Sustainable Winter Sanding with Pre-wetting

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Abstract

Low volume highways in northern Ontario are maintained to winter standards that result in either a centre bare pavement followed by complete clearing within a day after a winter storm, or in a drivable but snow packed surface through most of the winter that is sanded frequently to improve traction. The resulting use of road salt, winter sand and equipment operation add to the environmental effects and the cost of highway operations. A study was undertaken to evaluate whether these impacts can be reduced through a new spreading technology that helps to hold winter sand to a snow packed road surface by pre-wetting it with hot water during application.

Operational experience with the technology was gained at three highway locations over 80 days of winter service. The potential for reduction of environmental impacts and direct costs, and of improving winter safety and mobility, were assessed with maintenance records from conventional operations being compared to predictions for a highway maintained with a Hot Water Sander. It was concluded that all the benefits may be achieved through the integration of the existing winter classes into a single class maintained with the innovative technology.

Introduction

Environmental and economic sustainability is very important to maintenance of Ontario's highways during winter conditions. A road surface must be provided that is safe for the traffic level and speed at a given location, at an affordable cost, while minimizing environmental impacts of snow and ice control.

The balance of safety, cost and environment is maintained through a Winter Class system that moderates the level of maintenance to the average winter traffic level and the highway's importance in relation to other roads. As a result the environmental impacts of maintenance, primarily due to the application of road salt and winter sand, generally decrease with traffic level.

The low end of the traffic scale includes Winter Classes IV and V. The immediate maintenance objective for Class IV is to provide a centre bare condition within 24 hours where the left wheels are on bare pavement. The objective for Class V is to provide a plowed and sanded, snow packed surface through the winter, with bare pavement restored in early spring. The primary environmental impact on Class IV highways is the repeated application of road salt while the primary impact on Class V is the repeated application of winter sand which is necessary because sand is blown from the surface within minutes by passing traffic. This results in heavy use of a non-renewable resource on both highway classes, and in GHG emissions by maintenance vehicles. While less sand is used on Class IV highways, significantly more salt is used, while achieving a traction level that may be only slightly better than Class V.

The purpose of this study is to investigate the potential for reducing the frequency and quantity of both sand and salt application without impacting overall road safety by integrating Winter Standards Class IV and V through the use of innovative, Hot Water Sanding (HWS) technology.

Background

The Hot Water Sander is a winter material spreader developed in Sweden that pre-wets winter sand with near-boiling water as it is being spread on the road (Figure 1). The hot water coating freezes upon contact with a snow packed or ice covered surface and prevents the sand from being blown away by passing traffic. Tests in Scandinavia demonstrated that the sand may be retained on the surface for more than 10 hours (1) where conventional sand would be blown away within minutes (2).

With the potential to improve traction under winter conditions with reduced demand for maintenance services, the HWS concept supports economic and environmental sustainability in highway operations.

Figure 1: Hot Water Sander

Objectives and Methodology

The objectives of the project are to determine whether the improved sand retention on a snow packed surface as demonstrated in Scandinavia is sufficient to provide a safe driving surface while balancing the capital and operating costs of Hot Water Sanding in Ontario.

Two major approaches were used in this study: operational demonstrations to determine whether the mechanical layout and operation of the unit is compatible with local environmental conditions and equipment standards and, predictive analyses of the environmental and road safety benefits and cost structure.

Operational Demonstrations

The operational demonstrations were carried out over three winter seasons on Class V highways near Savant Lake, Mattawa and New Liskeard areas and one county road near Cochrane, to the west of New Liskeard (Figure 2). The demonstration routes were paired with conventional spreader routes. Hot water sanders were used on a total of 80 days over the two year period.

