Optimize Pre-Wetting for Sustainable Winter Road Maintenance

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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.

KEYWORDS: Winter Road Maintenance/ Pre-Wet Salting / Sustainability

1. INTRODUCTION

Salt and sand are the most widely employed materials for winter road maintenance under different conditions by many transportation municipalities and provinces. Salt is used to prevent/break the bonding of snow and ice to the road surface by lowering the freezing point. Despite the proven effectiveness of salt usage in clearing road surface of ice and snow, salts has some detrimental effects on the environment, the infrastructure and the vehicles (Perchanok et al, 1991; Environment Canada 2002). Many transportation agencies are therefore under increasing pressure to explore new ways to improve the effectiveness of salting while keeping the roads safe and efficient.

The current standards and best practices recommended by Ministry of Transportation, Ontario (MTO) for salting were developed based on the assumption of applying salt with a pre-wetting ratio of 5% by mass (MTO, 2003; MTO, 2013). MTO is seeking ways to improve the effectiveness of its material application. Pre wetting is one such method which provides enough fluid to cover the salt particle and help start the snow melting process earlier compared to dry rock salt. However, what is the optimum application rate is still largely unknown.

The objective of this study is, therefore, to investigate the performance of rock salt at different pre-wetting ratios by mass (10%. 20%) to the 5% standard PW ratio using similar granular rate (e.g. 130 Kg/2Ln-Km). The paper is divided as follows. Section two contains relevant literature review whereas in Section three the methodology and data are explained. Results are given in section four. Section five highlights the main conclusions and outlines some directions for future research.

2. LITERATURE REVIEW

Salt is one of the major winter road maintenance (WRM) materials since 1970's (Nixon 2001) and generally used when temperatures are above -12 C. It breaks the bond between road surface and snow/ice by lowering the freezing point (O'Keefe & Shi, 2006). However, excessive use of salt has led to serious environmental issues and therefore different jurisdictions are keener in finding ways on how to reduce salt usage. Pre wetting is one such measure which can reduce application rate of salt from 10% to 30% (White et al. 2006; O'Keefe & Shi, 2006). By pre-wetting the salt,

the chemical process of de-icing begins immediately after it is spread and thus helps clear the road surface of snow/ice earlier than dry salt. As part of literature review, a simple questionnaire was prepared and send to 75 different jurisdictions (Cities, municipalities, provinces/states, countries) to determine their best practices. Responses from 27 jurisdictions are being summarized in Table – 1.

Table 1: Salt Pre-Wetting Best Practices

Jurisdiction	Salt Pre-wetting Percentage (mass or volume)	Temperature Range	Precipitation / Conditions	Pre-wetting Rate (L/ton)	Granular Rate (kg/lane km)	Comments
City of Barrie	100% salt brine		Light	43 L/ton		Prewet settings are largely dependent on solid material application rate
			Normal	43 L/ton		
			Heavy	57 L/ton		
	70% salt brine and 30% Agrimelt 55	Sustained temperatures below -14°C	Light	9 L/ton		
			Normal	18 L/ton		
	70% salt brine and 30% Magic-O (molasses and MgCl2 mixture)		Heavy	18-27 L/ton		
City of Brampton	23.3% salt brine Denmar Freeze Fighter Sodium 23 Brine Denmar Freeze Fighter HI-CAL 50	Average temperatures		54 L/ton	52 kg/lane km 80 kg/lane km	Have reduced solid application rate (kg/km or g/sq. m) by 20% while adding 6% by mass (60 litres per tonne) liquid when pre-wetting salt
		Colder temperatures			104 kg/lane km 160 kg/lane km 208 kg/lane km	
City of Brantford	22% MgCl2 (Pro Mag 22%)		Red Routes (257.4 km)	39.5 or 43 L/ton	200 kg/lane km	
			Blue Routes (86.7 km)		100 kg/lane km	
			Green Routes (175.9 km)		100 kg/lane km	
Connecticut DOT	30% MgCl2 and 70% water			24 L liquid/ton NaCl/lane km		

Jurisdiction	Salt Pre-wetting Percentage (mass or volume)	Temperature Range	Precipitation / Conditions	Pre-wetting Rate (L/ton)	Granular Rate (kg/lane km)	Comments
Highways England	salt brine	Average temperatures	Normal			Brine concentration between 20-23%
	salt brine with ABP	Extreme cold (below -7°C)	Frost or forecast frost			
	CaCl2 brine		Forecast light snow or moderate/heavy snow and freezing rain			
	MgCl2 brine		Compacted snow or ice			
Liikennevirasto (Finnish Transportation Agency)	23% NaCl with 20-30% salt by weight		Little moist			
	32% CaCl2 with 20-30% salt by weight		Moist			
			Wet			
Idaho DOT	23.3% salt brine			68-76 L/ton		Materials used have a corrosion effectiveness of 12.5%
	30% Boost (18.8% NaCl and 2.3% CaCl2 by volume)			57-76 L/ton		
	30% MgCl2			45-68 L/ton		
Kansas DOT	NaCl brine MgCl2 brine agricultural by-product additives			30 L/ton	28-113 kg/lane km	Also for sand/salt mixture
Maine DOT	30% salt brine	Warmer temperatures	Light snow	23-227 L/ton	42-56 kg/lane km	
	Magic Minus Zero (MgCl2 and agricultural by-product mixture)	Normal temperatures	Normal snow		70-85 kg/lane km	
	70/60% brine and 30/40% MMZ	Colder temperatures	Heavy snow		99-113 kg/lane km	

