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Storm Water Management Fact Sheet

Minimizing Effects from Highway Deicing

DESCRIPTION

The United States is critically dependent on its road system to support the rapid, reliable movement of people, goods, and services. Even in the face of winter storms, we expect roads and highways to be maintained to provide safe travel conditions. In many states, this requires substantial planning, training, manpower, equipment, and material resources to clear roads and streets throughout the winter.

The dependency on deicing chemicals has increased since the 1940s and 1950s to provide "bare pavement" for safe and efficient winter transportation. Sodium chloride (common table salt) is one of the most commonly used deicing chemicals. Concern about the effects of sodium chloride on the nation's environment and water quality has increased with this chemical's usage. Automobile and highway bridge deck corrosion has also become a concern. However, in most cases sodium chloride is the most cost effective deicing chemical. Such concerns have led to major research efforts by the Strategic Highway Research Program (SHRP), the highway community, industry, government, and academia. This ongoing research is exploring many different areas in an effort to maintain the safest roads possible in the most economical way while protecting the environment.

This fact sheet summarizes research addressing water pollution and associated effects from deicing chemicals, and describes the methods used to control snow and ice on roadways while minimizing impacts on the environment. Because of this topic's breadth, sources for research and alternative methods are listed and can be referenced for more detail. This fact sheet emphasizes methods and practices for snow removal that are feasible and cost effective for local governments to implement and that are also consistent with sound environmental quality goals.

APPLICABILITY

Beginning in the late 1940s and 1950s, the "bare pavement" policy was gradually adopted by highway agencies as the standard for pavement condition during inclement weather. The policy provided safer travel conditions on roadways and became a useful concept for roadway maintenance because it was a simple and self-evident guideline for highway crews. Dispersion of city populations into suburbs, higher travel speeds, and growing dependence upon automobiles for commuting and commerce increased the need for snow and ice removal for safer roadways (Lord, 1988). Salt was first used on roads in the United States for snow and ice control in the 1930s (Salt Institute, 1994). In the 1960s, the use of salt as a deicing chemical became widespread in the United States because salt was readily available, effective on ice and snow, and the lowest cost alternative (Salt Institute, 1994).

A common perception that "more is better" led to practices of high application rates of salt. By the late 1950s, however, damage to roadside sugar maples (a salt- intolerant species) in New England had given rise to concern about the widespread use of salt. Shortly thereafter, contamination to drinking water from wells located near unprotected salt storage areas heightened this concern (Lord, 1988). Other adverse effects from the runoff of road salts, including the pitting and "rust out" of automobiles and corrosion of highway structures, especially bridge decks (Lord, 1988) were also becoming apparent.

These environmental concerns have spawned a number of research programs. The goal of this research has been to minimize the environmental effects of deicing while still providing a cost effective means of clearing roadways for safe travel. Early in the 1960s, research began on alternative deicing chemicals, reduced chemical use, improved operational practices, pavement heating, pavement modification, and mechanical approaches (Lord, 1988). More recently, a "Snow and Ice Control" study was conducted by the SHRP, a unit of the National Research Council that was authorized by Section 128 of the Surface Transportation and Uniform Relocation Assistance Act of 1987 (SHRP, 1994b). The snow and ice control research included five major initiatives: improved operational procedures; road weather information systems; alternative deicing chemicals; pretreatment; and mechanical approaches. These are discussed further in the Implementation section below.

ADVANTAGES AND DISADVANTAGES

Highway ice and snow removal is essential both to public safety and to local and interstate commerce. However, the traditional method of deicing roads through the use of salt has several drawbacks. First, the use of salt has led to degraded habitats in areas where salt accumulates in runoff. Second, the storage and use of salt can be expensive. In a 1988 paper, Lord estimates that 400,000 tons of salt, approximately 5 percent of the 8 million tons used annually in the United States is lost from uncovered stockpiles. An estimate of $30 per ton of salt equates to a monetary loss of $12 million dollars each winter (Lord, 1988). A well planned and operated snow and ice removal program is essential to ensure public safety and to minimize environmental effects and costs.

IMPLEMENTATION

Many initiatives have been taken to control ice and snow on roadways while minimizing any associated environmental effects. Several of these initiatives are discussed below

Improved Operational Practices

Clearing roadways after winter storms accounts for a large portion of the highway maintenance budget for many northern states. According to the Salt Institute's 1991 Snowfighter's Handbook, snow removal in 33 snow belt states accounted for 16.2 percent of total highway maintenance costs and 3.6 percent of all highway expenditures (Salt Institute, 1991).

