An Experimental Study on the Effectiveness of Anti-icing Operations for Snow and Ice Control of Parking Lots and Sidewalks

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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 a wide 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.
1. INTRODUCTION

The cost of winter road maintenance is substantial in Canada. Over $1 billion is spent annually for winter operations (TAC, 2003). This large cost includes the use of large amounts of road salts for de-icing and anti-icing operations to remove snow and ice from transportation facilities. However, salt is detrimental to the environment and has corrosive effects to the infrastructure and vehicles damages (Mussato et al., 2004, NCHRP-577, 2007; Shi et al., 2009; Jain et al., 2012). To reduce maintenance costs and the adverse effects of salts, a significant amount of efforts have been made to improve the efficiency and effectiveness of winter maintenance methods. One of the effective strategies is anti-icing, which involves applying salt or other freezing point depressants prior to a snow event in order to prevent the formation of snow or ice bond with the pavement surface (Ketcham et al., 1996; NCHRP-526, 2004).

Anti-icing has been recognized to have several significant benefits. First, it helps prevent the snow from bonding with the pavement, thus achieving a higher level of friction over a snow event. Second, for the same reason, anti-icing can substantially minimize the plowing efforts, resulting in clearer pavement or minimal leftover snow. Third, in the case of a light snow event, the pre-applied salt can melt all the snow, providing the level of service expected over a shorter period. Lastly, anti-icing treatments can be made over a wider time window, enabling contractors to be able to better manage their resources.

However, these benefits have mostly been shown or discussed in the context of roadway maintenance with very few studies focusing on the effectiveness of this strategy and determine its best practice when it is applied for snow and ice control of parking lots and sidewalks. The operating conditions of parking lots and sidewalks are significantly different from roadways, which means materials and rates that are ideal for roadway anti-icing treatments may not be suitable for parking lots and sidewalks. For example, only liquid salt is effective for roadway maintenance as solid would be easily dispersed by vehicular traffic; however, the vehicular traffic within parking lots is substantially lower than on roadways.

The objective of this research is to address several critical questions related to anti-icing operations for transportation facilities mainly concerned with pedestrian traffic such as parking lots, sidewalks, and platforms. In particular, the research is to answer the questions as follows: a) how effective is anti-icing treatment in preventing the bonding of snow and ice to pavement?
b) what is the relative effectiveness of anti-icing operation as compared to de-icing? c) what is the optimal anti-icing application rate for specific weather and site conditions? and, d) what is the comparative performance of different anti-icing materials?

This paper provides a detailed discussion of the results of a series of field tests conducted to determine the conditions under which the anti-icing method can be more effective for a wide range of pavement and environmental conditions in parking lots. The results of this study provide a solid foundation for determining the optimum anti-icing methods, materials and application rates for snow and ice control of parking lots and sidewalks under various winter conditions.

2. LITERATURE REVIEW

Numerous past studies have attempted to determine the effectiveness of anti-icing on road systems. Related guidelines and manuals have also been developed for highway anti-icing treatments (Ketcham et al., 1996; NCHRP-526, 2004; Minnesota DOT-TRS-0902, 2009). Blackburn et al. (1994) conducted a two year study to investigate the effectiveness of anti-icing. They found that anti-icing can be effective at a temperature above -9°C with solid salt application rate of 100lb/lane-mile (1.57 lbs/1000sqft), using saturate brine for pre-wet at a rate of 0.021 to 0.025 Liter/kg (5 to 6gallons/ton). They also found that anti-icing is not effective during prolonged snow fall or freezing rain. The study found that, compared to brine, magnesium chloride was more successful for preventing bonding at a temperature of -5°C. Also, based on a few case studies, they found that an anti-icing operation saves costs for both maintenance organizations and road-users. For maintenance organizations, the cost saving is lower application rates, and for road-user, the cost saving is fewer accidents due to the improvement in the pavement condition. Several other studies also reported the end benefits of anti-icing as compared to the conventional method of de-icing (Amsler D., 2006; O’Keefe and Shi, 2005).