Jurisdiction	Salt Pre-wetting Percentage (mass or volume)	Temperature Range	Precipitation / Conditions	Pre-wetting Rate (L/ton)	Granular Rate (kg/lane km)	Comments
Maryland State Highway Administration	23.3% salt brine	Average temperatures		23-45 L/ton	141 kg/lane km per inch of precipitation	Use very little abrasives
	MgCl2	Colder temperatures				
Massachusetts DOT	26-30% MgCl2			30-38 L/ton	68 kg/lane km	Use very little abrasives; higher amounts of liquid is added if colder
City of Mississauga	23% salt brine			36 L/ton		Add a total of less than 5000 L of brine
Missouri DOT	salt brine at 10% by weight	28-32°C	Flurry conditions		7 kg/lane km	
	Ice Ban at 10% by weight	down to 10°C	Heavier precipitation		up to 56 kg/lane km	
Montana DOT	NaCl + corrosion inhibitor MgCl2 + corrosion inhibitor			30-57 L/ton	56-225 kg/lane km 21-56 kg/lane km	Use limited straight salt, mostly sand/salt mixture 10% by weight
New York State DOT	MgCl2 CaCl2		Black ice	23-30 L/ton	25 kg/lane km	
			Freezing rain		32-101 kg/lane km	
			Sleet		25-63 kg/lane km	
			Light snow		28-45 kg/lane km	
			Moderate or heavy snow		28-56 kg/lane km	
North Dakota DOT	20% Geomelt (Beet 55) and 80% salt brine			30-38 L/ton		Also for sand/salt mixture; all material placed on the road is pre-wet
Town of Oakville	salt brine		Light	36 L/ton	70 kg/lane km	
			Normal		105 kg/lane km	
			Heavy		150 kg/lane km	

Jurisdiction	Salt Pre-wetting Percentage (mass or volume)	Temperature Range	Precipitation / Conditions	Pre-wetting Rate (L/ton)	Granular Rate (kg/lane km)	Comments
Region of Peel	23.3% salt brine	Down to -8 to -10°C	Light	18-25 L/ton	32.5 or 50 kg/lane km	
			Normal		65 kg/lane km	
	30% MgCl2 and 70% water	Below -10°C	Heavy		80-85 kg/lane km	
Pennsylvania DOT	CaCl2			23-45 L/ton		
	MgCl2			23-30 L/ton		
Government of Prince Edward Island	23.3% salt brine	0°C and warmer	Snow/freezing rain	36 L/ton (old) 18% brine and 82% dry salt (new)	65 or 37.5 kg/lane km	Newer trucks automatically cut salt rates when using brine i.e. 18% reduction
		-4 to 0° C	Snow/freezing rain		90 or 65 kg/lane km	
		-4 to 12°C	Snow		100 kg/lane km	
Transports Québec	≥ 24% MgCl2 ≥ 24% CaCl2 ≥ 24% NaCl ≥ 24% KCl			27 L/ton (aboard trucks) 36 L/ton (stockpiling)		Mixtures of salts and abrasives with high salt concentrations (≥ 75%) are pre-wetted; pre-wetting is only used locally
Transport Scotland	23% salt brine					
City of Thunder Bay	CaCl2		Frost/black ice	56 L/ton	100 or 300 kg/lane km	Also for 50/50 sand/salt mixture
			Light snow < 1 cm/hr		100 or 130 or 300 kg/lane km	
			Heavy snow > 1 cm/hr		130 or 150 or 350 kg/lane km	
			Freezing rain		150 or 350 kg/lane km	
Washington DOT	salt brine MgCl2 CaCl2	-9 to 0°C		57-132 L/ton		
City of Waterloo	MgCl2		Light	50 L/ton	50 kg/lane km	
			Medium		95 kg/lane km	
			Normal		141 kg/lane km (regional roads) 112 kg/lane km (city streets)	

Jurisdiction	Salt Pre-wetting Percentage (mass or volume)	Temperature Range	Precipitation / Conditions	Pre-wetting Rate (L/ton)	Granular Rate (kg/lane km)	Comments
Wyoming DOT	MgCl2	0-28° F -18 to -2°C		23-38 L/ton	169 kg/lane km	
	salt brine GeoBrine	12-28 °F -11 to -2°C				
Regional Municipality of York	23.3% salt brine			54 or 73 or 91 L/ton	70-220 kg/lane km	Pre-wetting is done on the truck at the point of salt discharge

From Table – 1 it is can be seen that pre wet ratio in the range of 20-100% has been used with sodium chloride with 23.3% pre wet ratio being the mostly used. For calcium chloride and magnesium chloride, the range of pre wet ratio are 24-36% and 24-32% with 32% and 30% ratios as the most widely used ones, respectively. Transports Québec Potassium chloride with a ratio of greater than 24%.

