# Implementing Passive Snow and Ice Control Measures

**By**

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## Introduction

Blowing snow in snowy and windy regions presents a major problem for winter maintenance personnel and those using the transportation systems. Reducing the negative impact and uncertainties associated with blowing and drifting snow requires a broad understanding of the interaction between the atmosphere, terrain, roadway design and blowing snow.

Mitigating these negative effects of blowing and drifting snow on the nation's transportation systems has been the focus of winter maintenance research and field evaluation and experimentation in the United States for decades. Various treatment options from these research efforts have been implemented with varying degrees of success. Each have made worthy contributions to improving visibility, mobility and safety and reducing drifting, roadway icing, winter maintenance costs and road closure times.

This paper summarizes two decades of foundational research and field evaluation, case studies, technology transfer efforts, the development of prediction models for when and where blowing snow will occur, and implementation of engineered mitigation techniques for blowing and drifting snow problems in the U.S. and other parts of the world. Roadway design that includes drift prediction modeling with trial fence and earthwork solutions, living snow breaks and constructed snow fencing mitigation strategies will be outlined and their environmental and cost benefits and effectiveness will be illustrated and discussed. Actions to advance technology transfer of this underutilized mitigation resource and promote implementing different forms of passive snow control in the U.S. and other countries that experience blowing and drifting snow problems will be presented.

## Early Mitigation Efforts

The hazards associated with blowing and drifting snow were recognized early in the settling of this country. Soon after shelters were built for people and live stock, trees and bushes were planted to slow the biting winter winds and deposit snow away from feed lots and living quarters. These early mitigation efforts were guided by common sense and previous experience. Today we would label those efforts as “living snow fences”. Common sense for these early settlers indicated one to three rows of Spruce, Cedar or Junipers, planted upwind about 100 yards from what was to be protected and perhaps two or three rows of scrubs planted midway to help snow control during the years before the trees become fully effective was a good rule of thumb. Evidence of those early blowing and drifting snow mitigation efforts can be seen as one drives the country side in the snow-belt states.

Blowing and drifting snow has major impacts on transportation safety and mobility and can add significantly to the cost of snow and ice control operations. These impacts were recognized in early construction especially in windy locations where the quantity of snow that blows onto a highway or railroad can be hundreds of times greater than the snow that falls directly onto the roadway. [1 pp6]. Tabler [1] shows examples of rock snow fences built in 1868 to protect the railroad cuts in southeast Wyoming. He also shows photographs of wooden snow fence being constructed in 1901 near Laramie, Wyoming and wooden snow fence, 4 meters in height built in 1900 near Skagway, Alaska to protect the White Pass and Yukon Railroad. One can quickly see the engineering advances in design made in those 30 intervening years. After 1930, design improvements for trucks, snow plows and locomotives made brute force snow removal possible. As such, the need for drift control research lost its importance and therefore little research was accomplished over the next forty years.

## Interstate Construction Brings a New Focus

Construction of a new design for the Interstate System brought new mobility and safety expectations from the transportation user. The new open cross section interstate design worked well in most of the country, but in the windy and snowy regions it was easy for Old Man Winter to get the better of even the new open cross sections of the Interstate. For example, Interstate 80, opened in October 1970 was the first documented quantitative evaluation of the effectiveness of snow control measures.

> “Three months later, snowdrifts as deep as 5 meters (16 feet) encroached on the traffic lanes at 27 different locations, and 6 bulldozers were working around the clock, 7 days a week, to remove these drifts. Winds commonly averaged more than 50 km/h (30 mi/h) for days at a time, and the road had to be closed for a total of 10 days because of poor visibility and accidents. As a result of this first winter, snow fences were designed to protect all of the locations where drifts reached the road that first winter, using the progenitors of the guidelines presented in this book. The initial

contract consisted of 18.3 km (11.4 mi) of snow fence that ranged in height from 1.8 to 3.8 m (6 to 12.4 ft), constructed at a cost of $480,000.

Careful monitoring of these first fence systems during the 1971-72 winter proved their effectiveness in preventing drifts (figures 2.4 to 2.7), but the improved visibility and road surface conditions in fence-protected areas (figures 2.8 to 2.11) were even more impressive because these latter effects were unexpected.

The dramatic effectiveness of those first fences led to many more being installed over the next 18 years. At present, the system on this same section of I-80 consists of 63.6 km (39.5 mi) of fence protecting about 64 km (40 mi) of highway, built at a total cost of $2,260,000.