Based on a series of workshops with the maintenance personnel, Amsler D. (2006) reported that anti-icing operations can be effective with solid salts if they are properly applied and can stay on the pavement after application. However, for the road sectors, solid salt with water or another liquid chemical is recommended in order to minimize the bounce and scatter tendencies of salts from the wind-blow caused by vehicular traffic. The NCHRP-526 report
(2004) also states that dry solid salt can be effective under pre-application (anti-icing) when applied at traffic speed under 45km/h, and traffic volume under 100 vehicles per hour. The report also indicates that parking areas present a unique potential for anti-icing operations with solid salt for the reason of less expected dispersion effects.

Regarding anti-icing materials, past studies have evaluated the relative performance of regular dry salt, pre-wet salt and regular brine. Fonnesbech J. (2007) conducted a study to evaluate anti-icing performance of pre-wetted salt and brine. They compared pre-wetted salt (salt and brine ratio of 70:30 by weight) at application rate 10gm/m² (2.05lbs/1000sqft) to 20 % brine applied at 20ml/m² (6.10L/1000sqft or 80gallons/lane-mile). The study showed anti-icing with brine is more effective than pre-wetted salt due to the more evenly distribution and longer retention of brine. Fu et al. (2012) conducted another study for the effectiveness of anti-icing using different liquids and pre-wetted solid salt. The study evaluated the performance of regular brine compared to a mixture of beet juice and brine (30:70 mixture). The effectiveness was measured comparing the friction data from the test sections treated by the above mentioned anti-icing materials. They employed both materials as pre-wetting liquids, and direct applications. Their study revealed that both brine and the mixture performed similarly by achieving the same range of coefficients of friction when they were used as a pre-wetting chemicals, while the mixture outperformed brine when they were applied alone as direct application on the roadways.

In summary, a number of studies have been conducted in the past to evaluate the effectiveness of anti-icing, and to develop guidelines for anti-icing materials and application rates; however, these studies have exclusively focused on highways. The results from these studies cannot be transferred to the low volume transportation facilities, such as parking lots, sidewalks, and transit platforms, due to the significant differences in service requirements and operating conditions. The objective of this study is to develop a quantitative understanding of the effectiveness of anti-icing for specific weather conditions, thus providing guidelines for selecting the right anti-icing methods, materials, and application rates for snow and ice control in parking lots and sidewalks.
3. DESCRIPTION OF FIELD TEST

In order to investigate the effectiveness of ant-icing, a series of field tests were conducted during the winter season of 2012-2013. The tests were conducted under a wide range of weather conditions covering 50 events (Figure 1). The following section details the test site, testing method and results.

![Figure 1: Winter Events 2012-2013](image)

### 3.1 Test Site

The test site location was Parking Lot C, which is at the south-east end of the University of Waterloo’s South Campus (Figure 2). The parking lot is made of asphalt concrete and is in good condition, with a slight sloping throughout. There are 900 parking stalls and 8 driveways. The tests took place in multiple locations within the parking lot. These locations were recorded on a map to avoid repetition and contamination of the data.
3.2 Test Method

Anti-icing treatments were performed 2 to 12 hours in advance of snow events while de-icing operations were done at the end of the snow events. Solid road salt was tested over all the anti-icing events under both plowed and unplowed conditions while liquid salts were only tested for the relatively long storms and under plowed pavement conditions.

The test sections were cordoned off to prevent traffic contamination of the tests. Hence, the results from these tests can be directly applicable for foot traffic ways (platforms, side-walks) and parking lots with low volume vehicular traffic. The results can also be equally used for the worst possible case scenarios for any parking lots. Note that separate tests have been conducted on driveways to account for traffic effects and the results will be reported in a separate publication.

The solid material used in this study was solid regular road salt. The liquid salts used were regular Brine, Caliber M1000, and Snow Melter 2. Table 1 shows the chemical compositions of each type of material used in the tests.
### Table 1: Materials Used in the Tests

<table>
<thead>
<tr>
<th>Salt Name</th>
<th>Constituents</th>
<th>Composition Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regular Road Salt</td>
<td>NaCl</td>
<td>100%</td>
</tr>
<tr>
<td>Brine</td>
<td>NaCl, Water</td>
<td>23.3%, 76.7%</td>
</tr>
<tr>
<td>Caliber M1000</td>
<td>Magnesium Chloride, Carbohydrate, Water</td>
<td>27%, 6%, 67%</td>
</tr>
<tr>
<td>Snow Melter 2</td>
<td>Glycerine, Polyether Polymer, Sodium Lactate, Sorbitol, Sodium Formate, Sodium Acetate, 1, 2-Butanediol, Water</td>
<td>15%-20%, 10%-20%, 4%-10%, 2%-4%, 1%-4%, 1%-4%, 1%-2%, Balance</td>
</tr>
</tbody>
</table>

There are many similarities of how the anti-icing and de-icing experiments were conducted. The salt types and application process were identical. The solid salts were measured out using an electronic scale and were applied manually, and the liquid salts were applied with the liquid sprayer called SnowEx SL-80.

