A Large Scale Field Test for Snow and Ice Control of Parking Lots, Platforms and Sidewalks (SICOPS)

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ABSTRACT

This paper presents a summary of the main results of a three-year study on snow and ice control of parking lots and sidewalks (SICOPS). Approximately 5000 tests were conducted over nearly 100 winter snow events over three winter seasons, covering a large number of treatment combinations in terms of material types, maintenance strategies, and treatment techniques under a wide range of winter weather conditions. The field data were then analyzed systematically and rigorously using various statistical techniques for generating quantitative information about the effects of various factors on the snow melting performance of different materials, rates and treatment methods. The project also included an extensive review of relevant literature and a set of comprehensive surveys of facility users, maintenance contractors, and government agencies. The understanding from these surveys, reviews and results from our field tests are used to develop a number of easy to use recommendations on optimal snow and ice control, that can ultimately help maintenance contractors and government agencies develop a cost-effective winter maintenance program for safer winter parking lots, platforms and sidewalks. This paper highlights the main results from this research whereas details of the approaches or methods utilized to derive these results are described in our previous publications.

INTRODUCTION

Snow and ice on pavement surfaces can create slippery conditions, causing slip-n-falls and vehicular accidents. To ensure public safety and mobility, various forms of maintenance operations such plowing and salting are performed to keep pavement surfaces free of snow and ice. The costs of winter maintenance operations are however substantial. For instance, over $1 billion is spent annually on winter maintenance of various transportation facilities in Canada, which includes the use of an average of five million tonnes of salts (Transportation Association of Canada, 2013). The release of large quantities of salts could cause significant environmental impacts, such as damage to the soil, water, vegetation and wildlife (NCHRP-577). Salt is also a significant factor contributing to the corrosion of bridges, buildings and vehicles, increasing maintenance costs by billions of dollars. Therefore, a sensible salting strategy is necessary in order to reduce the harmful effects of salt while keeping the various transportation facilities safe.

Developing a sensible salting strategy is a multi-step process; but one of the first steps is the development of snow and ice control guidelines for the selection of the best strategies and methods, materials, and application rates for specific facility and weather conditions. It is generally understood that developing appropriate facility-specific guidelines requires a quantitative understanding of the snow melting performance of the materials being used and the effect of different application methods and rates within the usage environment of these facilities (e.g., roadways vs. parking lots vs. transit platforms). Furthermore, different facilities have different service requirements (e.g., desirable bare pavement regain time) and traffic characteristics (e.g., only vehicular traffic vs pedestrians-vehicle mix, speed differences, etc.).

The goal of this three year research project is to address the need of developing guidelines for the snow and ice control of parking lots and sidewalks. This paper presents the highlights and key findings from the field tests which covered all major treatment methods (e.g., deicing, anti-icing) and snow control materials such as conventional road salt, brine and some emerging organic and inorganic blends.

DESCRIPITION OF FIELD TESTS CONDUCTED FOR DETERMINING OPTIMAL TREATMENT METHODS AND APPLICATION RATES

Test Site and Setup

The tests were conducted in Parking Lot C (Figure 1) at the University of Waterloo, Ontario, Canada over the winter seasons of 2011-2012, 2012-2013 and 2013-2014. The area of the parking lot is approximately 25,540 m^2 (6.31 acres). The parking lot contains approximately 900 parking stalls and eight driveways. Tests were conducted in multiple 10'x20' (3m x 6m) test sections. These test sections possessed similar external conditions, such as pavement type, snow type, initial snow depth, and traffic conditions for any given snow event. During the day, this parking lot receives a large amount of traffic due to its convenient location next to the University.

A large numbers of field tests were also performed on the sidewalks and walkways around the University Waterloo. The sidewalks sections included regular concrete pavement, interlocking concrete paver, and asphalt pavement. To maintain similar weather conditions, test areas were selected such that they were within 500 m (1640') of the parking lot. The sidewalk test segments chosen were heavily used by pedestrians, cyclists, and maintenance vehicles.

