DRIFTING SNOW AND AVALANCHE CONTROL FOR ROADS

Masaru Matsuzawa
Civil Engineering Research Institute for Cold Region, Public Works Research Institute, Sapporo, Hokkaido, JAPAN

Hiroki Matsushita
Snow Avalanche and Landslide Research Center, Public Works Research Institute, Myoko, Niigata, JAPAN

Keywords: snowdrift, blowing snow, snow avalanches

Contents

Summary

Snow cover, road surface freezing, snowstorms and avalanches are traffic hazards that can lead to road closures or accidents and thus can adversely affect regional economic activities and the lives of local residents. Because of the increasing dependence on automobiles for transportation, snow and ice control is critical for protecting people's livelihoods and maintaining regional economic activities.

Snow and ice control operations for road traffic safety are largely divided into those for snow removal, deicing or snow-control. Snow-control measures include blowing-snow control and avalanche countermeasures. This paper reports on blowing-snow control and avalanche control measures that are implemented in Japan for improving road traffic safety.

Blowing-snow control involves several measures. The most common means of blowing-snow control is artificial structures such as snow fences and vegetation placed on the windward side of the road. Other means include drift-control cuts, drift-control fills, delineation facilities and snow shelters.

Avalanche countermeasures include those for avalanche protection, which involve the construction of facilities such as snow bridges and snow sheds, and those for avalanche control, which involve management measures such as traffic control or the preventive removal of snow from slopes when the likelihood of avalanche occurrence is high.

1. Introduction

Snow cover, road surface freezing, snowstorms and avalanches are traffic hazards that can lead to road closures or accidents and thus can adversely affect regional economic activities and the lives of local residents. Because of the increasing dependence on automobiles for transportation, snow and ice control is critical for protecting people's livelihoods and maintaining regional economic activities.

Diverse measures are taken against the road traffic hazards caused by snow and ice. One measure is the removal of snow from the road surface. Snow removal operations are divided into fresh snow removal, road surface leveling, widening snow removal and snow hauling, which differ in terms of when and why the snow removal equipment is dispatched. In fresh snow removal, trucks mounted with snow plows are used for clearing fresh snow from roads and piling it at the roadside. In road surface leveling, motor graders with snow plows are used for smoothing the road surface by cutting and removing bumps and ruts. Widening snow removal is an operation for securing the effective road width by relocating snow piled at the roadside to the outer side of the roadside or by piling snow in banks at the roadside. In snow hauling, snow accumulated at the roadside is removed and transported to snow-dumping sites.

For deicing, anti-icing agents are spread to prevent the road surface from freezing. The main anti-icing agents are sodium chloride and calcium chloride. Deicing operations include the spreading of sand and crushed stone to improve the road surface skid resistance.

Snow control measures are taken to protect roads from snow avalanches and snowstorms as well as to secure road traffic safety. Avalanche countermeasures consist of the construction of structures for avalanche protection, such as snow bridges and snow sheds, and road maintenance through the artificial release of avalanches. In implementing blowing-snow control, snow fences and other structures are often built to mitigate the impacts of blowing snow on roads.

Of these snow and ice control measures, blowing-snow control and avalanche protection are detailed below.

2. Blowing/Drifting Snow and Snowdrift

2.1. Introduction

Snowstorm disasters are caused mainly by snowdrifts and poor visibility. Cars get stuck and stranded in snowdrifts. Poor visibility makes driving difficult and causes traffic accidents. Measures against snowdrifts and snowstorm-induced poor visibility are high priorities.

2.2. Characteristics of Blowing/Drifting Snow

2.2.1. Snow Transport

When reviewing blowing-snow control measures for highways, it is necessary to properly understand the characteristics of snowstorm phenomena, particularly those of snowdrifts and poor visibility, and to properly understand factors contributing to snowstorm disasters.