The solid salt application rates varied from 5 to 50lbs/1000sqft, where 5 to 25lbs/1000sqft were commonly used, and liquid salts tested at rates of 3 to 10L/1000sqft. First, trials were set on recommendations from manufacturers and then adjusted considering snow conditions, pavement temperatures, and other variables as tests proceeded over the period. For each liquid tested, the ejecting rate from the spray nozzle was calibrated first. Then the spraying times for tested sections (a typical parking stall 8ft x20ft) for various application rates for each liquid were calculated (this is due to the difference in their viscosity). The spraying times for Brine, Caliber M1000, and Snow Melter 2 have been tabulated in Table 2 as an example. Several iterations and calibrations of the spraying times were conducted, ensuring a uniform spray of each material on the test sections.
Table 2: Liquids Spraying Rates and Times

<table>
<thead>
<tr>
<th>Material</th>
<th>3L/1000sqft (40 gallons/lane-mile)</th>
<th>5L/1000sqft (65 gallons/lane-mile)</th>
<th>7L/1000sqft (90 gallons/lane-mile)</th>
<th>10L/1000sqft (130 gallons/lane-mile)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brine</td>
<td>23s</td>
<td>39s</td>
<td>54s</td>
<td>78s</td>
</tr>
<tr>
<td>Caliber M1000</td>
<td>21s</td>
<td>35s</td>
<td>50s</td>
<td>70s</td>
</tr>
<tr>
<td>Snow Melter 2</td>
<td>37s</td>
<td>62s</td>
<td>86s</td>
<td>124s</td>
</tr>
</tbody>
</table>

When applying the liquid salt, the desired amount of solution was poured into the sprayer. A timer was set while someone walked uniformly back and forth inside the parking stall. Spraying was continuous until the desired rate was achieved. After each material was used, the container was emptied and cleaned before the next chemical was applied. A flow chart showing the two test procedures is given in Figure 3.

Figure 3: Anti-icing and De-icing Process
3.3 Data Collection

At the start of the test, a master event and maintenance form was first filled out, including the start and end of the event. Then, a data form was filled out at a uniform interval (usually on an hourly basis), recording:

- Weather data from Environment Canada website (Region of Waterloo station)
- Time
- Pavement surface and snow top temperature (by IR surface temperature reader)
- Percent bare pavement
- Friction levels (qualitative, quantitative by T2GO Friction Tester)
- Snow-pavement bonding state
- Residual salts level (qualitative, quantitative by SOBO20 Salinity Meter)
- Contaminate type (snow, slush, wet pavement, ice)

Note that, for each test date, data collection continued until the desired level of service was achieved. A bare pavement of 80%-100% was considered as level of service, LOS_A.

4. DATA ANALYSIS AND RESULTS

This section examines all the data collected and compares different anti-icing methods, materials, and application rates. Note that, there were a total of approximately 100 anti-icing tests conducted with solid road salt, on average 20 tests were performed with three liquid salts. Two key performance measures are used, namely, bare pavement regain time (BPRT) and friction level. Bare pavement regain time (BPRT) is defined as the elapsed time from the end of a snow event to the time when the pavement reaches at least 80% bare. The friction level of a pavement is represented by the coefficient of friction and a descriptive measure of slipperiness. The former is collected using the T2GO friction tester described previously while the latter is checked manually by the observer. This section summarizes the results according to the three questions raised in introduction.

4.1 Effectiveness of Anti-icing for Preventing Snow and Ice Bonding

As discussed previously, anti-icing treatments are motivated by their potential in preventing the bonding of snow and ice to a pavement surface by lowering the freezing point of
water through the use of salt. To evaluate the effectiveness of anti-icing operations in achieving this potential, the states of bonding and friction levels at the treated sections (i.e., anti-icing was done) are compared to those of the control sections (do-nothing sections). For both cases, the accumulated snow was first removed by the plow truck or using a shovel before observations and friction were taken.