3. OVERVIEW OF METHODOLOGY AND DATA SOURCES

The main objective of this research was to compare the field performance of different pre-wet ratios (10% and 20%) by mass with the conventional pre wet ratio of 5% using similar granular rates. The relative performance of the different pre-wet ratios can be quantitatively evaluated using friction as a measure of performance.

3.1. Comparative Analysis

Comparative analysis was conducted to test different hypotheses using t-test such as whether or not there is any difference in friction levels resulting from different treatments as well any difference between the amounts of material consumed. Comparative analysis was performed at different levels of data aggregation such as event, day etc. however, the event based data was found to yield better and intuitively sound results.

3.2. Study Sites

In order to evaluate the relative performance of the different pre-wet ratios for salt, three highway sections, noted as section #1, 2 and 3, were selected on Ontario Highway 6 (Class 2), as shown in Figure – 1. The sites selected have the same orientation with similar weather conditions.

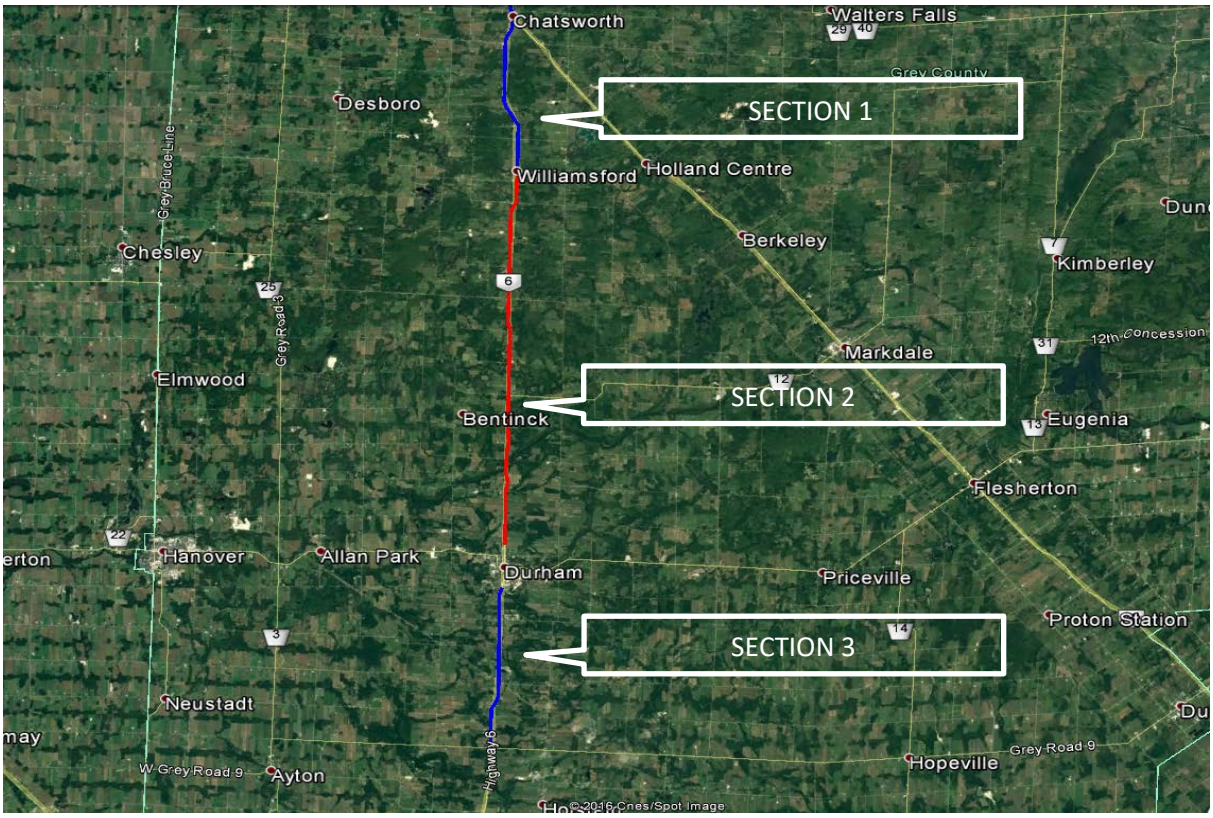

Figure – 1: study sites

Section 1 extends from Chatsworth to Williamsford with a length of 9.5 Km, Section 2 starts from Williamsford and ends at Durham with a length of 21.6 Km, whereas Section 3 starts from Durham and ends at Grey Rd 9 with a length of 9.33 Km excluding any built-up areas, as shown in Figure – 1. All sections are two lane highways falling under Class 2 standards as per Ontario Ministry of Transportation (MTO) winter road classification. The immediate maintenance objective for Class 2 is to provide essentially bare pavement condition A.S.A.P after the storm and not exceeding 16 hours. The test sections have winter average daily traffic (WADT) of 5500 and average annual snowfall of 305 cm. All these sections are maintained by the same contractor.