There are three movement patterns of drifting snow particles. The first is creep: Drifting snow particles start rolling as the result of wind. With stronger wind, the particles jump on snow-covered surfaces. This is saltation. With even stronger wind, the jumping particles are lifted into the air. Below the height of 10 cm, saltation predominates; above that height, suspension predominates (Figure 1).

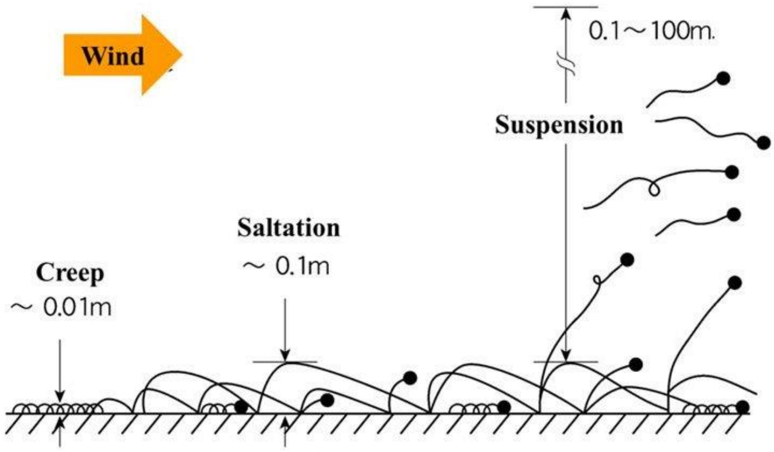

Figure 1. Modes of snow transport

Figure 2 shows the conditions under which blowing snow occurs. The horizontal axis is temperature, and the vertical axis is wind velocity. The triangles indicate the conditions under which snow saltates. The black circles indicate the conditions under which blowing snow is intermittently in suspension. The white circles indicate the conditions under which blowing snow is continuously in suspension. The intensity of blowing snow increases with increases in wind velocity and with decreases in temperature.

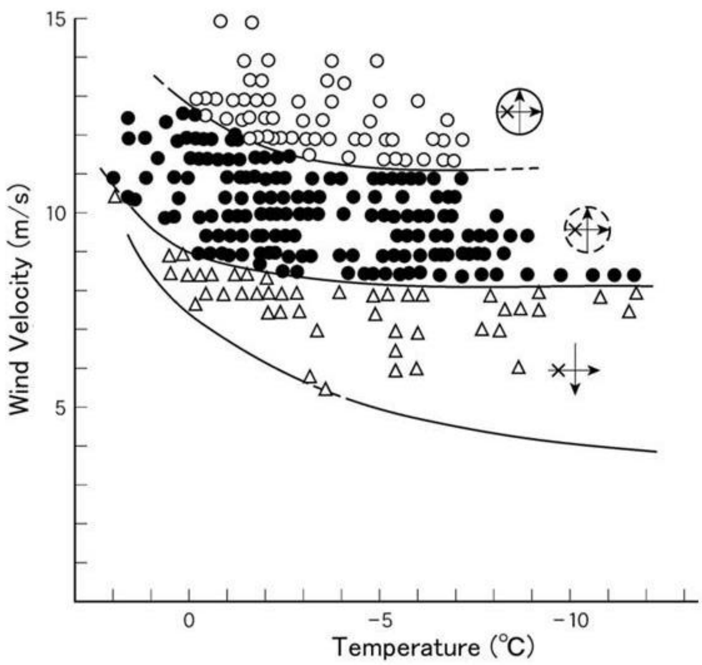

Figure 2. Weather conditions under which blowing snow occurs

The snow transport rate is an indication of the intensity of blowing snow. The snow transport rate is the mass of snow particles transported per unit time for a unit width perpendicular to the wind direction. Snow transport rate and wind velocity are closely related. Many researchers have tried to establish experimental formulas describing that relationship. Tabler (1991) established a formula in the State of Wyoming, U.S.A. (Equation 1), Matsuzawa et al. (2010) in Hokkaido, Japan (Equation 2) and Budd (1966) in Antarctica (Equation 3).