Test Protocols

To ensure data reliability, all tests were conducted according to a common protocol. For deicing tests, salts were applied manually on top of snow with application rates ranging from 5 to 70 lbs/1000sqft (24 to 342 g/m^2) based on the total snowfall, prevailing pavement surface temperature, and forecasted air temperature over the day, while anti-icing sections were salted before the event. A significant amount of training was conducted during the initial stage of field tests to ensure the highest possible uniformity in application. Moreover, each test section is approximately 10'x20' (6m x 12m), a small area, to assist in achieving a high degree of uniformity. It should be noted that, in practice, the uniformity of salt spreading

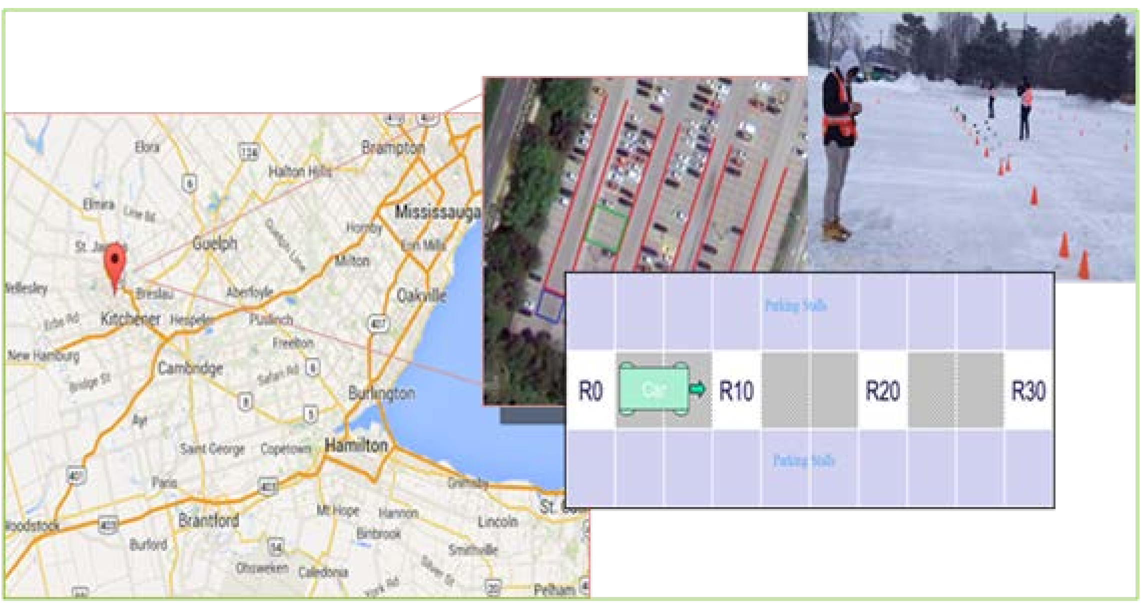

Figure 1: Test Site – Parking Lot at the University of Waterloo, Waterloo, Ontario

depends on the characteristics of the sprayer (e.g., manual rate setting vs. automatic rate control) and truck operational constraints (e.g., speed fluctuation) which remains an issue for investigation.

At the start of a test, a master event form was filled out with major information of the event, including start and end times of the snowfall, initial snow depth, snow type, density, and prevailing temperatures. To measure density, a 1m x 1m (3' x 3') area was sectioned off. The snow was then collected from this section and weighed to determine the snow density. An hourly data form was filled out at a fixed time interval including weather data, performance data i.e., percentage of bare pavement over snow covered area for deicing treatment and the coefficient of friction measured by T2GO for anti-icing treatment sites.

The weather data was collected from Environment Canada's nearest weather station and included air temperature, sky-view condition, humidity, wind speed, dew-point, and wind chill. Surface temperatures of the pavement and snow were measured on the pavement after removing patches of snow, and on top of the snow surface, respectively, using an infrared surface temperature reader. The event-based data collection form included the initial and final conditions of the tests, total snowfall over the event, as well as some processed data from the day, such as average temperatures for the event and pavement condition. Note that the data collection process was continued until every test section achieved the desired bare pavement. Figure 2 shows the major activities related to the field tests.

