Controlling Blowing Snow with Snow Fences

How to control blowing and drifting snow with snow fences and road design.

By Ronald D. Tabler

In exposed windy locations, snow blowing onto a road adds greatly to the cost of snow and ice control. Although costs vary widely, mechanical snow removal typically costs about $3 per 2,205 lb. For comparison, a snow fence 4 ft tall can retain 4.2 tons of snow per ft.

Snow drifts can cause loss of vehicle control, reduce sight distance on curves and at intersections, obscure signs, cause ice formation, reduce effective road width, and render safety barriers ineffective. Blowing snow is the primary cause of icy roads in wind exposed areas—melting extracts diurnal solar radiant heat stored in the pavement and substratum, and the quantity of snow blowing across a road can be hundreds of times greater than direct snowfall. Studies on I-80 in Wyoming indicate that over the last ten years, up to 25 percent of all crashes occur during blowing snow in areas without snow fences, compared to 11 percent in areas protected by fences.

Drifts contribute directly to pavement damage by blocking ditches, drains, and culverts, and serving as a source of water infiltrating under pavement. Snow removal equipment can also damage road surfaces.

Current drift control technology is based primarily on research conducted by the U. S. Forest Service in the 1960s and 1970s. Results from that research were used to solve a severe drifting problem on a newly completed section of I-80 in Wyoming the year after it was first opened to traffic in 1970.

The I-80 application provides the only documented quantitative evaluation of the effectiveness of snow control measures. The background and results of the I-80 study summarized here have and will continue to justify snow control projects on other highways.

The route selected for I-80 closely followed U. S. 30 across southern Wyoming. Between Laramie and Walcott Junction; however, a new location was selected along the foot of the Medicine Bow Mountains to save nearly 15 miles.

Aerial view shows the snow fence system at Wyoming I-80 Mile 280.8.

No snow fences were in place when this new 77-mile section of I-80 was first opened to traffic in October 1970. Three months later, snowdrifts up to 16 ft deep encroached on traffic lanes at 27 different locations, and six bulldozers were working 24/7 to remove these drifts. Winds averaged more than 30 mph for days at a time, and the road had to be closed for a total of ten days because of poor visibility, ice, and crashes. Because of the first winter's experience, snow fences were designed to protect all of the locations where drifts reached the road. The initial contract consisted of 11.4 miles of snow fence ranging in height from 6 to 12.4 ft and built at a cost of $480,000.

Careful monitoring of these first fence systems during the 1971-1972 winter proved their effectiveness in preventing drifts, but the improved visibility and road surface condition in fence-protected areas were even more impressive because these ancillary benefits were unexpected.

The dramatic effectiveness of those first fences led to many more being installed over the next 18 years. As of 2001, the system on this same section of I-80 consisted of 39.5 miles of fence protecting about 40 miles of highway, built at a total cost of about $2.3 million. Ten years after the first fences were built, a study was undertaken to quantify their effectiveness. The results of that original study, updated to incorporate an additional five years of data, are reported here.

Although an economic assessment of winter maintenance operations was complicated by changes in staffing, equipment, and maintenance standards over the period, expenditures were reduced by at least one-third to one-half. More importantly, the gradual increase in fence protection afforded a unique opportunity to quantify the reduction in crashes. In a winter with average snowfall and 1980 traffic volume, the original study concluded that the fencing in place in 1980 prevented 54 accidents and 35 injuries. Incorporating an additional five years of data, and adjusting for 2001 traffic and current average injury rate, it is projected that the fences now in place are preventing 78 crashes and 36 injuries over a winter with average snowfall. The savings in injuries and property damage alone could amortize the capital expenditure for this snow fence system within two years. With the added savings accruing from reduced road closure time and the savings in snow removal costs, it seems clear that the cost of replacing these snow fences could be recovered within a year's time.

Conditions at Wyoming I-80 Mile 280.8 before the construction of snow fences.