Tabler (1991): $$Q = 0.0043 U_{10}{}^{3.8} \quad (1)$$

Matsuzawa et al. (2010): $$Q = 0.0022 U_{10}{}^{4} \quad (2)$$

Budd(1966): $$Q = 10^{(0.0859 * U_{10} + 1.22)} \quad (3)$$

Where

Q = snow transport rate ($gm^{-1}s^{-1}$)
U_{10} = wind velocity at 10 m in height (ms^{-1}).

When the wind is strong enough to transport particles, blowing snow occurs. If the wind becomes stronger, the blowing snow "develops" and the snow-drift transport rate increases. However, the development has a limit; if that limit is reached, the blowing snow is said to have reached saturation. The snow-drift transport rate at that time is called the saturated snow-drift transport rate. When the wind abates after the saturated snow-drift transport rate has been reached, snow particles that the wind can no longer transport fall to the ground and the snow-drift transport rate decreases. Because Japan is snowy and humid, the saturated snow-drift transport rate tends to be reached at about 300 m from where the snow particles start to saltate, whereas in the Western U.S.A., where the sublimation of blowing-snow particles is not negligible, a distance as great as 5,000 m is necessary for the snow-drift transport rate to reach the saturation point. The snow-drift transport rate of blowing/drifting snow increases easily in wide-open spaces such as farmlands and pasturelands covered with snow.

2.2.2. Snowdrift

The wind velocity immediately upwind and downwind of an obstacle is lower than that far from the obstacle, so less force is available for carrying snow particles at these locations. Snow particles tend to settle at obstacles, and snow starts to accumulate. On the downwind side of an obstacle and at cuts or a ridge where the topography changes abruptly, turbulent eddies occur that cause snow particles to separate from the airstream. Where the wind profile changes, the particles accumulate to form snowdrifts. Therefore, snowdrifts often form around obstacles such as cuts, buildings, cars and on the like. Taking advantage of this characteristic, obstacles are artificially installed on the windward side of roads. The obstacles can prevent snow from blowing onto the road by trapping the snow particles.

2.2.3. Reduced Visibility

Visibility (Vis) is calculated by the following equation, in which σ is the light scattering coefficient and ε is the minimum value of luminance contrast detectible by the human eye ($\varepsilon = 0.05$, WMO(2008)) :

$$Vis = \frac{1}{\sigma}\ln\left(\frac{1}{\varepsilon}\right) \tag{4}$$

Suspended fine particles such as fog droplets and dust cause light to attenuate; therefore, the light scattering coefficient σ is proportional to the spatial density of suspended fine particles. Visibility during a snowstorm correlates strongly with the snow-drift flux (i.e., the mass of suspended snow particles passing through a unit cross section per unit time). Presumably, this high correlation is related to an afterimage in the presence of airborne particles as large as blowing-snow particles. At visibility distances shorter than 3,000 m, the following relational equation of visibility *Vis* (m) and snow-drift flux Mf (g/m^{2}s) holds true (Figure 3.)