In the testing seasons, there were about 100 snow events in total with pavement surface temperatures ranging from about -20 °C (-4 ºF) to 3 °C (37 ºF) and snow precipitation from about 0.2 cm to 22 cm (0.1 in to 9 in). Interestingly, these three winter seasons had different sets of weather conditions: the first season was very mild and contained a limited number of events (14 events in total); the second season contained average winter conditions for the region; and the last winter was extremely heavy, especially when the number of colder days is considered (over 15 events with temperatures below -15 °C (5 ºF)). Approximately 5000 tests were conducted using different salts and treatment methods, including tests with plowed and unplowed snow, with and without traffic, and in the stall areas, driveways and sidewalks. In order to closely simulate the way parking lot maintenance is performed in the real world, 60 to 70% of the test operations started between 3 am and 7 am. As indicated, a number of existing solid and liquid salts were tested. The key information of these salts is presented in Table 1 for solid salts and Table 2 for liquid salts.

SUMMARY OF THE FIELD TEST RESULTS

As mentioned in the previous section, a large number of tests were conducted in a real world environment covering different maintenance methods and salts under a wide range of winter conditions. Furthermore extensive exploratory analysis was then performed on the observational data with the goal of identifying the main factors (e.g., temperature, snow amount, application rate etc.) that affect the snow melting performance and snow melting speed (i.e., bare pavement recovery time – BPRT) and friction gained over the treated areas for various snow control chemical agents (Hossain et al. 2015). This section highlights the important findings from our field tests on evaluating effectiveness on deicing and anti-icing treatments for snow and ice control in parking lots and sidewalks.

Summary of Major Findings on Deicing Treatments

- Deicing treatments were conducted using regular rock salts, pre-wetted salts, and several semi to full organic salts such as Green Salts, Blue Salts, Jet Blue and Slicer described in the previous section. An analysis of the field data revealed that salt type, application rate, pavement temperature, snow amount and traffic volume are all statistically significant in influencing snow-melting speed/BPRT (Hossain et al., 2014).
- It was observed that when the pavement surface temperature drops below -10 °C (14 ºF) the melting speed in sites treated with regular salts dropped substantially and took significantly longer to regain bare pavement.
- It was also observed that alternative products generally outperformed regular rock salt. The bare pavement regain time on the sections applied with these alternatives was approximately one hour shorter in average than those using rock salt.