Section 1 was treated with 5%, section 2 with 10% and Section 3 with 20% pre-wet salt until February 9, 2016 after which the treatments were rotated among these sections and Section 1 was treated with 10%, section 2 with 20% and Section 3 with 5% pre-wet salt. This type of treatment rotation was used to account for the difference between any site-specific factors between the tests sections not accounted for otherwise.

3.3. Data Sources

To evaluate the relative performance of the three different pre-wet ratios for salt, data was obtained from a number of sources for winter season 2016/2017. A total of 25 snow storms were recorded (Table – 2). Short summary of the data collected and used in this research is given in the following section.

Table – 2: Summary of Events

Event	Event type	AVG TEMP	Max TEMP	Min TEMP	Avg WIND Speed	Max WIND Speed	Min WIND Speed	Avg Rel Humidity	Avg Wind GUST
1	Snow	-9.8	-3.2	-15.8	14.0	27.0	0.3	83.2	19.3
2	Snow	-4.8	-2.9	-6.8	23.0	41.0	14.3	74.4	32.1
3	Snow/Freezing Rain	-1.8	-0.4	-3.3	13.6	18.3	11.0	86.4	18.9
4	Freezing Rain	-3.3	-2.9	-3.9	16.8	19.3	16.0	88.5	23.8
5	Snow/Freezing Rain	-0.4	0.3	-1.0	15.6	21.7	11.0	86.4	21.6
6	Snow	-4.8	-4.2	-5.1	16.3	23.3	11.0	83.8	22.1
7	Snow	-2.8	-0.1	-6.0	18.4	28.7	7.3	86.6	24.9
8	Snow	-10.1	4.8	-16.8	20.5	51.3	1.7	84.1	28.1
9	Freezing Rain	-0.5	0.0	-0.9	11.2	15.7	4.7	99.0	16.3
10	Snow	-1.4	-1.0	-2.0	12.2	15.7	6.0	96.9	16.7
11	Snow	-7.6	-7.1	-8.3	16.6	22.0	9.3	73.9	23.0
12	Snow/Freezing Rain	0.1	0.6	-1.0	5.7	16.3	1.0	67.2	8.2
13	Snow	-3.0	-0.6	-4.5	20.7	31.3	10.3	87.2	28.5
14	Snow	-9.1	-7.7	-10.7	7.9	17.0	0.7	83.4	11.7
15	Snow	-7.2	-1.4	-10.7	17.7	34.3	3.7	80.6	24.4
16	Snow	-3.3	3.7	-8.3	19.9	32.0	0.0	75.3	27.9
17	Not Available	-7.2	-1.4	-10.1	16.1	24.7	5.7	81.5	22.6
18	Not Available	-3.8	-0.2	-7.0	18.5	34.0	1.3	85.8	26.4
19	Snow	-5.8	0.9	-12.3	13.5	24.7	2.3	89.6	18.8
20	Snow/Freezing Rain	-7.4	7.2	-11.5	19.8	29.7	9.3	88.5	27.5
21	Snow	-11.4	-8.0	-14.7	12.4	27.0	2.3	76.8	18.0
22	Snow	-12.9	-10.5	-16.1	13.8	32.0	0.0	78.3	19.6
23	Not Available	-11.2	-10.4	-11.9	16.3	19.7	12.7	76.5	22.0
24	Not Available	-9.3	-6.5	-11.2	23.0	31.7	16.0	58.4	33.1
25	Not Available	-1.2	-0.6	-2.2	14.8	20.3	10.0	82.4	20.5

Data from Teconer

Teconer is a system using Spectroscopic sensors which work in a non-intrusive way by emitting light of near infrared spectrum towards the road surface and then receiving and analyzing the reflected light to infer the status and amount of the contaminants on the surface spot being detected.

Teconer also provide additional information such as grip level, water film depth, or percentage of ice in water. The Spectroscopic sensor is connected to a cell phone/tablet which displays the information collected. Camera of the cell phone/tablet is used to capture images of the road condition.

Material Data
Material data was obtained from the automatic vehicle location (AVL) system and records data in both summary format and detail. Interested fields in this data are material usage and application rates.

Winter Operation Records (WOR) and Bare Pavement (BP) Reports
Winter operation records contain almost the same information as the material data from AVL system. The BP report records the start of the event, the time bare pavement was lost, the end of the event and the time bare pavement was regained.

Data Processing
Once the data was acquired, the next step was to process the data. All the data sources are GPS tagged so the first step was to extract the data for the three test sections. When the Mobile Data Collection Unit (MDCU) goes out for data collection, it records friction data at every few seconds along the test route. Each test section was usually covered in 10 to 15 minutes. In the first step, all friction data was averaged for each run for a test route to get an average estimate of the friction level of that test section for that traverse. In the next step, material data was calculated for each run and event for sand and salt usage. Comparative analysis is a simple way of comparing different alternatives usually using one variable as a measure of performance. In this analysis, friction data, obtained from Teconer, was is as the measure of performance.

4. Data Analysis and Results

4.1. Comparative Analysis - Friction

The three different pre wet salt ratios of 5%, 10% and 20% were compared using t-test with friction as a measure of performance. Moreover the material used under the different type of treatments is also compared. The first objective was see if any significant difference exists between the different treatments.