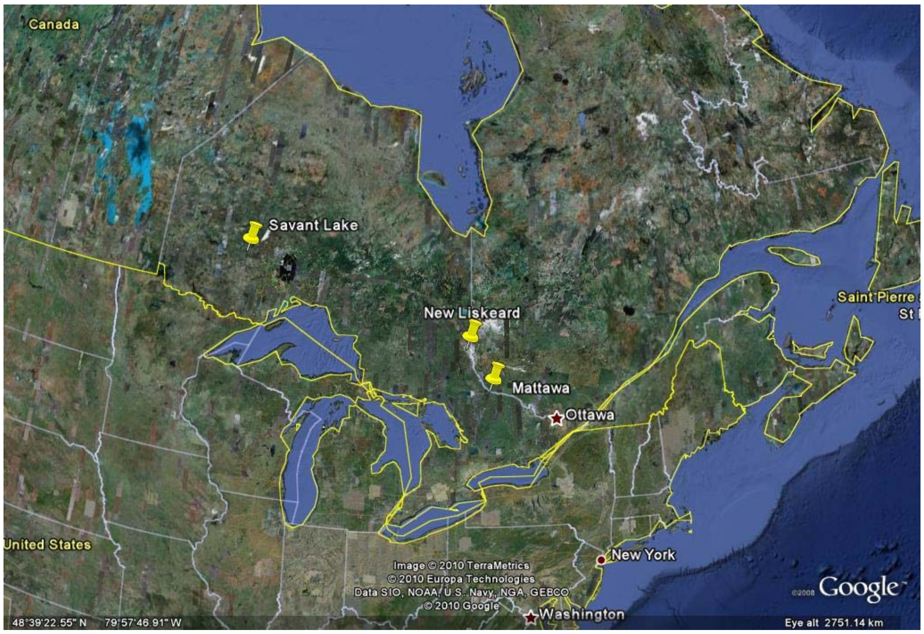


Figure 2: Hot water sand operational test sites.

Sand spreading rates on all routes followed the MTO guideline of 570 kg/2-lane km, using winter sand of the specified gradation (3) mixed with salt at a rate of 3-5% by mass to prevent freezing. Sand was applied at speeds up to 42 kph using a side-discharge spreader on the left side of the vehicle between the front and rear wheels.

Practical evaluations were conducted on two hot water sander units over three seasons. One was operated near Mattawa and New Liskeard and one near Savant Lake (Figure 2). Both units were successfully operated on conventional highway tractors and conformed to Ontario hydraulic, mechanical, electrical and weight requirements. The units were controlled by a PDA in the vehicle cab and collected the spreading and operating information required by contract management personnel. All operations were on snow packed highways in a temperature range of -10 to – 25^{o}C.

The water heated to a temperature of 95^{o}C in all operating conditions, with no delay from start-up. Sand was observed to spread in regular, closely spaced arcs across one lane (Figure 3) and to adhere immediately to the packed snow surface. The sand was observed to remain on the surface for at least one day after application under the traffic and weather conditions experienced on the test roads.

The field tests, however, also raised several practical concerns as follows:

1. During the HWS operations, a fog cloud is formed around the spinner, severely reducing visibility behind the spreader, which is a source of safety concern for the traffic following the spreader (Figure 4).
2. The HWS technology is currently designed to operate at a speed of 24 km/hr, which is lower than conventional spreaders in Ontario. This is another safety concern and could exacerbate in conjunction with the fog cloud
3. Sand is discharged at the rear end of the spreader, which means the spreader could be operating on unsanded surfaces or snow covered surface during the initial run. This could cause some problem for the spreader. For example, in one instance of the test, the spreader slid off an icy road.
4. The controller required reprogramming to meet the MTO standard sand application rate of 570 kg/2-lane km, although it operated successfully once this was done.
5. The operating range of the spreader is reduced by 40 **%** compared to conventional spreaders of the same load capacity, due to the load of water. This may require additional sand storage yards or adjustment of maintenance routes.
6. The recommended use of ‘dirty’ sand with no added salt may result in freezing of unheated stockpiles. Conventional sand with approximately 3% added salt was used in these demonstrations.

