About Snow Drifts

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This article discusses some geomorphological-climatic aspects in snow-drifting control. The growing consciousness about the importance of coping with snow drifting on roads causes highway construction and maintenance engineers to look for systematic, long-term data and more effective methods of snow-drifting control than what is now available that could be used in updating design criteria, for operation of existing roads, or included in a project for a new road alignment. It appears that, besides artificial methods of snow-drifting control, more attention than hitherto should also be paid to the natural ones, such as geomorphology of the terrain. To cope effectively with snow-drifting problems, a comprehensive theoretical and experimental research on geomorphological and climatic factors is suggested in this article. Reliable parameters for practical use, classification of snow drifting, and regional snow-drift maps delineating the regimen of the snow cover, should be the aim in these researches. Such researches should find an important place in the programs of various institutions, agencies, transportation boards and transportation departments, and authorities administering snow-drifting control work of various transportation facilities. With reference to the suggested research, some geomorphological aspects pertaining to snow drifting on roads are discussed in this article.

Need For Snow Drifting Control

Protection of the nation's ground transportation facilities against snow, and the removal of it is an undisputed necessity for unimpeded, year-round vehicular transportation.

Disucssion of snow removal practices by mechanical means is beyond the scope of this article. This topic, as well as the subject of various types of snow fences have been discussed adequately in References 1 through 5. In some regions here and abroad snow fences are being used empirically with some reasonable, practical success in reducing wind velocity and thus protecting roads from snow drifts. However, snow fences cannot and should not be used blindly everywhere. To combat snow drifting on roads effectively, local observations about snow drifting should be supplemented by theoretical and experimental studies on the geomorphology and climatic conditions, and the aerodynamics of snow drifting.

Whereas in recent years the problem of protecting roads against frost action has been given considerable attention, the protection of roads against the winter traffic impediment by drifting snow is still an enormous, unsolved problem of immediate necessity.

At the present time, publications about snow and ice appear in many different journals and conference proceedings. Studies along these lines are pursued in many individual laboratories.

From the hitherto available research results one may also notice that very few researchers have really pursued systematic, deeply scientific-technical studies on snow drifting for practical, immediate applications. All that has been studied so far was aimed at learning only about certain properties of snow, or those of a snow cover, and ice.

Another regrettable lack in disseminating knowledge about snow drifting is the episodic nature of research along these lines.

All the knowledge on snow and snow drifting so far available needs a comprehensive synthesis for building up and fusion of the engineering discipline called snow mechanics.

The nation's transportation depends to a great extent upon a complex network of highways that require constant grooming by maintenance crews to keep the system functioning all year round - and free of snow. In our contemporary economy, wheels must turn, freight and people must move. Therefore, prompt removal of snow from transportation facilities is a recognized necessity. Coping with snow drifts and snow removal, however, is an expensive, multimillion dollar enterprise: hundreds of thousands of tons of snow must be removed to keep the roads open to traffic. Added to this is the cost of ice control. Besides, the drifting control by portable snow fencing structures requires a lot of manual work, and is difficult to mechanize. Economy in snow removal usually results in snow piling up, snow which then freezes, and many traffic arteries become nothing else but continuously rutted pitfalls and treacherous tracks for motor vehicles and their users. All this means a traffic hazard to safety.

The growing consciousness of the importance of coping with snow drifting on roads has caused highway construction and maintenance engineers to look for systematic, long-term data and more effective means of snow-drifting control than now available. This information can be used in updating design criteria for construction and operation of existing roads, or included in the project of a new road alignment. It appears that besides artificial methods of snow-drifting control, also the natural ones, such as the geomorphology of the terrain, should be paid more attention than hitherto.

About Snow Drifts

All existing methods of coping with snow drifting on roads are based on the principle of protecting the road from the deposition of snow masses, carried by wind, on the road.