First the sections treated with 10% and 20% pre wet ratios were compared to the section treated with 5% and then the section treated with 20% pre wet was compared to the section treated with 10%. Using friction as the performance measure, first it was determined whether or not any significant different exists between the different treatments (Table – 3). Next, it was calculated as which treatment resulted in better traction values. This was determined by assessing the relative improvement of one section with respect to the other.

Performance of 10% pre wet ratio compared to 5% pre ratio:

Table – 3 shows that compared to 5% pre wet ratio, section treated with salt using 10% pre wet ratio shows an improvement of 9.5% in friction on the average. Out of the 25 events, only six are statistically different from each other, all showing that section treated with salt using 10% pre wet

ratio offers more improvement. Overall, for 18 events, section treated with salt using 10% pre wet ratio was found better and for seven events, opposite results were obtained.

Performance of 20% pre wet ratio compared to 5% pre ratio:

Table – 3 shows that compared to 5% pre wet ratio, section treated with salt using 20% pre wet ratio shows an improvement of 10.09% in friction on the average. Out of the 25 events, only six are statistically different from each other, all showing that section treated with salt using 20% pre wet ratio offers more improvement. Overall, for 19 events, section treated with salt using 20% pre wet ratio was found better and for six events, opposite results were obtained.

Performance of 20% pre wet ratio compared to 10% pre ratio:

Table – 3 shows that compared to 10% pre wet ratio, section treated with salt using 20% pre wet ratio shows little improvement of 0.68% in friction on the average. Out of the 25 events, only one event yielded statistically different friction for the two treatments favoring the 10% treatment. Overall, for 16 events, section treated with salt using 20% pre wet ratio was found better and for nine events, opposite results were obtained. Based on these results no clear advantage to the use of either of the rate with respect to the other.

Figure – 2 shows the relative performance of the three treatments over the different events in terms of average friction.