Figure 3: Arc spreading pattern on outbound and inbound lanes, Hwy 652

Figure 4: Fog cloud following Hot Water Sander

Cost-Benefit Analysis – Case Study

In order to evaluate the potential cost and benefit advantages of combining Class IV and Class V into a single class that is to be maintained by using HWS technology, two comparable highways, namely, Hwy 65 (Class IV) and Hwy 560 (Class V), are selected for a hypothetical case study. Both highways are located near New Liskeard and are maintained by the same maintenance contractor. A new class, designated as Class A, is created to represent a class of highways with road surface conditions being maintained as Class V but with HWS deployed for increased retention of sand. Table 1 summarizes the basic characteristics of these classes along with their designated maintenance standards (4).

Table 1: Summary of Maintenance Classes

	Highway	# of Lanes	Length (km)	Maintenance Standard
Class IV	#65	2	65	The defined level of service for Class 4 is essentially bare pavement. A minimum centre bare condition (the centre 2.5m), should be reached within 24 hours after the storm has ended or abated and be maintained until conditions permit baring thepavement to full width.
Class V	#560	2	172	The defined level of service for Class 5 is that a snow pack condition on the Travelled Portion be achieved, within 24 hours after the storm. A snow pack condition on the Travelled Portion is defined as a smooth, hard, snow covered driving surface with Shoulders that are void of loose snow.

The analyses consider four major performance components, including levels of road safety and mobility, environmental impacts, and direct costs of operations, as shown in Table 2. The measures used to represent operating costs and environmental impacts and are normalized into a per unit amount (tonnes/lane-km).

Table 2: Performance Measures for Comparison

Component	Direct Measures of Effectiveness	Measures Used
Operating Cost	Materials, work hours, equipment, fuel consumption	Tonnes of salt/sand #Operations
Safety Impacts	Expected # of collisions	Traction
Mobility Impacts	Delay and # of canceled trips	Traction
Environmental Impacts	Tonnes of salt/sand	Tonnes of salt/sand

Due to the low traffic level of these highways, historical data are not sufficient for deriving direct measures of safety and mobility. As a result, a surrogate safety/mobility measure called Road Surface Index (RSI) is used (5). RSI is a quantitative measure reflecting the traction level, or more specifically, the coefficient of friction, of a road surface. Friction is a measure used in road safety and mobility studies where the condition of the pavement surface is related to the relative risk of accidents and to safe driving speeds. It is also under consideration as a performance measure for winter maintenance (6, 7) and supports the use of RSI as a surrogate for road safety and mobility. A schematic has been developed to estimate RSI based on observed road surface conditions such as snow coverage and visual characteristics of surface contaminants, which are available from highway patrol records.

The road surface conditions of all highways in Ontario are reported by MTO at least five times daily during a winter season and archived as Road Condition and Weather Information System (RCWIS) data. Each condition record includes a standardized description of the general road surface state of individual road segments, usually 20-50 km in length, in terms of coverage and nature of surface contaminants. Figure 5 illustrates some examples of different RSC classes.

For both Hwy 65 and Hwy 560, historical RCWIS data are available and can be used to derive RSI based on the scheme developed by Usman et al (5). The following list shows the RSI range for each major class of the road surface condition.

- Bare Dry: 0.9~1.0
- Bare Wet: 0.8~0.89
- Center Bare: 0.5~0.79
- Partially Snow Covered: 0.5~0.79
- Snow Covered/Packed: 0.1~0.49

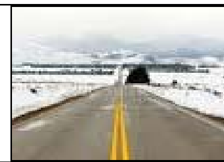
RSC Class	Visual Characteristic
Bare Dry	
Bare Wet	
Centre Bare	
Partially Snow Covered	
Snow Packed	

Figure 5: Illustration of Winter Road Surface Classifications

Traction levels for the hypothetical highway with HWS operation are predicted on the basis of the test results from Norway (1). Specifically, It is assumed that HWS would provide an initial traction level that is 0.1 (coefficient of friction) higher than conventional sand and that the sand from HWS would be retained on the pavement twice as long as conventional sand. Based on these assumptions a time series of RSI for the HWS highway could be derived.