Figure 4(a) shows the measurements of the coefficient of friction for sections treated with anti-icing as compared to those without anti-icing operations. As expected, anti-icing operations were highly effective in preventing the bonding of snow and ice. Except two cases, the improvement in friction level was over 50%. For the two events that anti-icing was not effective, the main reasons were the relatively low temperature and high amount of precipitation of the events, and long event duration. For instance, the event which occurred on January 22, 2013 had an average pavement temperature -11.5°C, which is below the effective temperature range of regular salt. Three additional tests were also conducted using liquid as an anti-icing agent. Figure 4(b) shows the friction of coefficients observed across the two scenarios: do-nothing and anti-icing using brine. Again, the effect of preventing pavement bonding was clearly shown for both solid and liquid. This quantitative evidence was further confirmed by the visual observation of slipperiness levels between treated sections and untreated sections.

![Coefficient of Friction Chart](image)

**a) Anti-icing Using Solid Road Salt**
b) Anti-icing Using Brine

Figure 4: Effectiveness of Anti-icing Using Solid Road Salt and Brine

4.2 Comparative Performance of Anti-icing and De-icing Treatments

While the main motive of the anti-icing strategy (e.g., applying salt in advance) is to prevent snow and ice from bonding to the pavement surface so that they can be removed easily by plowing operations, it could also be implemented as pre-application of salt for the purpose of melting snow and ice, similar to the conventional de-icing strategy (applying salt after the start, mostly at the end, of an event). Intuitively, if little dispersion and dilution occur after salt is applied, pre-application and after-application of the same amount of salt should perform similarly in terms of snow melting capacity (total amount of snow and ice that can be melted). However, the former should be expected to achieve better performance in terms of bare pavement regain time because it does not need to break the newly formed bonds. If this is true, it would mean that it is always preferable to apply salt in advance of an event (i.e., anti-icing) than after the event for the snow storms when less dilution is expected for some form of precipitation (e.g., freezing rain, wet snow). Furthermore, applying salt in advance has the advantage of an easier workload management as it has a wider time window for operations. To avoid any
confusion in terminologies, the following discussion still uses anti-icing and de-icing for pre-
application and after-application, respectively.

Tests were conducted for a comparative analysis of these two types of operations, which
included applying the same amount of salt before and after an event, at different sections, with
multiple application rates. Figure 5 shows how the coefficient of friction changed over time for
anti-icing and de-icing sections treated with regular salt with application rate 5lbs/1000sqft for
two similar events. Note that snow was not plowed in both cases. It can be observed that, in both
cases, anti-icing performed significantly better than de-icing operations in terms of the overall
friction level over the events and bare pavement regaining period.

Figure 5: Comparison of Performance between Anti-icing and De-icing Operations
(Legend shows test date, treatment type, application rate in lbs/1000sqft, pavement temperature,
snow amount and snow type)

The differences between anti-icing and de-icing operations are also compared using the
performance measure of bare pavement regain time (BPRT). Two scenarios are considered,
namely, unplowed and plowed. For the unplowed conditions, the tests included nine snow events with snowfall ranging from 0.3cm to 7.8cm and temperatures from ~0°C to ~4°C. Salts were applied before the event for anti-icing sections. For de-icing operations, salts were applied after precipitation stopped using the same rates as the anti-icing sections.

Figure 6 shows the relationship between average level of service (LOS) improvement, as represented as the reduction of BPRT, between anti-icing and de-icing operations, and salt application rate. Several observations can be made from the test results. Firstly, anti-icing operations outperformed de-icing in almost all cases with average BPRT being from ~0.5 to 3.5 hours shorter. Secondly, the advantage of anti-icing operations appeared to be higher in light events as compared to heavier events. Thirdly, an interesting and important observation is the trend between the salt application rates and the bare pavement regain time. It shows that the snow melting performance of salts is marginally sensitive to the application rate in general. It can also be seen that anti-icing was less effective when event duration was relatively longer, or the snow was wet. This result makes intuitive sense, as the salt applied in advance could be lost due to the high dilution, which is also supported by literature (Blackburn et al. 1994; Ketcham et al.1996; Fu et al. 2013).

