

Reduction of Winter Driving Hazards A Review of Research and Development in Ontario

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ABSTRACT

The Ontario Ministry of Transportation spends approximately \$120 million per year on winter maintenance of highways. Priorities have been set by the provincial government to improve highway safety while reducing expenditures, and this provides a strong impetus for research and development activities.

Research is focussed on reducing hazards from drifting snow through improved highway design, reducing environmental effects of winter maintenance by finding alternative de-icing chemicals, reducing the quantities of chemicals and abrasives applied by developing improved methods of using them, and adopting technology for remote detection of hazardous road conditions.

Activities are most advanced in the areas of drifting snow and remote detection, where efforts are focussed on implementation of research findings and integration with existing operating procedures. Research in de-icing chemicals and abrasives is at an earlier stage of completion and requires investigation of the processes of interaction of these materials with the driving surface and with vehicle tires as well as applied testing and the establishment of protocols for testing.

Research programs continue to address the outstanding scientific and engineering questions, and to ensure that results are applied to improve highway design and operating procedures.

Key words: snow drifting, de-icing, ice detection, salt, highways.

INTRODUCTION

Winter maintenance of provincial highways constitutes a direct expense to the Government of Ontario of approximately \$120 million per year out of a total operations and maintenance budget of \$313 million (Gaston, 1993). Approximately two thirds of the winter operations at rural patrols result from removing falling snow and packed snow from the

road surface, and one third from removing drifting snow in the two or three days following a snow storm (MTO, 1994a). Snow and ice are major contributing factors in 17% of all motor vehicle accidents on expressways in the Toronto area (MTO, 1994b).

The Ontario Ministry of Transportation (MTO) recently announced a goal of making the Province's highways the safest in North America by 1998. At the same time an expenditure reduction plan came into effect, providing a strong impetus for research and development to help in achieving the safety objective.

A research and development program is now underway to find methods of reducing winter safety hazards while reducing expenditures on highway maintenance. The program has four focus areas:

- 1) preventing snow from drifting across the highway
- 2) finding alternative de-icing chemicals
- 3) increasing the effectiveness of existing de-icers and abrasives
- 4) developing new technology to detect winter driving hazards.

This paper reviews the results of recently completed projects and the objectives and progress of continuing work.

PREVENTION OF SNOW DRIFTING HAZARDS

Drifting snow reduces driver visibility and causes snow and ice to accumulate on the driving surface. It also reduces the efficiency of maintenance operations since drifting snow requires equipment call-outs to service very localized areas.

Snow fences and hedges have long been used to reduce wind speed near ground level and cause deposition of drifting snow before it reaches the highway. The use of this method has declined over the past decade because resources are no longer available for seasonal installation or maintenance, and because they are perceived as being unreliable compared with mechanical snow removal (Brubacher, 1992).

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Basic and applied research on the mechanics of wind breaks and climatology of drifting snow (Baker and Williams, 1990, Tabler, 1994) is now being incorporated into highway designs, specifications and operating guidelines which will significantly reduce the frequency of hazards from drifting snow in Ontario. New approaches include:

- * a standard ditch shape and vegetation arrangement for locations which are susceptible to snow drifting,
- * a computer program which tests the effectiveness of landscaping in controlling drifting snow,
- * improved purchase specification for snow screen materials,
- * planting, maintenance and cost guidelines for snow hedges and snow fences.

Physical model tests were used to develop a specially shaped highway ditch which induces deposition of drifting snow before it reaches the road, and to promote erosion of snow from the road shoulder (Theakstone, 1973). The ditch has a back slope of 1:2 and side slope of 1:4. Snow deposition is augmented by a hedge row at the top of the back slope and tall grass or bushes in the ditch bottom while erosion is augmented by close cutting of grass on the side slope adjacent to the road shoulder. The width of the ditch is adjusted to accommodate a volume of approximately 30 m², a climatological estimate of the annual maximum volume of drifting snow in southern Ontario (Perchanok, McGillivray and Smith, 1993) (Figure 1).

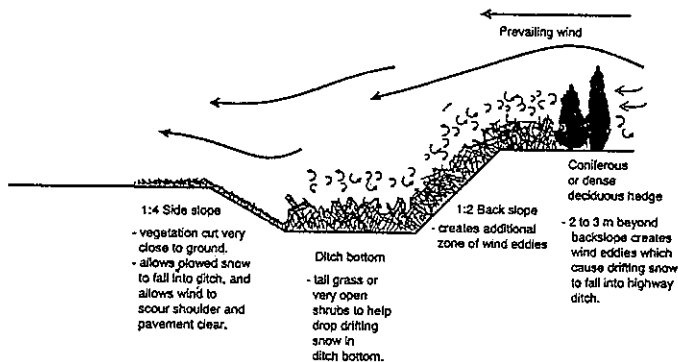


Figure 1. Ditch design to prevent snow drifting.