Information on maintenance operations are also extracted from MTO’s RCWIS data that includes records of daily maintenance operations. The plowing, salting and sanding operations on Class IV and V highways are estimated by summing their occurrence in the RCWIS reports.   HWS operations for the HWS highway are estimated by assuming that the demand for sanding would be reduced by half from conventional sanding operations.   The frequency of sanding and plowing was assumed unchanged from Class V.

The capital and operating cost over the equipment life span were estimated to be 1.5 times conventional equipment.

The environmental cost of operation can be estimated by comparing the annual mass of road salt and brine, and the annual mass of winter sand for the Class IV, V and HWS operating scenarios.

The base case salting and sanding operations of winter 2005-2006 for Class IV and Class V are derived from archived RCWIS and MTO's Maintenance Management Information System(MMIS) data, for Highways 65 (Class IV) and 560 (Class V). This dataset includes winter maintenance operation information from October 12 2005 to April 14 2006, which covers a typical winter season of northeast Ontario.

Comparison of Safety and Mobility Performance

Figure 6 shows the time series of the observed and predicted RSI for the three classes of highways. As described previously, the RSI of a highway can be viewed as a measure of the safety and mobility level of the highway. The safety and mobility levels for the three highways are quite similar at the beginning and ending periods of the winter season, but differ significantly during the mid-winter season. As expected, the RSI of the Class IV highway (#65) was much higher than that of Class V (#560) and the RSI of HWS is intermediate between that of the Class IV and V highways. However, the average RSI of the new Class is comparable to that of Class IV (0.66 vs. 0.74) (Table 4), which suggests that they are expected to have similar safety and mobility levels. It should also be noted that Class IV highways are to be maintained centre bare, which could lead to imbalanced traction for a vehicle because it could be running with one set of wheels on bare pavement and other set on snow. On the other hand, by converting Class V to HWS, a noticeable safety and mobility gain should be expected (0.66 vs. 0.53). The RSI of the proposed new class (.66) is higher than the means of the conventional classes (.63), suggesting an overall safety benefit depending on the relative traffic exposure of Class IV and V.

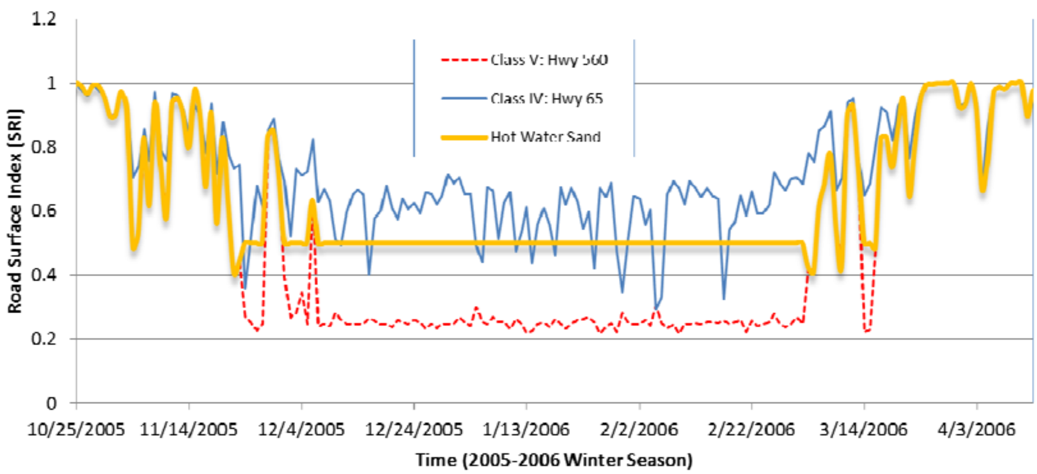


Figure 6: Road Surface Index

Comparison of Costs

Two key cost measures, namely, mass of materials used (including both salt and sand), and the number of maintenance operations are first used to compare the cost performance of the three classes. As shown in Figure 7, the HWS technology as applied to the HWS highway could reduce sand application by approximately 50%. In terms of salt application, the amounts of salt used are similar between Class V and HWS, which are however much less than Class IV.