Also at Wyoming I-80 Mile 280.8, conditions as they have appeared throughout the 31 years after building snow fences.

Effects of Snow Fences on Ice and Slush

Snow fences can also dramatically reduce the formation of slush and ice. By reducing the mass of snow reaching the roadway, diurnal solar radiant heat can accumulate in the pavement and substratum instead of being lost to melting snow that blows onto the road (Figure 1). It is common to observe surface temperature differences as great as 15° F in areas protected by snow fences compared to adjacent areas with active blowing snow.

Many successful projects have proven that properly engineered snow fences are effective. One example is Wainwright, AK, where 15-ft snow fences 2,600 ft long eliminated drifts that previously damaged buildings and made streets impassable to conventional wheeled vehicles.

The benefits of snow fences can also extend for considerable distances downwind. This is in part attributable to the pressure gradient from the wake region to the outer undisturbed flow, which retards the influx of snow into the wake. As a result, the boundaries between protected and unprotected areas may be visible for great distances downwind. The deposition of blowing snow behind a fence increases the eroding capability of the wind, resulting in a tendency for snow to be scoured out downwind of the fence. The advance of this snow erosion "front" extends the effect of the fence downwind.

Benefit-to-Cost Analyses for Snow Fences

Snow fences can effectively prevent snowdrifts, improve visibility, and reduce slush and ice. Benefits include reductions in:

- Snow and ice removal costs
- Vehicle crashes
- Road closures
- Pavement maintenance costs

It is possible to determine benefit/cost ratios for snow fence projects. For the 60-mile study section of Wyoming I-80, it is projected that with current traffic volume, the fences now in place are preventing 78 crashes and 36 injuries over a winter with average snowfall. According to the report *Economic Impact of Motor Vehicle Crashes 2000* (U. S. Department of Transportation, National Highway Traffic Safety Administration, Report No. DOT HS 809 446), the unit cost of "property damage only" crashes is $2,532, and the comprehensive unit cost of the average injury crash (including fatalities) is $46,422. This implies an average annual return of about $1.8 million on the original capital investment of $1.9 million. If the fences were replaced at current prices, and traffic volume remained constant, the benefits accruing from the reduced injuries and property damage alone would yield a benefit-to-cost ratio of 4.2:1. This calculation is based on the following conservative assumptions:

- Cost of replacing fences at current prices: about $4.2 million
- Interest rate: seven percent
- Physical project life: 35 years
- Annual maintenance cost: five percent of initial capital investment ($209,100)

Another important benefit of snow fences can be reduced traffic delays. In Wyoming, mandatory road closures are imposed when warranted by crash blockages or severe weather conditions. Because numerous factors affect road closures, including administrative

Figure 1. Transition from frozen slush to wet pavement corresponds to the beginning of the area protected by a 12.4-ft snow fence located about 500 ft upwind.

changes in closure criteria, the relationship between road closure time and fence protection for the I-80 study is not statistically significant with the limited years of data. The effect of the fences on road closure can be inferred, however, from the statistically significant relationship that exists between annual road closure time and ground blizzard crash rate.

The economic benefits of fences on winter maintenance operations include savings in overtime, contract equipment and services, operating costs for rotary plows and loaders, and sand and chemical usage for ice control. Although potential savings for a specific location must be determined from historical accounting records, their magnitude can be illustrated by considering snow removal savings to be proportional to the reduction in the quantity of blowing snow arriving at the road. Figure 2 shows how the benefit-to-cost ratio for snow fences varies with the cost of mechanical snow removal, and with the seasonal snow transport—the quantity of blowing snow that is transported by the wind in the first 15 ft above the ground, per unit of width across the wind. The following assumptions were made for this analysis:

- Total cost for snow fence equal to $1.39 per sq ft of fence frontal area
- 35-year amortization
- Seven percent interest rate
- Annual cost of fence maintenance equal to five percent of initial capital investment
- Design capacity equal to the quantity of blowing snow expected over an average winter.