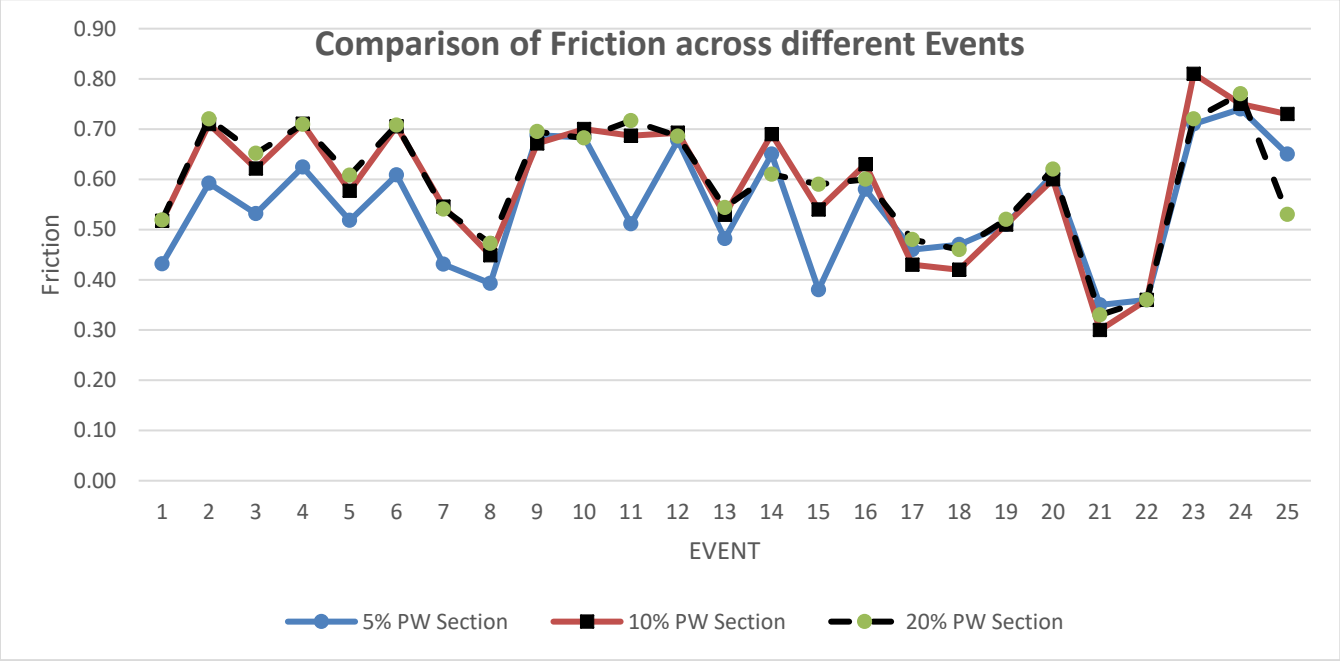

Figure – 2: Friction wise comparison of the three treatments

Table – 3: Comparative Analysis

Event Description			5% PW Section	10% PW Section	20% PW Section	Comparative Analysis - 10% PW w.r. to 5%			Comparative Analysis - 20% PW w.r. to 5%			Comparative Analysis - 20% PW w.r. to 10%		
Event	Start Date	End Date	Average Friction	Average Friction	Average Friction	Test Sections Differ Significantly	Section performing well	% improvement wrt 5% PW	Test Sections Differ Significantly	Section performing well	% improvement wrt 5% PW	Test Sections Differ Significantly	Section performing well	% improvement wrt 10% PW
1	12/15/2016 12:00	12/19/2016 19:30	0.43	0.52	0.52	YES	10%pw	19.88	YES	20%pw	20.26	NO	20%pw	0.32
2	12/20/2016 11:00	12/21/2016 9:00	0.59	0.71	0.72	YES	10%pw	19.92	YES	20%pw	21.63	NO	20%pw	1.43
3	2016-12-21 22:00	2016-12-22 10:00	0.53	0.62	0.65	NO	10%pw	16.88	NO	20%pw	22.54	NO	20%pw	4.85
4	12/23/2016 5:00	12/23/2016 8:00	0.62	0.71	0.71	-	10%pw	13.80	-	20%pw	13.62	-	10%pw	-0.16
5	12/23/2016 21:00	12/24/2016 9:30	0.52	0.58	0.61	NO	10%pw	11.38	NO	20%pw	17.34	NO	20%pw	5.35
6	12/27/2016 18:00	12/28/2016 10:00	0.61	0.71	0.71	YES	10%pw	15.95	YES	20%pw	16.32	NO	20%pw	0.32
7	12/28/2016 18:00	1/1/2017 11:00	0.43	0.55	0.54	YES	10%pw	26.64	YES	20%pw	25.49	NO	10%pw	-0.91
8	1/4/2017 2:30	1/11/2017 4:00	0.39	0.45	0.47	YES	10%pw	14.26	YES	20%pw	20.22	NO	20%pw	5.22
9	1/12/2017 6:00	1/12/2017 9:00	0.69	0.67	0.69	-	5%pw	-2.38	-	20%pw	1.03	-	20%pw	3.49
10	1/12/2017 12:30	1/12/2017 15:00	0.68	0.70	0.68	-	10%pw	2.45	-	5%pw	-0.17	-	10%pw	-2.56
11	1/13/2017 6:00	1/13/2017 16:00	0.51	0.69	0.72	NO	10%pw	34.39	NO	20%pw	40.26	NO	20%pw	4.36
12	1/25/2017 19:30	1/26/2017 12:00	0.68	0.69	0.69	NO	10%pw	2.22	NO	20%pw	1.21	NO	10%pw	-0.99
13	1/26/2017 17:00	1/28/2017 22:00	0.48	0.53	0.54	NO	10%pw	9.87	NO	20%pw	12.83	NO	20%pw	2.70
14	1/29/2017 11:00	1/29/2017 23:30	0.65	0.69	0.61	NO	10%pw	6.15	NO	5%pw	-6.15	NO	10%pw	-11.59
15	1/31/2017 11:00	2/4/2017 14:30	0.38	0.54	0.59	YES	10%pw	42.11	YES	20%pw	55.26	NO	20%pw	9.26
16	2/7/2017 18:00	2/8/2017 17:00	0.58	0.63	0.60	NO	10%pw	8.62	NO	20%pw	3.45	NO	10%pw	-4.76
17	2/9/2017 15:30	2/11/2017 9:00	0.46	0.43	0.48	NO	5%pw	-6.52	NO	20%pw	4.35	NO	20%pw	11.63
18	2/12/2017 8:00	2/13/2017 18:00	0.47	0.42	0.46	NO	5%pw	-10.64	NO	5%pw	-2.13	NO	20%pw	9.52
19	2/14/2017 20:00	2/16/2017 8:00	0.51	0.51	0.52	NO	5%pw	0.00	NO	20%pw	1.96	NO	20%pw	1.96

Event Description			5% PW Section	10% PW Section	20% PW Section	Comparative Analysis - 10% PW w.r. to 5%			Comparative Analysis - 20% PW w.r. to 5%			Comparative Analysis - 20% PW w.r. to 10%		
Event	Start Date	End Date	Average Friction	Average Friction	Average Friction	Test Sections Differ Significantly	Section performing well	% improvement wrt 5% PW	Test Sections Differ Significantly	Section performing well	% improvement wrt 5% PW	Test Sections Differ Significantly	Section performing well	% improvement wrt 10% PW
20	3/1/2017 15:30	3/2/2017 11:00	0.61	0.60	0.62	NO	5%pw	-1.64	NO	20%pw	1.64	NO	20%pw	3.33
21	3/3/2017 3:30	3/4/2017 12:00	0.35	0.30	0.33	NO	5%pw	-14.29	NO	5%pw	-5.71	NO	20%pw	10.00
22	3/10/2017 16:30	3/12/2017 12:00	0.36	0.36	0.36	NO	5%pw	0.00	NO	5%pw	0.00	NO	10%pw	0.00
23	3/13/2017 18:00	3/13/2017 22:00	0.71	0.81	0.72	-	10%pw	14.08	-	20%pw	1.41	-	10%pw	-11.11
24	3/14/2017 12:30	3/15/2017 21:00	0.74	0.75	0.77	NO	10%pw	1.35	NO	20%pw	4.05	NO	20%pw	2.67
25	3/18/2017 2:00	3/18/2017 12:00	0.65	0.73	0.53	NO	10%pw	12.31	NO	5%pw	-18.46	YES	10%pw	-27.40