To aid highway management personnel in improving operational practices, the Salt Institute initiated a "sensible salting" program in 1967 (Lord, 1988). These guidelines have evolved with technology to include the following: planning; personnel training; equipment maintenance; spreader calibration; proper storage; proper maintenance around chemical storage areas; and environmental awareness (Salt Institute, 1994). Further information on the "sensible salting" program can be obtained from the Salt Institute, located in Alexandria, Virginia.

While all of these guidelines reflect key concerns, proper storage is considered one of the most effective in source control of deicing chemicals (U.S. EPA, 1974a). Guidelines for siting and designing deicing chemical storage facilities are provided in the Manual for Deicing Chemicals: Storage and Handling (U. S. EPA, 1974b).

In addition to reducing the amount of salt lost due to runoff, the actual amount of salt used on the roads can be reduced. The Regional Groundwater Center (1995), estimated that 10 million tons of salt are used each winter in the United States to melt snow and ice on roads and surface streets (Regional Groundwater Center, 1995; Salt Institute, 1994). Salt application rates range from 300 to 800 pounds per two-lane mile, depending on road, storm, and temperature conditions (Salt Institute, 1994).

One of the most effective measures for reducing chemical application has been the use of a calibrated spreader using the optimal application rate. Automatic controls on spreaders are recommended to ensure a consistent and correct application rate. The spreader should be calibrated prior to and periodically during the snow season, regardless of whether automatic or manual controls are used.

Uncalibrated controls and poor maintenance are often responsible for excessive salt use (Salt Institute, 1994). Guidelines for the calibration of spreaders and determination of application rates are given in the Salt Institute's Snowfighter's Handbook (1991) and in the EPA document *Manual for Deicing Chemicals: Application Practices* (U. S. EPA, 1974a).

Road Weather Information Systems

In an effort to maximize the effectiveness of control efforts and to reduce costs, the SHRP has sponsored research using road weather information systems (RWIS) for highway snow and ice control. Components of the RWIS include meteorological sensors, pavement sensors, site-specific forecasts, temperature profiles of roadways, a weather advisor, communications, and planning (SHRP, 1993b, 1993c).

The RWIS can maximize the effectiveness of icing and plowing efforts by pinpointing and prioritizing roadways that need attention. It can also eliminate unnecessary call-outs and improve scheduling of crews based on estimates of the extent and severity of the storm. Research indicates that the use of the RWIS technologies can improve efficiency and effectiveness as well as reducing the costs of highway winter maintenance (SHRP, 1993b). Thus, RWIS may improve snow and ice removal service. This report concludes that road weather information system technology may improve service. The report recommends that every agency that regularly engages in snow and ice control consider acquiring some form of road weather information systems; at a minimum, forecast services should be used.

The SHRP has also pointed out that additional research beyond the scope of the original RWIS project would be helpful (SHRP, 1993b). Additional information about RWIS and intelligent and localized weather prediction is provided in the following SHRP manuals: Road Weather Information Systems, Volumes 1 and 2 (SHRP, 1993b, 1993c); and Intelligent and Localized Weather Prediction (SHRP, 1993a).

Alternative Deicing Chemicals

The most commonly used salts for deicing are sodium chloride (NaCl) and calcium chloride (CaCl) (Salt Institute, 1994). The eastern and north-central sectors of the country use more than 90 percent of the approximately 10 tons of salt used each year (Lord, 1988). However, sodium chloride has several drawbacks, including its harmful environmental effects. Therefore, due to both environmental concerns and the importance of snow and ice removal programs in terms of public safety and economic factors, there has been an abundance of research on alternative deicing chemicals.

An acceptable alternative deicer must have an effective melting range similar to salt's, and must be cost-comparable or less expensive. One such chemical is calcium magnesium acetate (CMA). CMA is made from delometric limestone treated with acetic acid. While CMA does not overcome all the undesirable characteristics of salt, it is still an effective deicer. CMA is frequently used because it has less potential to affect the environment and is not as corrosive as salt. However, to achieve the same deicing effectiveness as salt, CMA materials need to be applied in larger quantities. In addition, CMA's cost exceeds salt's by a factor of 10 to 20 (Lord, 1988). Continual efforts are being made to find a more effective production technology to lower the cost of CMA, but these efforts have had limited success (Lord, 1988).

Because of the growing interest in deicing technology, the SHRP published a handbook to standardize testing procedures used to evaluate deicing chemicals (SHRP, 1992). Deicing chemicals are evaluated based on their fundamental properties (e.g., ice melting potential, thermodynamic factors), physicochemical characteristics, deicing performance (e.g., ice melting, ice penetration, ice undercutting), materials compatibility, and additional engineering parameters. Additional information on these testing procedures is provided in the *Handbook of Test Methods for Evaluating Chemical Deicers* (SHRP, 1992).