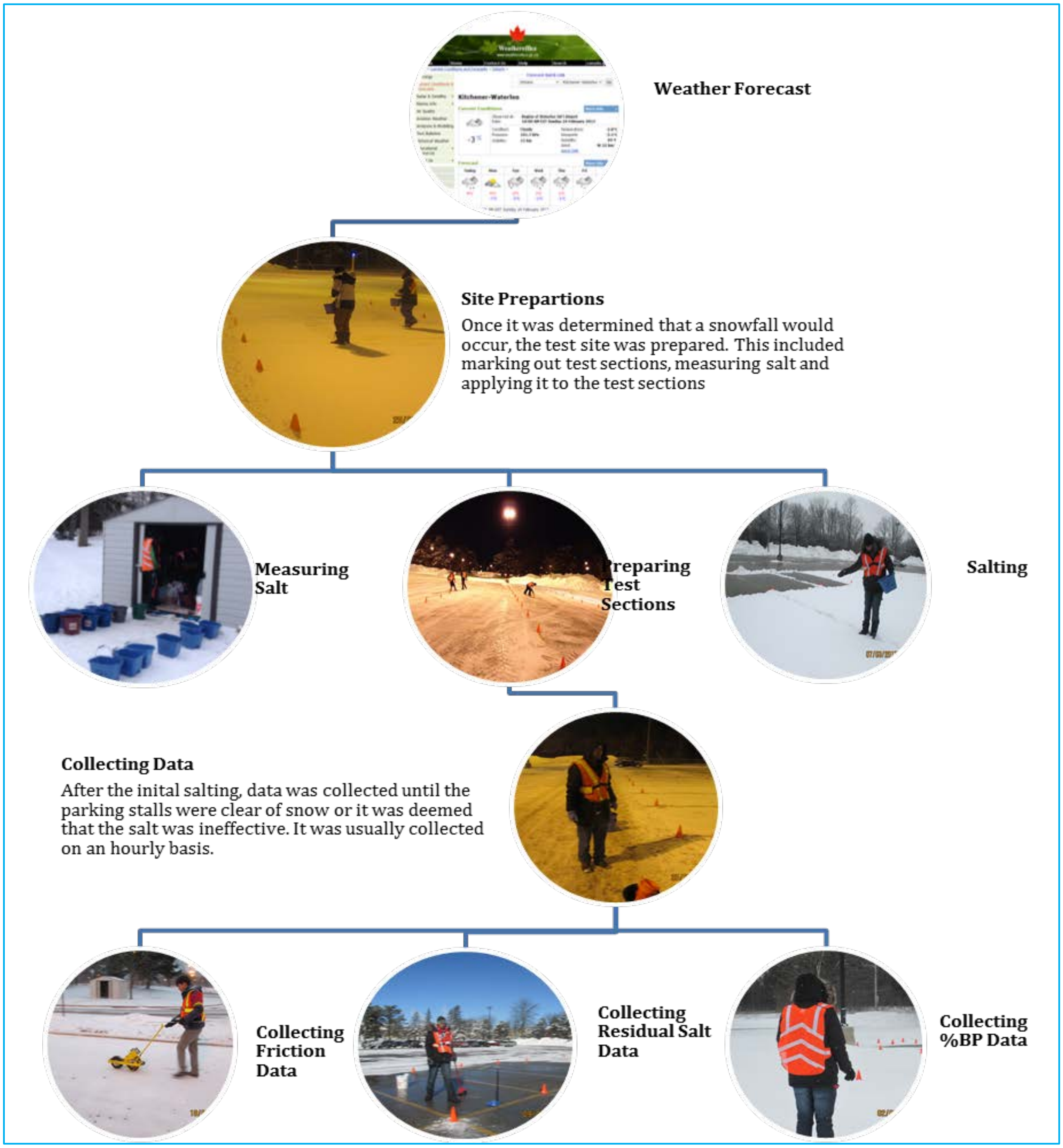

Figure 2: Test Procedure

Table 1: Solid Materials Tested

Trade Name	Composition*	Effective Temp* ºC (ºF)	Cost ($/ton)*	Physical look
Road Salt	Sodium Chloride	-10 (14)	80	
Blue Salt	Sodium Chloride Treated with Magnesium Chloride (Proportion not known)	-15 (5)	100	
Slicer	78% NaCl 9.4% $MgCl_2$ 2-3% and rest P/U	-25 (-13)	358	
Green Salt	Sodium Formate Treated with GEN3 runway Deicing fluid (Proportion not known)	-30 (-22)	950	
Jet Blue	Sodium Chloride Treated with proprietary polyol (Proportion not known)	-30 (-22)	495	

Table 2: Liquid Materials Tested

Trade Name	Composition*	Effective Temp* ºC (ºF)	Cost ($/L)*	Physical Look
Brine	23% NaCl 77% Water	-7 (19)	0.15	
Fusion 2350	12% NaCl 50% Degraded Beet Juice 38% P/U	-27 (-17)	0.30	
Snowmelt	15-20% Gylcerine 10-20% Polyether Polymer 3-8% Lactic Acid 2-4% Sorbitol 1-3% Formic Acid 1-3% Acetic Acid 1-2% 1,2-Butanediol Balanced with Water	-20 to -40 (-4 to -40)	0.29	
Caliber M1000	27% $MgCl_2$ 6% Carbohydrate 67% Water and P/U	-29.4 (-21)	0.40	

*Note: The information is based on product descriptions provided by the suppliers or found in the literature. P/U stands for Propitiatory/Unknown.