Table – 4: Significant vs. Non-Significant Events

										5% PW Section		10% PW Section		20% PW Section	
	Test Sections	AVG TEMP	Max TEMP	Min TEMP	Avg WIND Speed	Max WIND Speed	Min WIND Speed	Avg Rel Humidity	Avg Wind GUST	Salt (tonnes/Km)	Sand (tonnes/Km)	Salt (tonnes/Km)	Sand (tonnes/Km)	Salt (tonnes/Km)	Sand (tonnes/Km)
Sections differs Significantly	10% PW w.r. to 5%	-7	-1	-10	18	34	6	82	25	2	7	3	5	2	4
	20% PW w.r. to 5%	-7	-1	-10	18	34	6	82	25	2	7	3	5	2	4
	20% PW w.r. to 10%	-1	-1	-2	15	20	10	82	20						
Sections don't differs Significantly	10% PW w.r. to 5%	-6	-2	-8	15	26	6	80	22	1	2	1	2	1	2
	20% PW w.r. to 5%	-6	-2	-8	15	26	6	80	22	1	2	1	2	1	2
	20% PW w.r. to 10%	-6	-2	-9	16	28	6	81	23	1	4	2	3	1	3

Table – 4 summarizes the average conditions for the events when the test sections differed significantly and when they didn't. It can be seen from Table – 4 that, on the average, when the test sections differed significantly, more material was used comparatively and the events were relatively more severe in nature e.g. colder, higher winds etc. From this it can be concluded that for relatively warmer events, no statistical difference exists between the different treatment types. One reason for this can be the presence of enough moisture in the snow to complement any low pre wet ratio used.

4.2. Comparative Analysis – Material

In the next step, material usage during the 25 events were compared. Due to different lengths of the test sections, material usage was calculated as material used per Km as shown in Table – 5. In the next steps odds ratios were calculated for the total material usage as shown in Figure – 3. Figure - 3 shows that test section treated with 10% pre wet salt uses 13% more salt and 23% less sand compared to the section treated with 5% pre wet salt. Similarly, Figure - 3 shows that test section treated with 20% pre wet salt uses 23% less salt and 28% less sand compared to the section treated with 5% pre wet salt. Comparing the sections treated with 10% and 20 % pre wet salt, it can be seen that from Table – 5 that section treated with 20% pre wet salt has consumed 18% less salt and 7% less sand.

Table – 5: Material usage comparison

Event Description			5% PW Section		10% PW Section		20% PW Section	
Event	Start Date	End Date	Salt (tonnes/Km)	Sand (tonnes/Km)	Salt (tonnes/Km)	Sand (tonnes/Km)	Salt (tonnes/Km)	Sand (tonnes/Km)
1	12/15/2016 12:00	12/19/2016 19:30	3.23	5.00	3.23	6.70	2.92	5.59
2	12/20/2016 11:00	12/21/2016 9:00	-	-	-	-	-	-
3	2016-12-21 22:00	2016-12-22 10:00	0.57	0.00	0.58	0.00	0.52	0.00
4	12/23/2016 5:00	12/23/2016 8:00	0.11	0.00	0.10	0.00	0.14	0.00
5	12/23/2016 21:00	12/24/2016 9:30	0.39	0.00	0.42	0.00	0.53	0.00
6	12/27/2016 18:00	12/28/2016 10:00	0.67	0.00	0.58	0.00	0.54	0.00
7	12/28/2016 18:00	1/1/2017 11:00	2.02	4.51	4.02	1.59	1.74	0.74
8	1/4/2017 2:30	1/11/2017 4:00	3.54	15.95	5.09	13.77	3.17	11.07
9	1/12/2017 6:00	1/12/2017 9:00	0.09	0.00	0.19	0.00	0.13	0.00
10	1/12/2017 12:30	1/12/2017 15:00	0.11	0.00	0.13	0.00	0.16	0.00
11	1/13/2017 6:00	1/13/2017 16:00	0.31	0.00	0.50	0.00	0.07	0.00
12	1/25/2017 19:30	1/26/2017 12:00	0.62	0.00	0.81	0.00	0.64	0.00
13	1/26/2017 17:00	1/28/2017 22:00	1.43	4.90	1.62	4.42	1.90	2.68
14	1/29/2017 11:00	1/29/2017 23:30	-	-	-	-	-	-
15	1/31/2017 11:00	2/4/2017 14:30	2.25	9.45	1.53	3.63	1.83	2.52
16	2/7/2017 18:00	2/8/2017 17:00	-	-	-	-	-	-
17	2/9/2017 15:30	2/11/2017 9:00	0.84	2.34	0.84	0.90	0.83	4.53
18	2/12/2017 8:00	2/13/2017 18:00	0.86	4.16	0.21	2.13	1.07	4.32
19	2/14/2017 20:00	2/16/2017 8:00	-	-	-	-	-	-
20	3/1/2017 15:30	3/2/2017 11:00	0.72	0.88	0.66	1.39	0.64	0.88