Ten years after the first fences were constructed, a study was undertaken to quantify their effectiveness. The gradual increase in fence protection over the 10-year period afforded a unique opportunity to quantify the reduction in accidents (figure 2.12). In a winter with average snowfall and traffic volume, statistics suggest the fencing in place in 1980 prevented 54 accidents and 35 injuries. The original construction cost of the I-80 fences was amortized in less than 15 years by savings in property damage alone. In addition, eliminating drifts reduced winter maintenance expenditures by one-third to one-half ". [1 pp9-10]

## Focused Research Brings New Progress

Although considerable progress in controlling blowing and drifting snow occurred from 1971 to 1981 on I-80 in Wyoming, much more could be learned through additional research, evaluation, and application. As luck would have it, Transportation Research Board (TRB) was completing a series of efforts entitled the "Strategic Transportation Research Study" (STRS) that assessed and recommended transportation research priorities for various modes of transportation taking into consideration their expected payoffs and chances for success. Results of one of the studies, "America's Highways, Accelerating the Search for Innovation" completed in 1984 examined a wide range of highway research activities and "…concluded that a unique opportunity exists to undertake a new approach in highway research by focusing on a limited number of major initiatives in a few critical areas." [2] One of those "few critical areas" was snow and ice control on highways. A total of $1.6 million was designated for the Strategic Highway Research Program (SHRP) in that area. SHRP let contracts for a number of snow and ice control research projects, one of which addressed how to design effective and economical measures for controlling snowdrifts and reducing the concentration of snow in the air. The deliverable from that contract was a report entitled, "Design Guidelines for the Control of Blowing and Drifting Snow". [1] The report:

"…provides all of the information needed to design effective and economical measures for controlling snowdrifts and reducing the

> concentration of snow in the air. Snow control is as technically complex as other areas of civil engineering. The guidelines for drift control are derived from mathematical analyses of the evaporation of wind-transported snow particles, turbulent mixing behind barriers, turbulent diffusion processes, and boundary layer mechanics. For this reason, control measures should be designed by individuals with an engineering background. It is for such an audience that this book has been prepared. Because this specialty involves material not included in most civil engineering curricula, sufficient background information is presented to make this a self-contained "bootstrap" reference. [1 pp1]

As one can surmise from reading the above quoted material, the guidelines are very detailed and complete with every step and description. The guidelines didn't, however, just jump out of the report and stand ready to be implemented; some class room instruction was needed. The guidelines were very helpful in assisting field maintenance supervisors in getting started with fine tuning their snow fence installations. Most field maintenance personnel were using 4 foot lath fencing and the guidelines opened their thinking to other types of snow fence materials. The guidelines also helped in introducing higher fences for more storage.

The 1994 "Design Guidelines for the Control of Blowing and Drifting Snow" was updated in 2003 and titled "Controlling Blowing and Drifting Snow with Snow Fences and Road Design". [3] A PDF of the report is posted on the American Association of State Highway and Transportation Officials (AASHTO), Snow and Ice Cooperative Program (SICOP) website www.transportation.org/?siteid=88&pageid=2173 . The report, now more than 300 pages in length, contains documentation for much of the logic and many of the algorithms for the mitigation measures for blowing snow. The purpose in providing more detail was to stimulate additional research and facilitate the development of computer-assisted snow control technology. The report also describes the rationale for the guidelines incorporated into the interactive Internet sites developed by the Minnesota DOT and the University of Minnesota, websites at:

http://climate.umn.edu/snow_fence/Components/Design/locationb.asp and

http://www.livingsnowfence.dot.state.mn.us/index.html

## International Winter Maintenance Scanning Tours Bring New Ideas

In March 1994, an International Winter Maintenance Scanning Tour was conducted to view winter operations in Japan, Austria, and Germany. The purpose of the Scanning Tour was to discover important differences in winter maintenance and evaluate those winter maintenance technologies for appropriate application in the United States. Many differences in snow removal equipment, weather monitoring, winter hazard mitigation, road user information services, public perception, methods used for financing, and the cooperation between public agencies and private enterprise in research and development efforts were unearthed. These discoveries were well documented for later evaluation to determine their applicability to operations in the United States. [4]

A unique discovery was an alternative snow fence called a “blower” fence, used by the Japanese in areas of limited available right of way that could not accommodate the conventional snow fences. The blower fence is designed to accelerate the airflow in the immediate vicinity of the roadway and reduce snow accumulations on the lee side of these fences by vigorous wind action.

The Hokkaido Development Bureau’s Construction Machinery Engineering Center developed a unique blowing and drifting snow wind tunnel for modeling and analyzing the effects of highway cuts and fills, structures and simulated blizzard using clay particles that behaved like blowing and drifting snow. A terrain model would be constructed and placed in the wind tunnel and then subjected to the blizzard conditions. After studying the resulting drift patterns, the cross-section design could be altered or snow fence placed and the model rerun to evaluate results. The end product would be an optimized design.

The major advantages of the Scanning tour for introducing change in winter operations in the U.S. were: 1) the equipment and methods being used in Japan and Europe for improving winter operations were already in use; 2) photographs were taken and used in reports and presentations; and 3) Scanning tour participants were enthusiastic supporters for improvement to U.S. winter operations and to ensure technology transfer was accomplished used the photographs and talked about their experiences at conferences, workshops, and winter snow roadeos.