The first full-scale installation of this standard treatment was completed in the fall of 1993. The effectiveness of the treatment will be monitored and reported after a three year period, and adjustments will be made if required in future installations.

The standard treatment cannot be used in all situations due to topographical, land-use or budgetary constraints, and a computer program was developed to

test and optimize alternative treatments in these situations. The program calculates erosion and deposition of snow in 4 metre grid cells over a 1 km x 1 km area, at time steps of one hour. Empirical formulae developed at the Unversite de Sherbrooke are used to estimate the volume of snow eroded or deposited according to surface slope and roughness in each cell and several adjacent cells. Formulae developed in-house (Perchanok, McGillivray and Smith, 1993) and by the U.S. Strategic Highways Research Program (Tabler, 1994) are used to calculate the effects of sub-resolution features such as snow fences or ditches. Program results are currently being verified against field data, and implementation in the highway design offices will begin when this is complete.

A field and laboratory testing program was used to develop specifications for snow fence materials. The specification is designed to ensure that all materials meet minimum standards in terms of snow trapping performance, handling and durability, and is expected to provide greater flexibility in the selection of products and also to ensure that snow fences are used effectively. The project compared the operational performance of a variety of products against results of controlled tensile strength and elongation tests, and proposed standards for geometric and material properties of fence materials (Figure 2) (Perchanok, 1993). Project results are currently under review by a focus group of users and suppliers.

Results of all of these projects will be incorporated in a standard procedure for designing and maintaining highway ditches and roadside vegetation to minimize the hazard and expenditure due to drifting snow. The procedure will include criteria and catalogues for selection of standard or alternative treatments, instructions for testing their effectiveness using the computer program, and a spreadsheet for analysis of costs of alternative treatments (Perchanok and Bacchus, 1993).

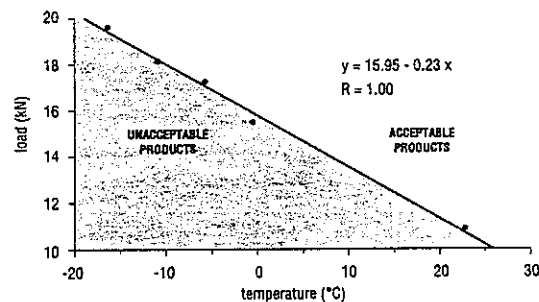


Figure 2. Proposed specification for snow fence; ultimate tensile strength.

ALTERNATIVES TO SALT

Salt is applied to a road surface to facilitate mechanical removal of snow pack by penetrating through it and melting a thin layer at the interface between the snow and pavement (Perchanok, Manning and Armstrong, 1991). Salt is an effective de-icer but it has several adverse environmental effects, including corrosion of steel in automobiles and highway structures, contamination of surface and groundwater, and damage to roadside vegetation.

MTO began a program in 1977 to find alternative de-icing chemicals which have fewer adverse effects than salt and are effective and affordable (Manning, 1990). The investigation has been accomplished through regular review of the literature, sponsorship of an annual Colloquium on Snow and Ice Control, and physical testing of promising chemicals. The physical testing program introduced several innovations to help quantify the performance of de-icers, including measurement of de-icer effectiveness with pavement markings and time-lapse video, and quantitative analysis of de-icing rate (Fig. 3) (Manning and Perchanok, 1992).

In spite of a large international effort, no viable alternative has been found to date and further research is required. Previous efforts to evaluate possible alternatives involved lengthy and expensive full-scale testing programs, and international research has been directed recently to establishing a uniform set of testing protocols for de-icers (Chappelow et al, 1992). Further work is needed to identify key indicators of effectiveness and potential adverse effects under field conditions without the requirement for extensive full-scale testing.

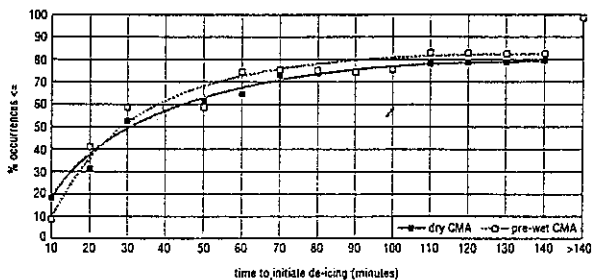


Figure 3. Graphical measure of effectiveness of Calcium Magnesium Acetate de-icer.