21	3/3/2017 3:30	3/4/2017 12:00	-	-	-	-	-	-
22	3/10/2017 16:30	3/12/2017 12:00	1.22	3.53	1.03	4.74	0.95	4.41
23	3/13/2017 18:00	3/13/2017 22:00	-	-	-	-	-	-
24	3/14/2017 12:30	3/15/2017 21:00	-	-	-	-	-	-
25	3/18/2017 2:00	3/18/2017 12:00	-	-	-	-	-	-
Overall usage /Km			**19.00**	**50.71**	**21.53**	**39.28**	**17.78**	**36.73**

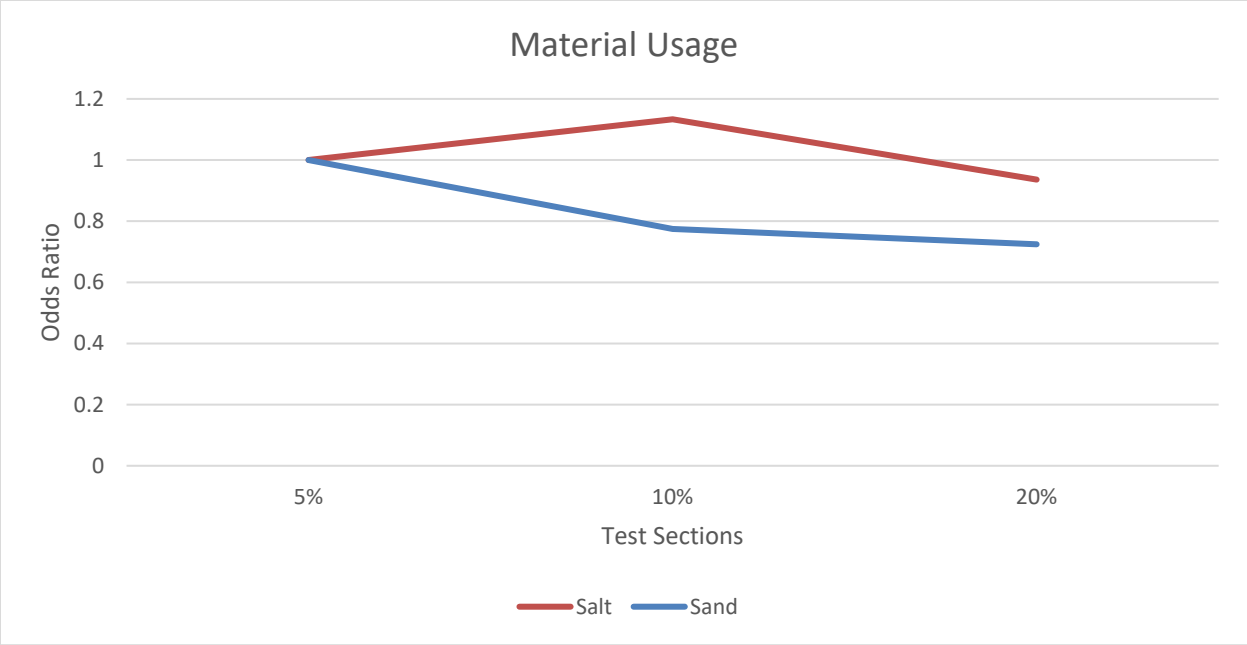

Figure – 3: Material usage

4.4. Analysis Results

This section highlights the main results in the above sections as discussed below

- Using salt with pre-wet ratio of 10% will result in 9.5% higher friction values while consuming 13% more salt and 23% less sand compared salt used with 5% pre wet ratio,
- Using salt with pre-wet ratio of 20% will result in 10.09% higher friction values while consuming 23% less salt and 28% less sand compared salt used with 5% pre wet ratio,
- Using salt with pre-wet ratio of 20% will result in 0.68% higher friction values while consuming 18% less salt and 6% less sand compared salt used with 10% pre wet ratio,

Based on these results it can be seen that section treated with salt with a 20% pre wet offer better results in terms of friction while utilizing the least amount of material. This finding is very close to the general practice (see Table – 1). However, before adoption of these results, complete cost benefit analysis is suggested.

5. CONCLUSIONS AND FUTURE WORK

This research presents the preliminary findings from a field study aiming at a comparative performance analysis of three different pre-wet ratios for salt using similar granular ratios. The objective was to find a whether or not a higher pre wet ratio will result in any improvement. Using friction and material data for the winter season 2016/2017 the assessment was done using comparative analysis. The test results show that using a pre-wet ratio of 20% results in higher friction values while consuming less amount of material.

While some valid results are obtained from this analysis, there are some aspects which are not covered in this analysis and will be part of our future endeavours such as:

- Comparative analysis is a simple technique accounting for only one variable at a time whereas the true effects of any treatment will involve impacts from a number of other variables such as those related to road, traffic, weather etc. To account for these effects, more rigorous analysis will be performed using statistical models.

- Cost benefit analysis of the different pre-wet ratios.

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