## Technology Transfer

Two major efforts have occurred since the completion of the August 2003 guidelines in “Controlling Blowing and Drifting Snow with Snow Fences and Road Design”. [3]

1. The author and principal investigator Ronald Tabler developed a formal training program and has provided on-site training for many of the state DOTs maintenance and design employees. This comprehensive training has filtered down the ranks and newer and better designed snow fence installations and living snow fences are appearing in the snow-belt states.
2. AASHTO in cooperation with the Clear Roads Consortium developed a computer-based training (CBT) program entitled “Blowing Snow Mitigation”. This interactive CBT has been distributed to 32 of the snow-belt state DOTs who joined the pooled fund to develop the CBT training. American Public Works Association (APWA) actively markets the CBT to local governments. National Association of County Engineers (NACE) distributed the CBT to the Local Technical Assistance Program (LTAP) for use in their training program. The CBT was developed using an Expert Task Group (ETG) consisting of field maintenance personnel from state and local governments to take the rather complicated research material found in the guidelines and simplify it for an

interactive, self-paced, computer-based training that is designed to accommodate multiple learning styles. The CBT contains seven units as follows:

a. Unit 1: The Problem of Blowing Snow
b. Unit 2: How Snow Fences Work
c. Unit 3: Identifying and Analyzing Problem Areas
d. Unit 4: Structural Snow Fence Design
e. Unit 5: Living Snow Fences
f. Unit 6: Road Design to Mitigate Blowing Snow
g. Unit 7: Working with Landowners

## Deploying Computer-Based Expert Systems

There have been several efforts involved in developing computer-based tools to assist with the computations involved in the design of passive control of blowing and drifting snow. These include PASCON, an expert system for passive snow control on highways [5], Wyoming DOT Drift Profiler, which predicts drift profiles [6-7], and an interactive web site www.livingsnowfence.dot.state.mn.us/index.html developed by the University of Minnesota and Minnesota DOT, that allows the user to determine the required height, setback, and overlap of snow fence systems for locations in Minnesota. The PASCON and Minnesota DOT system are not integrated into the CAD environment utilized by highway designers. The Wyoming DOT application does not actually design the fence systems.

The most recent means of engineered blowing and drifting snow mitigation using both road design and snow fence design can be found in a software tool called SNOWMAN, which is an acronym for Snow Management. SNOWMAN was supported by New York State Department of Transportation (NYSDOT) and developed through the joint efforts of Brookhaven National Laboratory and the State University of New York at Buffalo, with Cornell University providing project management. The software was developed as a MDL (MicroStation Development Language) application to run within the Bentley MicroStation CAD software environment used in NYSDOT highway design projects. The system utilizes a platform for generating terrain cross-sections parallel to the prevailing snow transport direction from digital terrain model files. The desired solution can be specified, either earthwork or snow fence, and specific constraints. The system uses a New York statewide climatological database for quantifying snow transport for a specific location. A more complete description of SNOWMAN can be found in "Computer-Aided Design of Passive Snow Control Measures". [8]

The effort began in 1997 and the first designed mitigation was constructed on a road serving the Erie County Correctional Facility in the snowy region of Buffalo, New York. A single row of wooden plank snow fence, 700 feet in length and six feet tall was constructed along the west side of Wende Road in an area that was noted for repeated callouts to remove blowing and drifting snow. The new design was evaluated during the winter of 2008-2009, a winter noted for heavy snow and high wind episodes. Results exceeded expectations with improved visibility and a great reduction in drifting. The Highway Supervisor for the area reported that he did not have to call the crew out for any drift removal since the snow fence had been installed. Correctional facility staff who need to use the road at all hours everyday provided very positive feedback on the effectiveness of the snow fence.

SNOWMAN has been exported to the Iowa DOT to determine its ability to be installed on their CAD MicroStations and adapted to the Iowa climate. Several trial problem area locations will be explored in 2009-2010 for engineered mitigation techniques application and construction.

## Summary and Conclusions

Blowing and drifting snow can add significantly to the cost of winter maintenance operations. Tabler studies referenced earlier in this paper report benefit to cost ratios ranging from 50 to 100:1 for permanent snow fences, based only on reduced costs for snow removal. The 15-year study on I-80 in Wyoming showed snow fences reduced snow removal expenditures by one-third to one-half. Society also pays a high price since adverse weather is associated with over 1.5 million motor vehicle crashes each year resulting in over 800,000 injuries and 7,400 fatalities. [9]. Statistics were not available to determine how many of the crashes nationwide were in part due to poor visibility due to blowing and drifting snow. However, Tabler's study on I-80 in Wyoming in areas where blowing and drifting snow was a problem, indicated up to 25% of all crashes occur during blowing snow in areas without snow fence, compared to 11% in areas protected by snow fences provides some indication of the safety benefits of engineered blowing and drifting snow mitigation solutions that could be applied nationally.

This paper has illustrated the progress that has been made in research, modeling, technology transfer and implementation of engineered mitigation techniques for blowing and drifting snow problems in the U.S. and other parts of the world. These mitigation techniques, while presently underutilized, are becoming easier to understand and utilize and are experiencing increased implementation. The SNOWMAN software that brought the science of engineered mitigation of blowing and drifting snow to a CAD-Microsoft application in New York State DOT is in the process of being adapted and extended for use in Iowa. If this export is successful, it is anticipated other state DOTs will follow.

## References


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