SAND AND SALT APPLICATION

As an interim method of reducing the adverse effects of salt as well as reducing expenditures on winter maintenance, various methods of reducing the required application rates for salt and sand are being investigated. Sand is applied to increase the friction

on icy road surfaces when air temperature or other conditions preclude the use of salt (Perchanok, Manning and Armstrong, 1991).

Two projects were undertaken in 1993-94 to screen alternative methods of material application. A laboratory scale program investigated possible improvements to application rates and methods, and full-scale field trials investigated alternative sand application methods.

The laboratory program measured the sliding friction of a locked wheel on an asphalt test pad covered with various combinations of bare, salted and sanded snow and ice (Comfort, 1994). The field tests measured the locked wheel deceleration of a vehicle on a highway under icy and sanded conditions. The test programs provided a preliminary assessment of a range of alternative application rates and methods, and showed those which warrant further investigation.

Laboratory scale tests showed that the friction factor produced by abrasives on a compacted snow surface is sensitive to material gradation and to temperature, and suggests that improved friction may be achieved with reduced material application if a coarser gradation of sand is used (Figure 4). Full scale tests will be conducted to confirm these laboratory results.

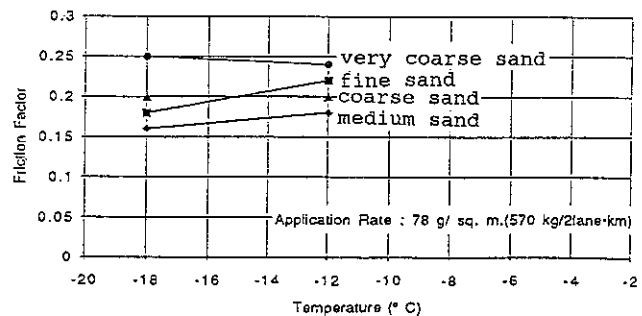


Figure 4. Change in friction coefficient with size gradation and temperature at laboratory scale.

Full scale tests compared the duration retention of dry sand and sand which had been prewetted with a de-icer solution, on icy roads under very cold and windy conditions. The duration of improved skid resistance was compared between test sections using dry and prewet sand (Fig. 5). Retention was improved by prewetting in four out of eight trials, and the average duration of retention for all tests was 24 minutes for dry sand and 39 minutes for prewet sand (Table 1) (Perchanok and Comfort, 1994). Investigation is continuing to determine the reasons for the variation in results, and to better define the conditions under which material retention can be

improved by prewetting.

Improved performance of sand through changes to size gradation or to application method have several benefits to highway operators. In addition to direct cost savings through reduced material application, a better understanding of pavement friction under icy conditions may provide an objective basis for setting maintenance quality standards. For example, road

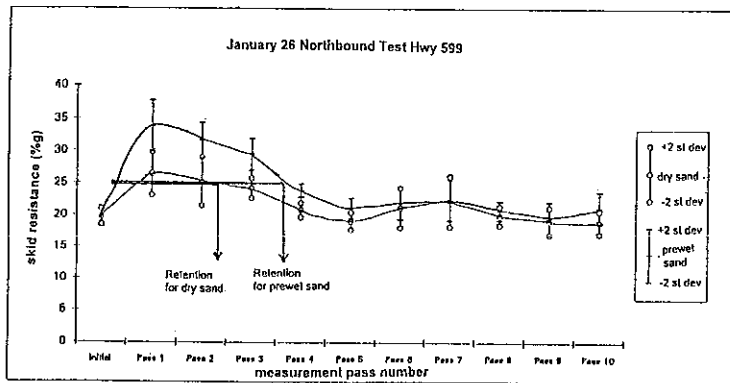


Figure 5. Retention of Dry Sand and Prewetted Sand on Adjacent Highway Sections, January 26 1994.

maintenance contractors may be paid for friction results achieved rather than for equipment time or quantity of material spread. Future work will address both problems.

An empirical approach has been used in these tests and in investigations by other highway agencies. However, a fundamental study of the interaction between vehicle tires, packed snow and abrasives is also needed to aid in understanding and extrapolation of test results, and to guide future work.

Table 1. Duration of Sand Retention

Test #	Retention (minutes after application)	
	dry sand	prewet sand
1	60	81
2	20	10
3	80	100
4	10	10
5	0	0
6	10	90
7	15	20
8	5	5

HAZARD DETECTION TECHNOLOGY

Highway patrol offices in Ontario are being gradually amalgamated to reduce maintenance

operating costs. Amalgamation reduces staffing requirements but may also increase the time delay between onset of hazardous road conditions and site inspection and maintenance by patrol personnel. This may result in an increased likelihood of errors in service procedures. For example, lack of timely information on road conditions distant from the patrol office may result in service trucks being called-out when operations are not necessary at those locations. Alternatively, the need for service at distant locations may go undetected until hazardous conditions have developed. Electronic systems are available which can provide information on road conditions remote from the patrol office.