In snow, viz., water resources management, the functional intent of a snow fence is not the prevention of drifting of snow. Rather, its function is to facilitate purposive drifting and deposition of snow in the catchment basin. Also, in agronomy, in conserving the treasure of the "white gold," the principle of snow-drift control is the spreading out of the drifted snow over the field (catch basin) in a uniform layer facilitating vegetal growth. This means approximately equal thawing time in the spring; otherwise, ponding in some places may occur; crops may become damaged; the soil may become eroded, and slides may occur. Thawed, undrained water from accumulated masses of drift snow may also endanger stability of earthworks. On the other hand, the snow cover protects the soil from deep frost penetration. Thus, one realizes here the importance of the snow cover to engineering, traffic, and farming.

Snow

Snow is a familiar phenomenon. Most of us have tramped through it, revelled in it, admired it and even cursed it. Yet, what do we really know about snow?

A considerable amount of precipitation on our planet Earth is in the form of snow. Winter snow falls have occasionally occurred even in the far south of the United States.

Snow is a precipitate of porous, unstable aggregate mixture of ice particles and air, - a material of bewildering complexity difficult to study and to work with. Snow is formed directly from the water vapor of the air at a temperature less than 0°C. It is not a frozen rain.

A very dry, fluffy layer of snow may contain as much at 97% air. Therefore it has a very small coefficient of thermal conductivity. This porous quality of a new snow makes it efficient insulating material against frost penetration into soil. A newly fallen snow consists of hexagonally crystallized ice crystals whose form depends upon the condition of their crystallization.

Fresh snow has a definite but low strength depending partly on "cogging" between the branched ice crystals and partly on real grain bonds. Essentially, snow is an unconsolidated sediment. During and after its deposition, snow undergoes its metamorphosis, i.e., changes in its character. During the course of time, wind may shake and densify the snow, whereupon it settles, becoming more dense. Thus heavy snow drifts may become greatly densified. It is the weight and inertia of deep and/or dense, heavy snow that brings vehicles, trains, and aircraft to a halt. Hence, removal of dense snow drifts costs considerably more than removal of fresh, loose snow drifts.

The physical, mechanical and thermal properties of the snow are important factors in the snow drifting problem in particular, and in snow mechanics in general. Snow mechanics is a complex engineering-science discipline, and its research results for practical application do not come easily. Hence, the snow mechanics aspects of snow drifting and snow removal problems are very complex, too. An appraisal of the major difficulties in snow mechanics was made by Melor (6).

Information about physics of ice and snow may be found in Reference 7. The properties of snow were discussed by Mellor (8). A discussion about the metamorphosis of snow can be found in Reference 9 and 10. The physical characteristics of the snow cover is dealt with in Reference 11. Reference 12 pertains to an interdisciplinary symposium about advanced concepts and techniques in the study of snow and ice resources.

Snow Drifting

Coping with snow drifting on roads is now merely a problem of snow removal and using snow fences. It is based on the theory of snow drifting (13, 14). Aerodynamically, a drifting or blowing snow is a two-phase flow containing ice and air, arising on the interface of wind stream and snow cover. If snow transport by wind takes place only up to about 20 cm above the ground (viz., snow surface), one usually speaks about a snow drift.

At a certain intensity, the wind is able to pick up, lift up from the interface of the wind stream and the snow cover, and whirl up loose, powder-fine surface snow flakes, ejecting them into the wind stream, which gain momentum from their motion, and to carry them away over and along the snow or ground surface to considerably long distances.

A snow particle can be removed from the surface of snow cover

a. By a direct drag of the wind, and
b. By the impact of a snow particle on the interface flying down the wind.

Depending upon the air-stream velocity, the movement of the snow particles in an airstream can basically take place by suspension, or by saltation, or by creeping along the surface. These modes of motion may be operative singly, or in any variety of combination together.

Some of the basic conditions conducive to snow drifting are:

1. There must be enough snow on the ground; drifting will occur to a large scale after all irregularities on the ground surface have been smoothed out;
2. The air temperature must be below 0°C, and the snow should be dry, although drifting may set in even at air temperature of 0°C;
3. The lowest wind speed for bringing about drifting is usually regarded as approximately 15 km/h. At wind velocities higher than 15 km/h, more snow particles are ejected into the wind stream, gain momentum, and are drifted away. If the wind that drifts the snow is swift, great volumes of snow will be carried over and far beyond a level terrain. Great, thick drifts can thus be built up, and deep gullies can thus be packed to the brim.