$$Vis = 10^{-0.773\log(Mf)+2.85} \tag{5}$$

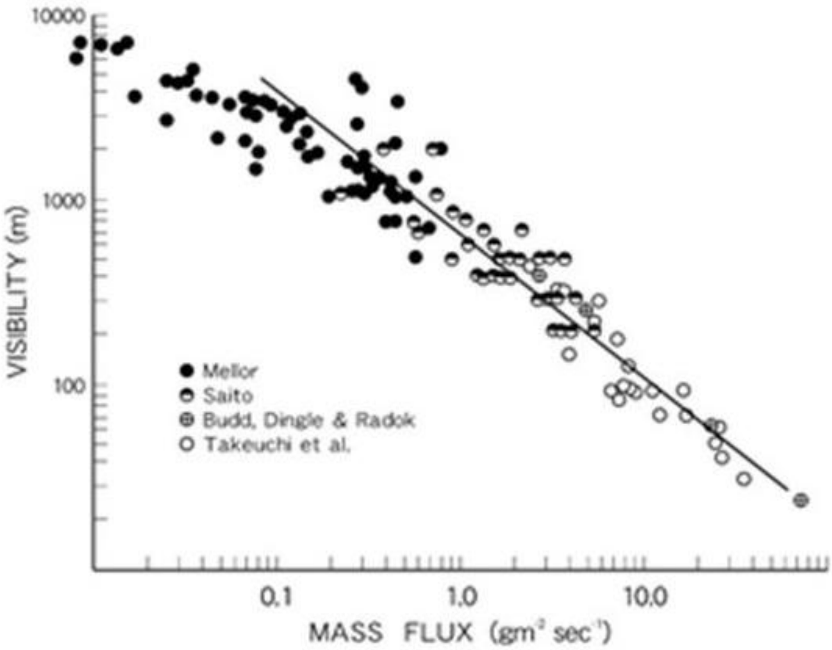

Figure 3. Relations between the mass flux of snow and visibility

2.3. Blowing Snow and Snowdrift Control

This section explains common measures in Japan against snowdrifts and poor visibility: snow fences, snow-break vegetation, drift-free cuts and drift-control fills.

2.3.1. Snow Fences

Figure 4 shows the types of snow fences used in Japan. The structure is vertical poles with boards installed with the long axis horizontal and the short axis vertical. There is a space between the bottom board and the ground. This is the bottom gap. Additionally, the fence has gaps between boards. The ratio of the area of these openings to the total area of the fence is the porosity ratio. The fence is installed on the windward side of the road to reduce the wind velocity so that blowing snow deposits in front of and behind the fence (windward and leeward), so as to prevent the suspension and drift of snow particles (Figure 5).