Automated systems have been available for a decade or more, but several basic questions must be answered before they will be accepted as an operational tool by highway agencies. These include: reliability, cost to benefit ratio, criteria for siting, and method of incorporation of ice detection data into existing operating procedures (Boselly, 1993).

Two systems were recently evaluated by MTO; a remote video surveillance system and a remote ice detection system. The video system consisted of one surveillance camera connected via commercial telephone lines to a personal computer located in the patrol office. The camera angle, field of view and focus were controlled by an operator at the computer terminal and the video image was displayed on the computer monitor. Images were also stored on disk.

The remote ice detection system included in-pavement sensors, an on-site weather station, and processing and display equipment at the patrol office. It provided real-time information of the presence of water, slush or ice at the in-pavement sensor locations. A short-term forecast of pavement icing conditions was also provided as part of a vendor meteorological service.

The reliability of each system was evaluated over one winter season and a preliminary cost to benefit analysis was performed for the remote video system. Reliability of the video system was evaluated by comparing road and weather conditions displayed on the computer terminal at the patrol office with conditions recorded on site on high resolution video tape. Seventy-nine tests were conducted at random times through one winter season and included clear and storm conditions in roughly equal proportions. The comparison showed that road conditions were interpreted correctly 92 percent of the time using the remote display. The total capital cost of the system was \$27,000, and the annual capital and operating costs assuming a ten year service life were estimated at \$4640. Cost savings expected from the system in terms of reduced accidents and reduced salting,

sanding and plowing were also estimated and resulted in a cost to benefit ratio of 0.91 over a ten year period (Perchanok and Raven, 1994).

Reliability of the ice detection system was evaluated by comparing conditions reported by the system with conditions reported by on-site observers. It showed similar results to the video system. The reliability of the pavement icing forecast was also evaluated by comparing the forecast with actual conditions at the forecast time of ice formation. The forecast was correct approximately 75 percent of the time over one winter season. The capital cost of the system was \$124,000 and annual operating costs were approximately \$9,000 (Masliwec, Leung and Jewer, 1993). Potential benefits or cost savings were not estimated.

The evaluation projects demonstrated the technical feasibility of providing information on pavement ice conditions at remote locations but additional investigation is required to establish the criteria, such as cost savings or improved safety, which justify the installation of ice detection and road condition information systems. This is a complex task because both costs and benefits are affected by the number and location of sensors in a patrol area, and the estimation of benefits involves a large number of uncertainties. For example, possible reduction in staffing levels, improvements in operating procedures and in road surface condition are all interrelated and are affected by the number, type and location of sensors.

CONCLUSIONS

New technologies and improved methods of operation hold the potential to reduce winter driving hazards from drifting snow and icy pavement, and to reduce highway operating expenses in controlling these hazards.

Improvements to methods for controlling drifting snow have been developed and are now in the implementation stage. Additional work is needed to integrate new technology and designs with existing practice.

Investigations to date have not been successful in finding an alternative to salt which meets the criteria of effectiveness, affordability and reduced environmental effects. The development of standard protocols for testing and acceptance of alternative deicers is a priority which will significantly reduce the complexity of the research effort in this area.

Preliminary empirical research into alternative material application methods such as prewetting of abrasives, holds promise for reducing maintenance

expenditures and improving winter driving conditions. Additional study to develop a better understanding of the underlying processes of interaction between a snowpack and abrasive materials would assist in interpreting and extrapolating the empirical test results, and developing improved operating procedures.

The technical feasibility of automated systems for remote detection of snow and ice conditions has been adequately demonstrated. Implementation of these technologies is limited by a poor understanding of the cost to benefit equation, and lack of systematic criteria for selecting and prioritizing sensor locations.

The challenge to reduce both the hazards of winter driving and the costs of winter road maintenance provide scope for research and development in a range of subject areas encompassing sensors, numerical modelling, the mechanics of interaction between snow, abrasives and pavement, and operations research in the implementation of new design and maintenance technologies. The Ministry of Transportation strives to meet these challenges through continuing research and implementation efforts.

ACKNOWLEDGEMENTS

The author acknowledges support and assistance from the Research and Development Branch, the Maintenance Office, the Engineering Materials Office, and the Surveys and Design Office, Ontario Ministry of Transportation.

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