Pretreatment

Limited experience (mainly in Scandinavian and other European countries) has shown that applying a chemical freezing-point depressant on a highway pavement prior to, or very shortly after, the start of accumulation of frozen precipitation minimizes the formation of an ice-pavement bond (SHRP, 1994a). A liquid salt solution has been applied prior to a snowfall in Scandinavia and has proven successful for pretreatment (SHRP, 1994a). This anti-icing or pretreatment practice reduces the task of clearing the highways and decreases the amount of chemical applied from that required when deicing chemicals are applied after snow and ice have begun to accumulate.

When properly implemented, pretreatment practices may reduce costs and be more effective than conventional practices. However, most state highway agencies have not adopted pretreatment because they are uncertain how and when to implement it. Other concerns with pretreatment practices include the imprecision with which icing events can be predicted, the uncertainty about the condition of the pavement surface, and the public's perception of wasted chemicals. Some early attempts to utilize pretreatment practices in the United States have failed because of these problems (SHRP, 1994a).

Technological improvements in forecasting weather and in assessing pavement surface conditions, as previously mentioned, offer the potential for successful implementation of pretreatment. Research during the winters of 1991-92 and 1992-93 by the SHRP indicated that a 40 percent and 62 percent reduction, respectively, in chemical usage was possible using pretreatment (SHRP, 1994a). Pretreatment's success depends on accurate RWIS, a technology that is still evolving. Development of spreaders specifically designed or retrofitted to distribute prewetted solid material or liquid chemicals, calibration and evaluation of spreaders, training of maintenance personnel, and effective communication also need further attention to ensure the success of a pretreatment program (SHRP, 1994a). Additional information on pretreament is available in the SHRP manual entitled *Development of Anti-Icing Technology* (SHRP, 1994a).

Mechanical and Structural Approaches

Many mechanical and design approaches have been and are being evaluated in an effort to improve snow and ice control practices. Some of these attempts have been very successful, while others have had limited success or need additional research. This section examines several mechanical and design approaches, including pavement heating, pavement coatings, mobile thermal deicing equipment, snow fences, and snowplows. This list is not comprehensive.

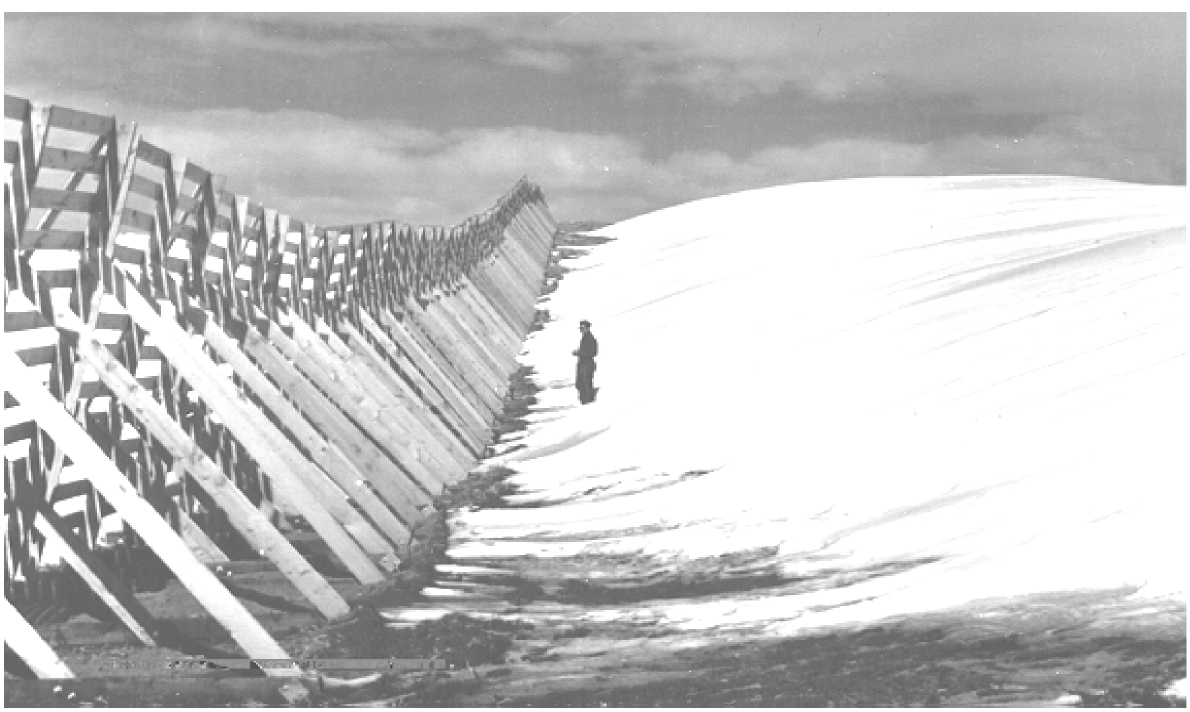
Because of cost or feasibility, pavement heating and pavement coatings have had limited success in snow and ice removal. Pavement heating systems are costly to install, and operational costs exceed those of salt on the order of 15 to 30 times (Lord, 1988). Pavement coatings involve using hydrophobic or icephobic coatings to reduce the adhesion of ice and snow to the roadway. Pavement coatings are required to weaken or prevent bonding, while not decreasing vehicle traction in no-snow conditions. They are also required to persist in extremely harsh conditions. Pavement coatings were generally unsuccessful because they were unable to meet these goals (Lord, 1988 and U. S. EPA, 1976b). A 1976 EPA Manual, *Development of a Hydrophobic Substance to Mitigate Pavement Ice Adhesion* (U. S. EPA, 1976b), describes this research. Mobile thermal deicing equipment has also been evaluated and determined to be impractical.