- The alternatives tested also performed significantly better when pavement temperatures were below -5 °C (23 ºF). The BPRT reduction ranged from 1 to 5 hours, depending on application rates. One interesting characteristic of the alternative salts is that their snow-melting rate (i.e., bare pavement time reduction) differed by the application rate used (Hossain et al. 2014).
- Pre-wetted salts were also evaluated alongside ordinary dry rock salt. In the tests conducted, same gross amounts of dry salt and pre-wetted salt were applied to the test sections. Since the pre-wetted salt mixture contains brine, its use means a reduction in the use of sodium chloride by approximately 20%. Despite this reduction, the pre-wetted salt and ordinary dry rock salt had similar performances and BPRTs in the tests conducted. Accordingly, the use of pre-wetted salt has the potential to reduce salt usage directly while still maintaining a comparable LOS (Hossain et al. 2014).
- The effect of traffic was clearly observed in the field experiment with the test sections located in the driveways being more effective than those in the parking stalls. Quantitative evidence on the

relative effect of traffic was subsequently obtained under various simulated traffic loads. The study concluded that to reduce salt usage while still achieving a desired level of service, different application rates should be applied for stall areas and driveways (Hossain et al. 2014).
- From the tests conducted, it was also found that snow melting performance varied by pavement type. The tests conducted on asphalt concrete and Portland cement concrete revealed that snow melting speed is higher on asphalt concrete sections. A substantial amount of comparable tests were conducted on the two pavement types. From these sample tests, it was found mean snow melting speed on asphalt concrete was 10% faster than Portland cement concrete. This difference was found to be statistically significant at a 95% confidence level (Hossain et al. 2014).
- Between Portland cement concrete and interlocked concrete, the difference in melting speed was not found to be statistically significant.
- Snow melting performance models were developed and used to determine the minimum application rates and adjustments factors. Recommended application rates and adjustment factors are presented in the next section.

Summary of Major Findings on Anti-icing Treatments

- Anti-icing treatment tests were conducted using conventional chloride salts and some emerging organic products. These include regular salt, brine, Fusion, Snowmelt and Caliber M1000. It was found that all materials were highly effective in preventing the bonding of snow, i.e., improving friction levels. The average friction gain on the anti-icing sites over the control sites (without anti-icing treatments) varied from 10% to 70% depending on event conditions (Hosseini et al. 2014).
- The test results did not indicate statistically significant differences between the performance of organic products and chloride based salts. This finding has confirmed that the organic products are at least as effective as the regular products for anti-icing operations in addition to the advantage of being environmentally friendly.
- A relatively low application rate, for example, 5 lbs/1000sqft (24 g/m2) for solid salts and 3 L/1000sqft (0.033 L/m2) for regular brine, was found to be sufficient to achieve the main purpose of anti-icing operations.
- When comparing the performance of regular dry salt and brine, it was found that brine treated sites outperformed sites treated with regular salts when the total mass of sodium chloride applied was the same.
- The performance of anti-icing operations also depended on the characteristics of the snow event. For long and intense events, anti-icing operations were found to be ineffective in preventing the snow from bonding with the pavement. Anti-icing operations, when used as pre-application, were found to perform much better than after-application (Deicing) for light snow events.
- It was also observed that the effectiveness of anti-icing became much lower when the pavement temperature dropped below -10 ºC (14 ºF). This trend was observed for all the tested anti-icers.

CONCLUSION

This paper has presented a summary of the main results from a three year research study focused on developing optimal snow and ice control for parking lots, platforms and sidewalks. While winter maintenance contractors from Landscape Ontario have started to apply the results from this study, the research team at the Innovative System Solution Lab together with various industry partners have started another three-years research journey with an intent to validate and update these results/recommendations on optimal treatment methods and application rates. Test sites have been setup on number of parking lots, transit platforms and sidewalks in number of cities in Ontario and New York. Any changes that need to be made in the recommendations set from this research will be presented in our future publications for the research community and the practitioners.

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