Figure 6: Benefit of Pre-application (Anti-icing) - LOS Improvements (BPRT Reduction) as Compared to After-application (De-icing)
4.3 Optimal Anti-icing Application Rates Using Solid Road Salt

When anti-icing is implemented for the sole purpose of preventing bonding of snow to pavement, the amount of salt being used may not need to be large. To find out the minimum application rates for achieving this anti-icing objective, a series of tests were conducted using different anti-icing application rates. Figure 7 shows the coefficient of friction of a pavement surface as a function of the anti-icing application rate for the plowed anti-icing sections. An application rate of zero means that the section was not treated with anti-icing. As it can be observed, an application rate as low as 5 lbs/1000sqft could achieve the main purpose of preventing the bonding and improving the friction level. This is also true with respect to bare pavement regain time, as shown in Figure 8.

It can be clearly seen that only a small amount of salt (5lbs/1000sqft or less) was needed to achieve bare pavement immediately after plowing.

![Figure 7: Friction Performance of Anti-icing Treatments](image_url)

(Notes: Friction measurements were taken after plowing. Legend shows different test days with pavement temperature, snow amount and snow type)
Figure 8: BPRT Performance of Anti-icing Treatments
(Notes: Bare pavements regain time from plowing. Legend shows different test days with pavement temperature, snow amount and snow type)

4.4 Comparison of Different Materials for Anti-Icing

Tests were also conducted to investigate the differences in anti-icing performance between three liquid products, including regular brine, Caliber M1000, and Snow Melter 2. As shown in Figure 9, all sections treated with liquid anti-icing had higher friction levels than those which were not treated. The differences between the three liquids were relatively small, which were also true in terms of bare pavement regain time (BPRT), as shown in Figure 10. It can be observed that the three liquids had similar performances under all application rates, similar to the results for rock salt. The anti-icing treatment sections generally reached 100% bare pavement at similar times, regardless of application rates. This suggests a low application rate (e.g. 3 L/1000sqft) is needed to reach the desired level of service immediately after plowing. Note that, snow started again, after the plowing operation, during the tests conducted on February 27, 2013, resulting in relatively longer bare pavement regain time.

In addition to the testing results shown in Figure 10, the three liquids were also tested for a big event amounting in 21cm snow, which was plowed at the end of the event. Three pavement
conditions were clearly noticed. First, the snow was bonded to the pavement, degrading the performance of the plowing operation. Second, the pavement condition remained the same across the test sections, regardless of salt type and application rate. Third, the sections treated with Snow Melter 2 had marginally higher coefficient of friction than other sections, but the differences were relatively small.

Figure 9: Coefficient of Friction for Do-nothing Sections and Liquid Salts Applications
(Note: Snow Melter2 was not tested on Mar. 6, 2013)
5. CONCLUSIONS

This paper has presented the results from a series of field tests aiming at determining the performance of anti-icing treatments for snow and ice control of parking lots and sidewalks. The research is mainly concerned with the issues of the effectiveness and relative performance of anti-icing operations using different materials and application rates under different weather events. The main findings from this study include:

- Anti-icing was found highly effective in preventing the bonding of snow, improving friction levels, and improving bare pavement regain times;
- Anti-icing operations, when used as pre-application, were found to perform much better than after-application (de-icing) for light snow events;
Compared to solid salt, brine was found to be more effective under the condition that the same amount of salt (NaCl) was used;

- The two other alternative liquid products were found to perform similar to regular brine for anti-icing treatments;
- The performance of anti-icing operations also depends on the nature of the snow event. For long and intense events, anti-icing operations were found to be ineffective in preventing the snow bonding with the pavement.

It should be noted that additional field tests will be conducted in the coming winter season to address some of the limitations and remaining issues of this research. More tests will be conducted using alternative liquid products for both anti-icing and de-icing purposes. In particular, there is a significant interest in applying non-chloride de-icers for minimizing the environmental and corrosive effects of chloride salts used for maintenance operations. Future research will also attempt to quantify the effects of other various factors, such as dilution potential, traffic, and pavement type on the performance of anti-icing operations.

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