The amount of snow deposited depends also upon the quantity and physical properties of the snow; velocity of the wind and its direction; the nature of the topography of the terrain and its relief; exposure of the protected area to the wind, as well as upon the areal extent over which the drifting snow is transported. The area may be situated in relation to its surroundings in such a way that the vertical profile of the ground surface is streamlined. Lack of ground surface relief affords extensive snow transport by drifting.

When the snow-laden wind stream encounters natural and/or artificial obstacles, snow whirls or eddies in the wind stream are formed, and a local reduction in wind velocity takes place. Upon decrease in wind velocity, the snow particles are deposited out of the wind stream into these zones of relative calm to form a drift. The large snow particles tend to collide with each other, and with the obstacle. Collision among snow crystals decreases their velocity, and upon colliding with an obstacle they rebound and settle at a short distance from the obstacle. This process continues for as long as an obstacle is effective in reducing the velocity of the wind (15). Such obstacles may be vegetation, fences of all kinds, built-up areas, changes in the relief of the terrain, and various geomorphological landforms encountered in a region prone to snow drifting. In glaciated regions, such landforms may be ground moraines, terminal moraines, drumlins (long, egg-shaped oval hills whose long axis is parallel to the glacial ice movement), eskers (long, meandering ridges), kames (low, cone-shaped mounds), and other landforms (16). Thus, under certain combinations of climate, meteorology, topographical terrain features, and the velocity of wind blowing across the various landforms and the road may cause snow to drift and pile up where it is not wanted. Areas which seem to be prone to accumulation of drifting snow are usually encountered around knolls, mounds, hills, ridges, and peaks and at point of low elevation, and depressions in the ground surface. Shallow trenches, borrow pits and quarries become quickly filled up with snow. Therefore, snow drifting on a road is very much influenced by its position in the terrain, and by the direction and intensity of the wind. Usually the amount of drift is greater at perpendicular winds than at longitudinal ones. The filling up of cuts with snow is slower when their slopes are gentler. Here a considerable amount of snow is carried across the cut. For a complete picture about snow drifts in cuts, it is necessary to know the geometric dimensions of the whirl (eddy) zones which are formed in the depressions.

From the above discussion one may get the notion that the environmental parameters such as landforms and climatic conditions influence the formation of snow drifts. Also, one becomes cognizant that transportation alignments and their facilities such as parking areas, fuel stations, maintenance centers, and the like, as well as housing developments must fit properly, purposely, geomorphologically, climatologically, aerodynamically, and aesthetically in the landscape with respect to wind, snow drifting control, drainage, and appearance. It is believed that geomorphological and aerodynamical considerations in engineering design will help to cope with undesirable chronic winds from being a nuisance where snow drifting is concerned.

It is for the reasons discussed above that a comprehensive theoretical and experimental geomorphological research on snow drifting in drift-prone regions is advocated herewith, namely;

1. Geomorphological-climatic (and microclimatic) studies,
2. Aerodynamics of various landforms,
3. Aerodynamics and snow mechanics of snow drifting,
4. Climate and hydrology of drift-prone regions,
5. Soil mechanics, and
6. Thermal soil mechanics in connection with snow drift problems.

Such studies should include the proper tracing of traffic routes through the given climatic spaces, which, as is known, may vary considerably from place to place on a small areal extent. They should also include studies on climatic weather zones and weather trends; "detours" of the prevailing wind and snow drifting paths; the study of plantation effects such as woods, trees, shrubs; wind gaps; jet streams; sunny and shady positions; fog zones; run-off; drainage, and other pertinent factors. Especially, it is necessary to obtain information about the casual connection between geomorphology and the wind-streaming regimen, as well as the snow-drifting processes in mountainous, hilly, flat terrain and other landforms.