Snow fences are used to keep snow from being blown into drifts. Studies show that snow fences minimize costs associated with snow clearing, reduce the formation of compacted snow, and reduce the need for chemicals. Mechanical snow removal costs approximately 100 times more than trapping snow with fences (SHRP, 1991).

One concern regarding snow fences focuses on their position and design. About 20 years ago, it was very common to find that 4 foot picket snow fences had buckled under the weight of accumulated snow (SHRP, 1991). When properly designed and positioned, a taller snow fence is more effective than the traditional low picket snow fence. Not only is size relevant to the fence's performance, but so is its weight. A lightweight plastic, for example, allows for the construction of a portable fence up to 8 feet tall (SHRP, 1991). A 15-foot-tall snow fence used in Wyoming is shown in Figure 1. To minimize improper positioning and design of snow fences, the SHRP has provided publications such as *Design Guidelines for the Control of Blowing and Drifting Snow* (SHRP, 1994b), *Snow Fence Guide* (SHRP, 1991), and a 21-minute video entitled "Effective Snow Fences."

Snowplow designs in the United States have evolved empirically. These designs, however, have neglected to incorporate the effects of the physical properties of the materials handled by the plow and the aerodynamic and hydrodynamic principles involved in the flow of fluidizing snow. Consequently, more energy is expended in displacing snow than is necessary, and the short cast distance necessitates rehandling of the snow (Lord, 1988). The SHRP has funded research at two universities to improve development of plow blade design and cutting edges for the plow blades (SHRP, 1991). The first research project, conducted by the University of Wyoming Department of Mechanical Engineering, focused on developing an improved snowplow blade that minimizes energy needed to throw snow clear of the roadway. The plow design, based on analytical methods and laboratory scale experiments, showed a 20-percent improvement in efficiency over conventional plows. The plow underwent testing in West Yellowstone, Montana during the winter of 1990-1991 (SHRP, 1991). Research for additional technological advances in plow design is ongoing.

Another research project, conducted by the University of Iowa Institute of Hydraulic Research, sought to improve snowplow efficiency by improving cutting edges of plow blades (SHRP, 1993e). Laboratory tests were performed with a hydraulic ice-cutting ram to determine the effects of the geometry of the cutting edge of a snow plow blade on the force required to remove ice from a highway pavement surface. Results of this research indicate that changes in the cutting edge geometry result in substantial improvements in ice cutting; cutting edge performance may still benefit from further studies (SHRP, 1993e). An Iowa



Source: Reprinted with permission, Tabler and Associates, 1972.

Department of Transportation “plowing truck” cutting ice is shown in Figure 2. Additional information can be obtained in the SHRP manual entitled “Improved Cutting Edges for Ice Removal” (SHRP, 1993e).

COSTS

The United States and Canada spend over $2 billion dollars each year on snow and ice control (SHRP, 1993b). However, very little cost data has been generated to show the direct costs of, or the cost reductions due to, the specific snow removal alternatives and process improvements discussed in this fact sheet. Some cost information has been generated for alternative deicing chemicals. NaCl is both the most common and the most cost-effective deicing agent, with costs per ton ranging from $17 to $30 (Lord 1988; Jesperson, 1995). The Michigan Department of Transportation drew this conclusion in a recent evaluation. The evaluation examined the costs of sodium chloride (road salt), CMA, CMS-B (also known as Motech), CG-90 Surface Saver (a patented corrosion-inhibiting salt), Verglimit (patented concrete surface containing calcium chloride pellets), and calcium chloride (MDOT, 1993). Most of the alternative deicers ranged in cost from $200 to $700 a ton (Jesperson, 1995), and were thus significantly more expensive than sodium chloride.

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FIGURE 2 A PLOWING TRUCK CUTTING ICE

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