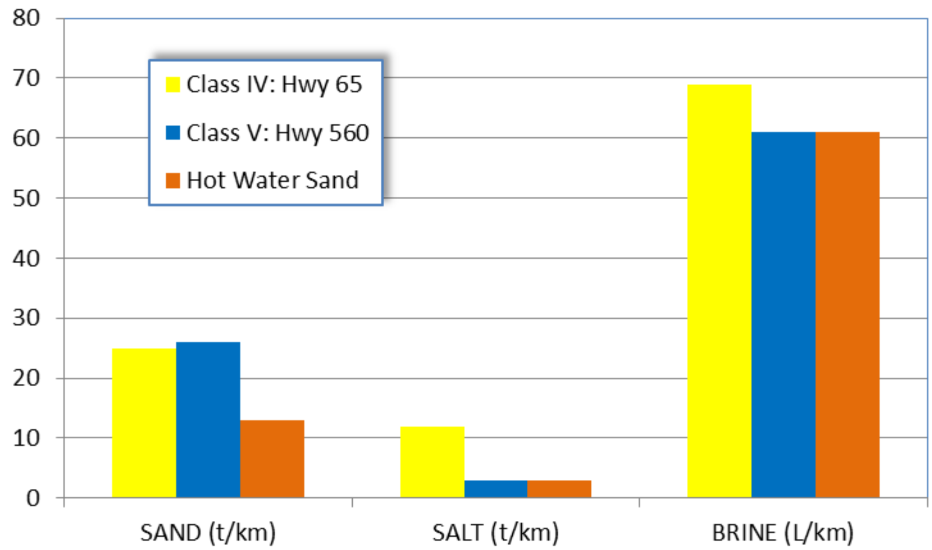


Figure 7: Material Usage

In terms of treatment frequency, the number of sanding trips is dramatically reduced with HWS compared with both Class IV and Class V (Figure 8). The number of salting and plowing trips with HWS is also reduced from Class IV, but similar to Class V.

These cost surrogates can be converted to dollar values based on the nominal unit costs as given in Table 3. Considering both operations and materials, the HWS concept results in slightly lower predicted costs than Class V operation and substantially lower costs than Class IV (Figure 9), with the largest cost reduction due to lower frequency of salting, sanding and plowing.

The resulting costs are summarized in Table 4, which suggests that highway maintenance costs could be reduced by converting Class IV and V to HWS.