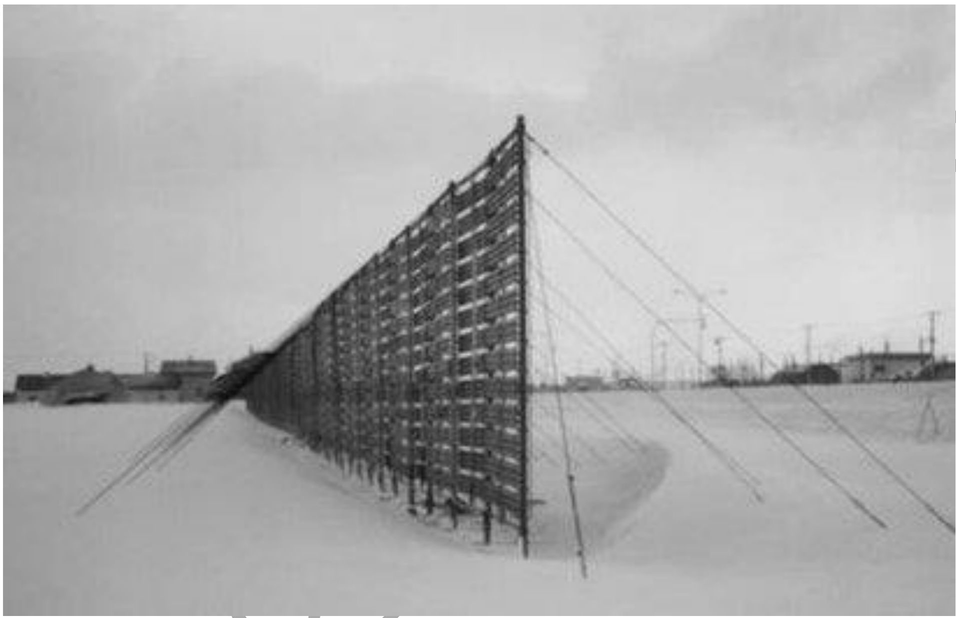

Figure 4. Snow fences

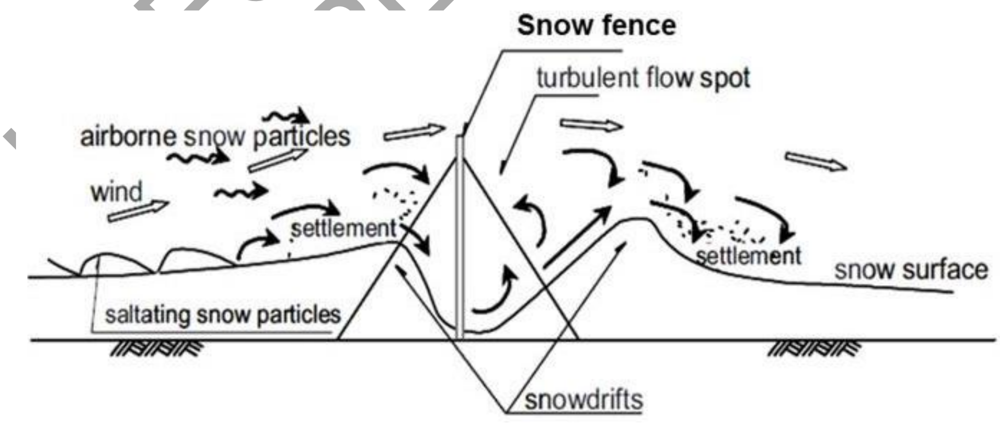

Figure 5. Windward and leeward drifts caused by a snow fence (CERI, 2011)

The blower snow fence was developed in Japan for use at road sites with little space. This fence has slanted snowbreak slats and a 1-m bottom clearance (Figure 10.) It mitigates visibility hindrance because the slanted snowbreak slats divert the wind toward the road surface and away from the driver's eye level. Additionally, strong wind coming through the bottom clearance onto the road surface blows snow particles off the road, thus minimizing the formation of snowdrifts there. Snow within a distance of about twice the height of the fence is blown from the road surface.

Figure 6. Blower snow fence

The solid barrier was chiefly developed to prevent snowdrifts and mitigate poor visibility caused by winds blowing up slopes in mountainous regions of Japan. It is a kind of snow fence that holds suspended/drifting snow particles on the windward side and reduces the wind velocity on roads (Figure 7).

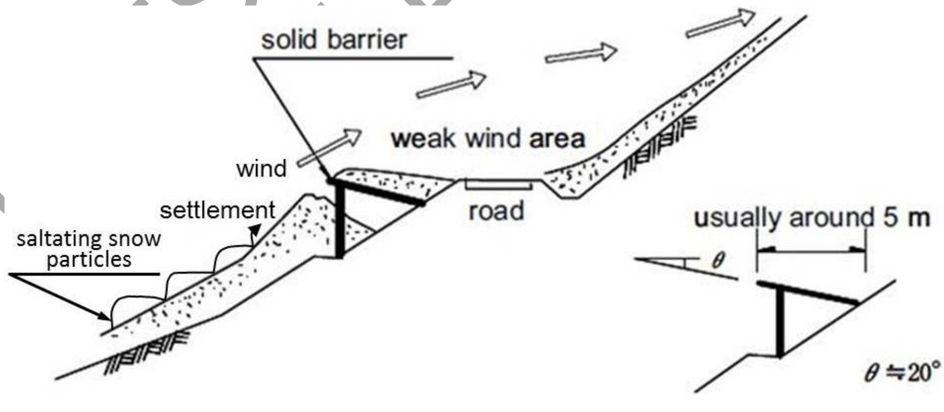

Figure 7. Solid barriers (CERI, 2011)

2.3.2. Snow-break Woods

Snow-break plantings are forest zones on the windward side of roads that protect roads from blowing snow (Figure 8). Snow particles flying from the windward side are trapped by the vegetation, thus preventing snowdrifts on roads. The Highway Snowstorm

Countermeasure Manual was developed in 1990 in Japan. It was translated into English and was published by the Federal Highway Administration in the United States (FHWA, 1996).