Because costs for easements or right-of-way acquisition vary, these are not included in this analysis. (The nominal cost of a perpetual easement paid by the Wyoming Department of Transportation is $1 per ft of fence length.) Although costs for mechanical removal vary widely, $3 to $5 per ton is typical, and similar to costs for earth excavation and wasting.

It has long been recognized that proper road design can be effective in preventing snowdrifts. However, this method of drift control cannot be expected to improve visibility and road surface conditions to the extent possible with fences. Although roads should be designed for drift-free conditions to the extent possible, this control method should not be construed as eliminating the need for snow fences. Snow fences are invariably a less expensive and more effective solution to snow drifting problems than reconstruction to change the cross-section of an existing road.

Conclusion

The potential for eliminating drifts, improving visibility, and reducing slush and ice, are compelling reasons for controlling drifting snow. The evidence of how effective fences can be is irrefutable, and it is incumbent on public officials to apply this technology to improve the safety and convenience of the public. As summarized in the previously cited reference, proper application requires attention to engineering detail. GE

Mr. Tabler, principal with Tabler and Associates, can be reached at tabler@sprynet.com.

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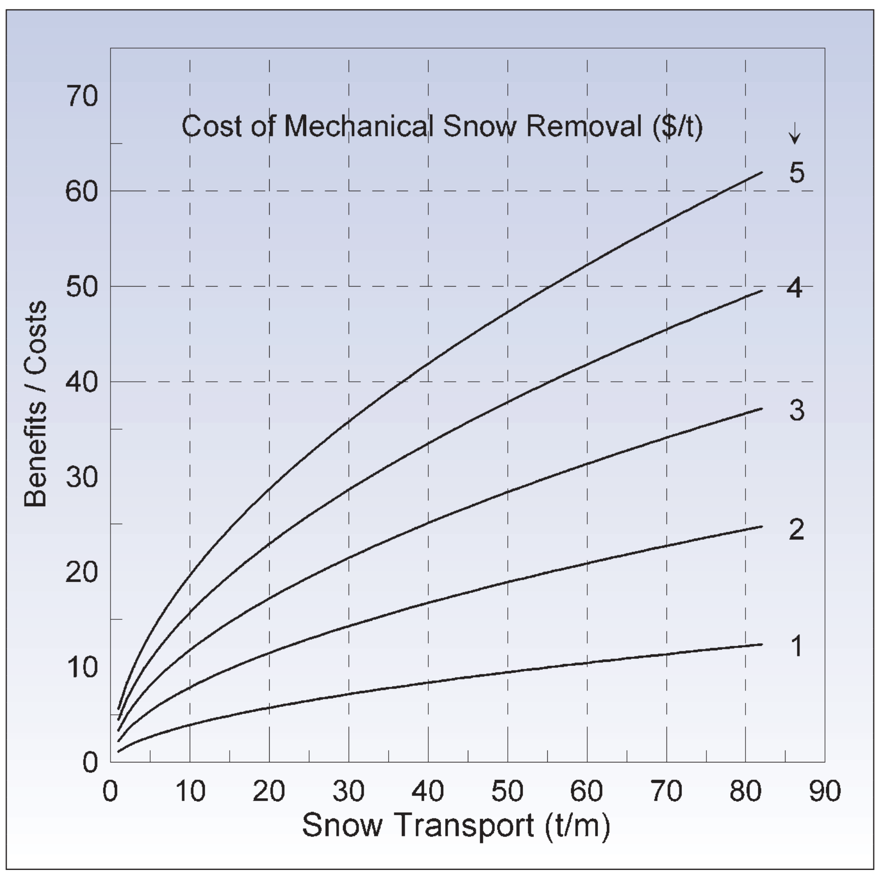

Figure 2. Benefit-to-cost ratios for permanent snow fences in relation to seasonal snow transport and costs for mechanical snow removal.