Model Technique for Controlling Snow on Roads and Runways

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Snow has always been a most difficult element to predict and also to control in areas where there is heavy accumulation. An open channel water flume and models have been used to predict consistently the patterns developed by falling snow. Light, white sand is used to simulate snow. Various densities of snow storms are created within minutes, and qualitative analyses are made for remedial measures. A wind tunnel study is carried out to ensure positive results.

Snow is an element of nature that displays many contradictory characteristics. It is both a nuisance and a necessity. It is both beautiful and ugly, depending on the conditions through which it is viewed. To some it is a hindrance to travel, and to others it is the only medium through which conveyance is assured. It is clean, it is dirty; it is almost weightless as a snowflake, but as a mass it can collapse large structures. Individually snowflakes are things of beauty, and it seems that no 2 flakes are alike in their intrinsic and delicate patterns.

Snow is, indeed, a fascinating element characterized by dual and often opposing tendencies; but perhaps the greatest and most distinguishing fact is that, although we know so much about the element snow, there are times when we know little or nothing.

The behavior of most elements of nature can be predicted through studies of recurring incidents such as wind storms, rain storms, and snow storms. In this respect, protective measures can be provided long before the storm arrives at the site. However, snow again does not conform to normal behavior because many of the problems created by snow occur after the storm.

The movement of snow particles or dry granules on the surface of crust or ice or frozen ground and the subsequent buildup is called "saltation." Accumulation of snow occurs at the bottom of a turbulent zone because the particles tend to drop out at the region of low velocity. Because turbulence occurs from an obstruction in the wind direction, it follows that predictions can be made for sites of accumulated snow. Furthermore, it is possible to cause drop out of snow by creating the turbulence where it is desired in the prediction plan.

Basically, control of snow is a matter of adjusting the energy of the wind that is the transporting agent. It is true that energy cannot be created nor destroyed, but it is also true that the total energy can be distributed in such a way that the total force is dissipated before the wind reaches critical zones. Experimentally, it is time-consuming and often unrewarding to study snow in the field, because there is no control of the variables. However, the resulting patterns are undeniably correct and the researcher can take advantage of the prototype when using laboratory procedures. For example, aerial photographs taken at 500-ft elevation provide a clear picture of problem areas on roads, runways, buildings, and parking lots; and the details are invaluable in the collection of laboratory data.

The laboratory procedure established at the University of Guelph utilizes an open-channel water flume to simulate wind. Because water and wind are both fluids having similar characteristics, it is possible to compare the fluids to scale. The chief advantage, however, is that the flow is decreased to an extent where observation of the particle movement can be used as a study medium.

The open channel is 25 ft long, 3 ft wide, and 18 in. deep at the observation section. The side walls are made of plexiglass. The steel entry area is 10 times the cross-sectional area of the open channel to conform with fluid dynamic principles. The supply of water comes from a constant head tank to give a steady rate of flow. The velocity of

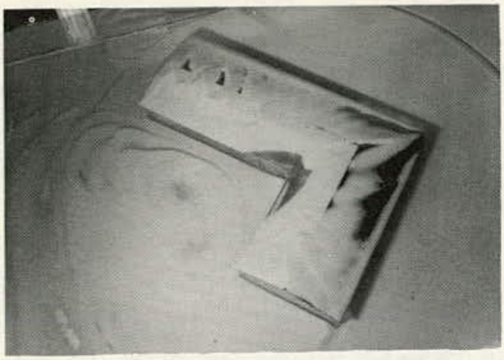

Figure 1. Typical snow pattern on the roof of a building with a valley (wind from right).

Figure 2. Solid triangular fences used to collect snow (wind from right).

the water, however, can be varied by raising or lowering a steel plate at the end of the flume. Normally the flow is at the rate of 3 cu ft/min. The discharge water is collected in a sump and pumped to the constant head tank for further circulation.

The snow is simulated by white Ottawa silica sand (density No. 100). It is injected in the water flume by means of a metering device to provide a dense, medium, or light snow storm as required by test. The storm is effective immediately and qualitative analysis can be obtained in a very short time. Obstructions to the wind, such as fences, trees, shrubs, and buildings are scaled (1 in. = 16 ft) and placed in the flume on a circular base so every wind direction can be observed during the tests (Figs. 1-4).

The model technique assures a quick, positive method of analysis with 100 percent results from a qualitative point of view. The exigencies of snow particles make it more difficult to determine results quantitatively with such accuracy, but certainly close estimates of depths can be made with sufficient success to be useful in design. The models used are often made from plexiglass because they can be scaled easily and assembled quickly with acetone chloroform and fixed to the circular base in the same manner.

Snow fences for roads and runways should be assessed for porosity, height, and location, though other considerations such as materials of construction, strength, durability, and cost are important factors (Figs. 5 and 6). It has been useful to establish a base from which all other comparisons can be determined. A solid fence provides clear characteristics with regard to accumulation of snow. There is always "cupping" action on the windward side due to the rotation of the particles as they

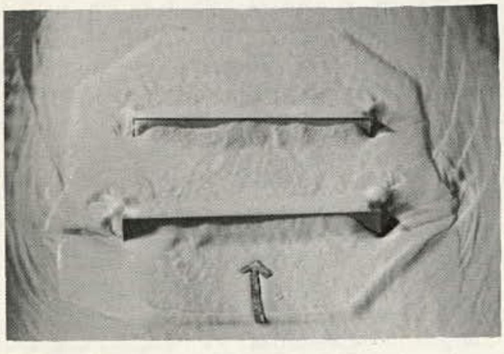

Figure 3. Solid fences 16 ft high collect snow in between (wind from bottom).