Figure 8. Snow-break plantings

Figure 9 shows the structure of a 23-m-wide snow-break planting. Deciduous trees such as willows are planted at both sides. Firs, pines, spruces and other evergreen conifers are planted at 3-m intervals. As the snow-break vegetation grows, maintenance is required, such as thinning of some trees. Therefore, a work path should be built.

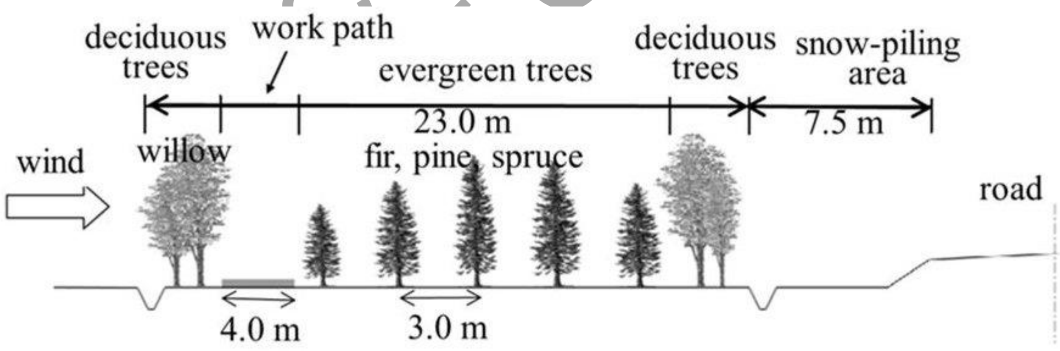

Figure 9. Basic structures of snow-break plantings (CERI, 2011)

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Biographical Sketches

Masaru Matsuzawa was born in Hokkaido, Japan, in 1965. He received a B.S. in geophysics from Hokkaido University in 1989, an M.S. in geophysics from Hokkaido University in 1991, and a Ph.D. in civil engineering from Hokkaido University in 2006.

From 1991 to 1996, he worked as a snow engineer for the Civil Engineering Research Institute (CERI) in Sapporo. From August 1996 to July 1997 he was dispatched to the Minnesota Department of Transportation as a visiting research engineer to study winter road maintenance technology in the U.S.A. From 1997 he worked for CERI again, where he has been a leader of the Snow and Ice Research Team of CERI since 2008. He is responsible for research on blowing/drifting snow control and avalanche control for highways. He has been a member of the Winter Service Committee of the World Road Association (WRC/PIARC) since 2009 and a member of the Winter Maintenance Committee of the Transportation Research Board (TRB) since 2010. He holds the certificate of Professional Engineer of Japan (P.E. Jp.).

Hiroki Matsushita was born in Hokkaido, Japan, in 1971. He graduated from the undergraduate program of the Hokkaido University of Education in 1994 and the Master’s Program of the University of Tsukuba in 1996. He received a Ph.D. from Chiba University in 2005. At these universities, he studied meteorology and snow science based on data analysis and field observations.

After graduating from the master’s program, he worked as an engineer at consulting companies in Tokyo. His research covered various fields related to atmospheric icing, evaluating design values of wind, precipitation and snow for structures, and the like. In 2006, he moved to the Civil Engineering Research Institute (CERI) of the PWRI and started to research snow avalanches. Since 2014, he has been a senior researcher at the Snow Avalanche and Landslide Research Center of the PWRI in Myoko, Niigata. He is a member of the International Glaciological Society, the American Meteorological Society and other organizations, and he received the annual award for the best article from the Japanese Society of Snow and Ice in 2007.