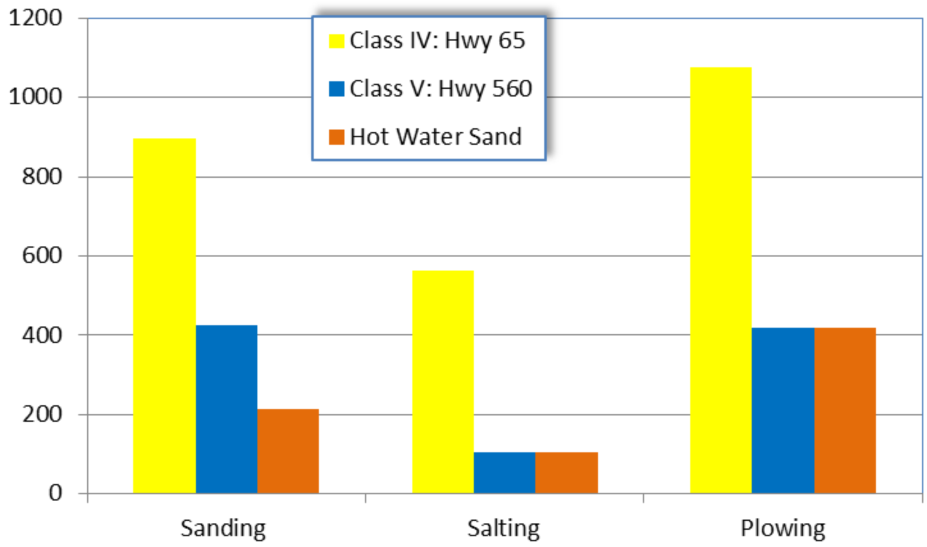


Figure 8: Frequency of Maintenance Operation

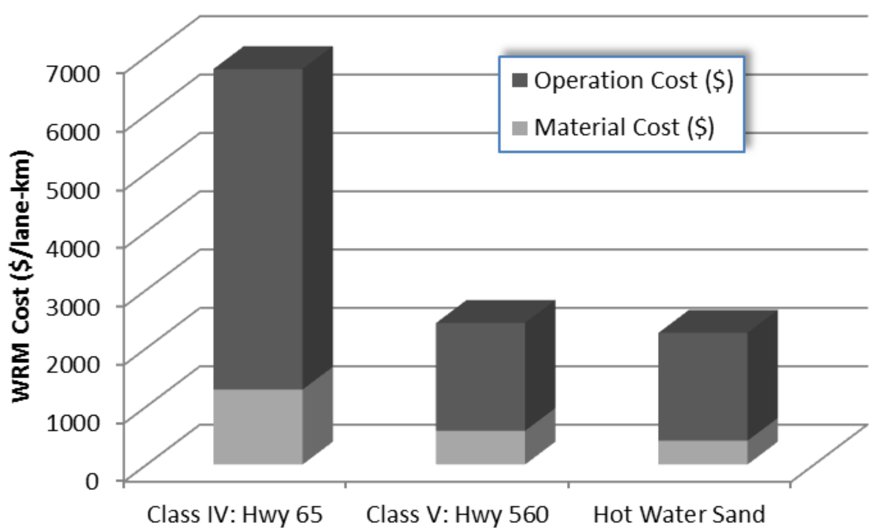


Figure 9: Direct Costs of Winter Maintenance

Comparison of Environmental Impacts

The environmental implication of the new classing scheme could be assessed by the amounts of salt and sand used and fuel consumption (operation frequency). As shown in Figure 7, by converting Class IV to HWS the relative environmental footprint could be reduced by over 50%.

Table 3: MTO Winter Maintenance Operation and Material Cost

(A) Operation Cost

	Class IV - Hwy 65	*Class V - Hwy 560*
SAND ($/2-lane km)	3.93	3.93
SALT ($/2-lane km)	3.93	3.93
Plowing ($/2-lane km)	1.42	1.42

(B) Material Cost

Material Cost	*Class 4 - Hwy 65*	*Class 5 - Hwy 560*
SAND ($/tonne)	13	13
SALT ($/tonne)	80	80

Table 4: Predicted Annual Cost and RSI

Class	*Mean annual RSI*	*Annual $/lane-km*
IV	.74	6783
V	.53	2428
HWS	.66`	2258

Conclusions

This study predicts significant economic, safety-mobility and environmental benefits resulting from the revision of Class IV and V winter standards using the Hot Water Sanding concept.

The predicted Road Safety Index for the HWS is intermediate between that of a conventional Class IV and V highway and higher than the average of those classes. This suggests that road safety can be improved on a road network basis by replacing Winter Class IV and V with a new class having a traction performance standard that can be achieved using the Hot Water Sander concept.

The HWS concept also demonstrates the possibility of environmental benefits from the predicted large reductions in road salt and winter sand as well as a reduction in GHG emissions, compared with conventional methods on Class IV and V highways. Furthermore, both operating and material costs on Class IV and V highways can be reduced.

Several operational and safety related issues were encountered during field trials in Ontario, and these must be overcome to achieve the predicted, network-level economic, environmental and safety benefits. In addition, the predictions use assumptions based on intensively monitored field trials in Scandinavia. Validation of the results under Ontario operating conditions would increase certainty in the predictions.

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