Figure 4. Studies around buildings indicate recurring patterns.

Figure 5. A steel wire fence is not very effective as a windbreak or snow barrier.

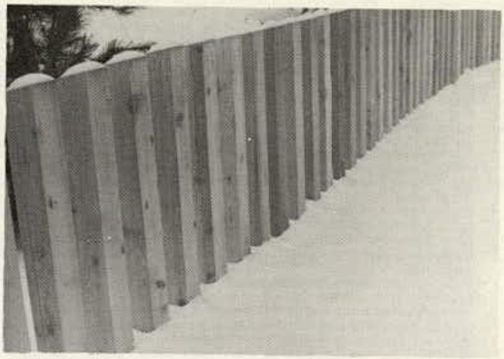

Figure 6. Decorative fence with 50 percent porosity showing energy dissipation at each opening.

rebound from the obstruction. This action continues until a "bridge" is constructed on a slope to the top of the fence. When the bridge is completed the usefulness of the fence becomes less, and the "ramp" effect tends to carry particles over the obstruction to drop out on the leeward side immediately behind the fence. Even extremely low obstructions to the wind will create this effect, but the most suitable solid fence is one with a height of 6 to 8 ft and placed a minimum of 35 ft from the area to be protected, such as a road or runway strip. It is likely to be more effective if placed 60 ft from the area where space is available. By using the solid base as a standard, porous fences have been studied with the specific purpose of determining efficiencies for roads and runways.

The conventional snow fence used for highways consists of wood slats spaced vertically; it has served a useful purpose but has definite limitations that must be recognized by the user. The location of the fence has not been established by any scientific approach but rather by intuition or to correct an obvious accumulation area. It is, at best, a hit-or-miss method and often has caused as much harm as good. The primary purpose of the porous fence is to permit some wind through the open section while retaining snow on the windward side. A 50-50 percent porosity is probably the best ratio, but this depends entirely on the condition to be remedied by the protective device.

A snow fence of the conventional wood slats and wire type is usually relatively low in height, and the snow reaches the top of the fence with little snowfall. When this situation occurs a ramp effect over the fence will not only deposit snow on the road or runway but will, in fact, cause turbulence and will often create zero visibility hazardous to ground vehicles and airplanes.

Fences of varying heights and porosities have been studied with some rather interesting and useful conclusions. Fences with either horizontal or vertical openings with a ratio of 50 to 50 percent will provide some protection and will not accumulate snow to the top of the fence. However, this porosity will cause turbulent effects on the leeward side of the fence resulting in a heavy buildup of snow. It has been observed that considerable gusts are built up at the highway or runway when high velocity winds are passing through the fence. Higher porosities (e.g., 60-40, 70-30, and 80-20 percent) have been more effective in control of snow than those of equal open and closed portions.

An interesting development in snow fence design has been introduced by one industry in the form of plastic, which is durable, is strong, and has considerable longevity. Diagonal openings shaped like a rhombus create turbulence behind each opening in the fence and the venturi-like action deposits snow on the leeward side of the fence. The fence is excellent provided the proper porosity is maintained, but it is recommended that a fence height of 4 to 6 ft be used for heavy snow areas. The fence is also useful in areas where sand blowing is a problem because it offers similar remedial measures.

Open hangars on airfields or landing strips can be seriously impeded by snow. Often orientation of the structure is the solution to this problem, but it must be emphasized that any obstruction to the wind, including buildings, will cause turbulence with resulting accumulation. This is particularly true with gable-roof structures because the vortexes initiated at the ridge continue to the ground in line with the sloping roof.

Snow particles within the resulting turbulent zone will be drawn into the open structure, and usually a bank of snow will be deposited immediately in front of the hangar. There are several ways to remedy this occurrence; one is to construct a solid fence on the windward side of the building. Another is the construction of a "swirl chamber" as close to the windward side as possible. The swirl chamber is simply a solid fence constructed 16 ft from the front of the structure and 16 ft parallel to the end of the building forming a box-like area. The fence can be built any length once the box-like section has been formed.

Studies of the action of snow in and around hangars and other buildings have indicated a need for the designer to be very conscious of the action of the elements and to take steps in the exterior design features to protect the user against undue accumulation effects. Prediction of snow buildup is easily and quickly made from the model technique and is an effective medium for engineers, designers, and architects.

Informal Discussion

L. G. Byrd

Have you used any highway structures, facilities, or appurtenances in your modeling.

Theakston

No. We did some highway bridges because somebody wanted to find out what happened to the snow on the bridge surface, and we found out. We also found out how to determine the scour of the abutments by using the sand in the base of our model. But other than that, the highway people have not come to us yet, and we have not gone to them.

Byrd

I presume they are invited.

Theakston

They are invited, yes.

L. David Minsk

Your laboratory work would be amenable to quantitative studies because you control all of the factors and determine, for instance, the effectiveness of various aperture ratios of the fence, proper height, and opening at the bottom—those things that can be quantified.

Theakston

Yes, I think so, and this is our next step. We have done some of that already, but we have a long way to go. I really do not know enough about the quantitative aspects myself, and so I would like some assistance on that. We do consulting work on this outside of agriculture. If it is an agricultural problem, it is done for nothing; but if it is something else, then it can be done on a consulting basis.

Byrd

How close were the patterns of the models and the actual physical structures you made?

Theakston

These models were made on $^{1}/_{16}$ scale, and then we went back and confirmed this on the site and from aerial photographs. The patterns were always the same, and it does not matter really what the velocity of the wind is. If it is a high velocity wind, there is less buildup, particularly in and around buildings. With the slow velocity, there is more chance for buildup, and that is the only difference. The pattern is about the same.