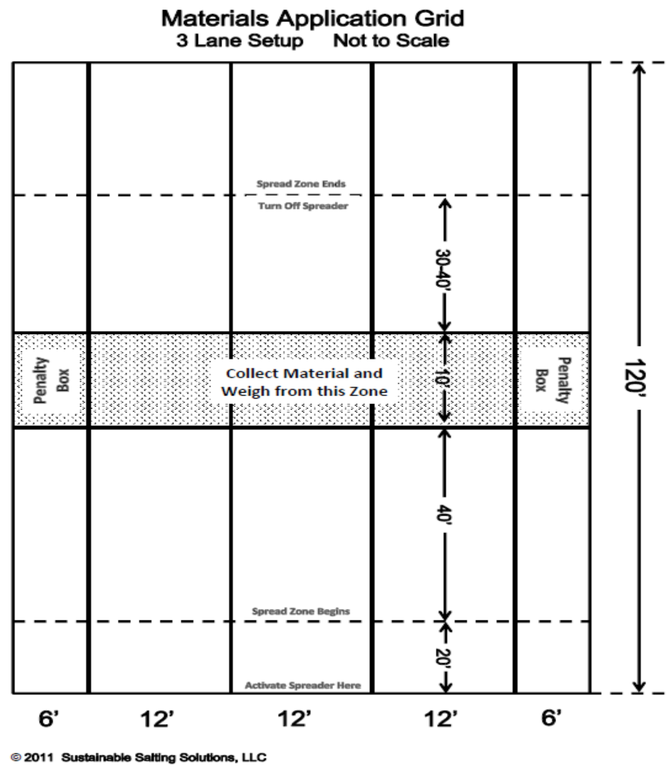

Figure 12:: A possible Materials Application Grid for the FOTs of pre-wetting operations

For the field operational tests (FOTs) designed to investigate the best practices of pre-wetting operations, the following provides a draft document of considerations.

3.1.3. Data to be Collected

- Weather: air and pavement temperatures, relative humidity, wind speed and direction, solar radiation, and sky condition (clear, partly cloudy, or overcast). The temperature should be measured in the same place, even if it is necessary to remove the snow to measure the below pavement temperature but it must be the same location not adjacent any point. The ambient air temperature must be recorded as well. Snowfall intensity, duration and density should be measured throughout the test.
- Pavement surface condition: wet or dry, surface temperature.
- Field measurements: spread area in test lane, scattered area out of test lane.
- Test materials: Liquids and solids from the same source and batch should be used throughout the field testing. Before use in testing, a sample of the material will be tested for its moisture content and gradation of the nominally dry salts and abrasive following standard procedures.
- Spreader Equipment Type, Calibration, and Application Timing/Rate/Speed: Preferably, three types of spreader equipment will be tested: easy, moderate, and advanced. Conduct a grab test where a truck is elevated and samples of both solid

and liquid are collected at varying truck speeds. Adjust factors like truck speed, spreader angle, etc. to achieve desired application rate. Calibrate the on-board friction sensor unit.

- Friction at regular intervals throughout test
- Video and images throughout test

5.2 Summary

Field operational tests will be critical to fully quantify pre-wetting benefits and recommend specific best practices. Tests should be conducted in multiple states with cooperative maintenance staff dedicated to quality data collection.

Chapter 6. Conclusions and Recommendations

6.1 Introduction

Applying prewet deicers during winter storms is a cost-effective strategy to improve deicer performance. Prewet deicers have a small amount of liquid product applied to solid salt or salt/sand which helps activate the ice melting and penetration and significantly reduces bounce and scatter. Prewetting keeps the product on the road and improves the ability of plows to removed compacted snow and ice. While many agencies use prewet deicers, there is not enough reliable data to determine optimal prewetting rates or product type.

6.2 Summary and Conclusions

For the ice melting tests, pre-wetted salt worked better than dry salt at 1,000 lb/LM at 25°F and 2,000 lb/LM at 15°F. The biggest different observed between the types of liquid used for pre-wetting were at 25°F 1,000 lb/LM tests. At the colder temperature of 15°F the pre-wetting liquids worked similarly and each better than dry salt. Considering all temperatures and application rates the ranked order of liquids from best to worst are: $CaCl_2$, Grape blend, Beet blend, 23% NaCl, $MgCl_2$. For the snow–traffic–plowing–friction tests, pre-wetting reduced the snow–pavement bond compared to dry salt and control tests (no deicer application). The highest friction after plowing was observed with the dry salt test, although this experiment did not mimic the bounce and scatter that would be expected during application by material spreaders. The best-performing pre-wetting liquid with respect to friction was NaCl and with respect to snow–pavement bond was beet-modified salt brine. The laboratory tests confirmed that pre-wetting liquid-to-solid application rates in the range of 8–16 gal/ton are reasonable for increasing the speed and total ice melting capacity of solid salt.

6.3 Directions for Future Research

Field testing should be conducted to assess the effects of various pre-wetting liquid-to-solid application rates and specific liquid products to 1) reduce bounce and scatter, 2) reduce overall salt application rates, 3) improve friction, 4) quicken bare pavement regain time, and 5) increase longevity of winter traction materials with variable-speed traffic.

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Appendix A: Survey Questionnaire

This survey is part of a CAMMSE research project to understand the influence of prewetting product type, prewetting ratio, and application rate of prewet deicing salt on the friction performance of asphalt pavements. Prewetting materials and application rates vary significantly - please let us know what products you use. Individual responses will be aggregated to protect your privacy. For any questions or clarification, please contact Michelle Akin at michelle.akin@wsu.edu or 509-335-0514.

Q1 Do you prewet solid material with liquids before spreading onto roads?

- O Yes, at the spinner with on-board prewetting equipment
- O Yes, at the stockpile
- O Yes, as material is loaded into the truck
- O No

Q2 What solid material do you use?

- ☐ Salt
- ☐ Sand
- ☐ Sand/Salt mix (see Q3)

Q3 What is your sand/salt mix ratio? (For example 5:1 by volume/scoops or 5:1 by weight)

____

Q4 What liquid product do you use?

____

Q5 What prewetting rate do you use?

- O 8 gallon/ton
- O 10 gallon/ton
- O 12 gallon/ton
- O other (see Q7)

Q6 What "other" prewetting rate do you use? ____________________________

Q7 What are your typical road application rates (for example 250 pounds per lane mile) for prewetted material? For what temperatures and snowfall amounts?

____

Q8 Is all your material prewetted before applying on roads, or do you sometimes apply dry salt, sand or salt/sand mix?

- O All prewet
- O Sometimes prewet

Q9 Please describe your location. WSDOT, ITD, ODOT or AKDOT&PF (which region or area, city or county?)

____

Q10 May I contact you to hear more about your prewetting practices and performance?

- O Yes (see Q11)
- O Maybe (see Q11)
- O No

Q11 Great, thanks! What's your name and email or phone number? ____________________

Q12 Do you have any comments about prewetting you want to share, or any other information to provide? ____

Thanks so much for sharing information about your prewetting practices. If you want to contact me with any additional information you can reach me at michelle.akin@wsu.edu or 509-335-0514.