The above described phenomena and criteria also bring to the fore the question whether wind protection is always necessary, or desirable, or even advisable. Sometimes there may be cases where the relocation of a road section is justified in order to avoid excessive snow drifts. Thus, one sees that there are no simple, general solutions to snow-drifting control. Until more knowledge becomes available, one resorts only to making intelligent choices.

Some Geomorphological Aspects Pertaining to Drifting of Snow

In practical alignment work of a road, it so often happens that a great deal of thought is given to balancing favorably soil masses in cuts and fills. The question whether a mere lateral shift of the alignment of the road might be beneficial relative to snow drifting control is being paid very little attention. Available information about the causes and control of snow drifting points first to highway design factors such as placing of highways in locations free of snow drifting; alignment of the highway with exposure to prevailing winds; slope of the terrain; elevation of the road grade line above the average snow level;flattening both cut and fill slopes to or below the air flow line; avoiding obstructions which cause drifting, and providing for areas of catchment for storage of snow. Avoiding high fills with steep slopes may be helpful. At a high dam, the snow first fills in the toe (Fig. 1). Then the snow-laden wind, moving upward along the slope, increases in velocity so that the suspended snow in the windstream, too, is carried upward. Because the upward-directed wind at the top of the dam cannot change its direction suddenly, there forms above the crest of the dam a wind-calm space where the wind loses part of its velocity. Hence snow particles settle out and deposit a drift. The crest of the dam becomes covered with snow.

On not too high, gentle slopes the snow is swept across the crown of the road. Therefore, flatten out slopes, or make curved slopes of cuts and fills. Also, rounding up junctions with terrain and top of the fill (top and bottom of the cut) facilitates streamlined drifting. To avoid excessive snow removal, roads should be elevated above the natural ground surface.

Avoid shallow cuts. Unprotected excavations, trenches, borrow pits, and quarries can be drifted full of snow quickly during a period of one single drifting. Fig. 2 illustrates the concept of snow drifting in a cut made in a sloped ground. Because of the cut, the cross-section of the blowing windstream across the cut increases. This brings about fall-out of snow from the windstream and sedimentation of snow. The cut is drifted full quickly. The drift continues until the effect of the opposite slope of the cut makes itself felt, and the cut is drifted full.

Figures 3a and 3b show snow drifts at various obstacles. Figure 4 illustrates a wind gap between two hills. Figure 5 illustrates a road section along the windward slope of a hillside prone to snow drifting. The hillside is exposed to a broad, level expanse of an open fore-field. Figure 6 shows a good position of a road protected against the wind by trees.

Conclusions

1. Coping with snow drifts on ground transportation facilities is of national importance.
2. Snow-drifting control is also of utmost importance in planning of housing developments, as

Figure 1. Snow drifting at a high dam.

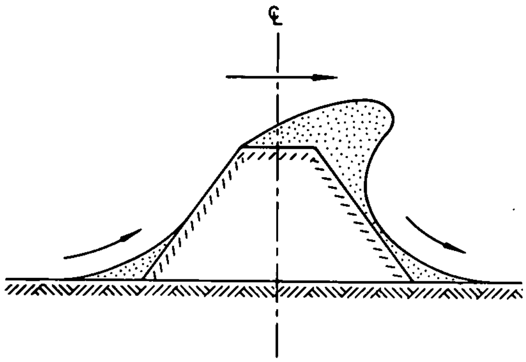
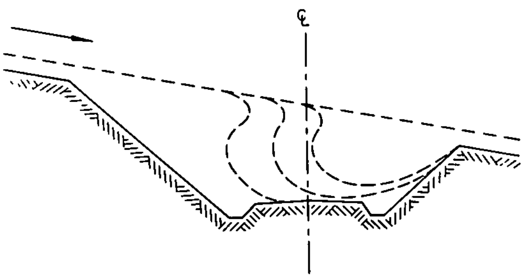


Figure 2. Snow drifts in a cut made in sloped ground.



Figures 3a and 3b. Snow drifts at various obstacles.

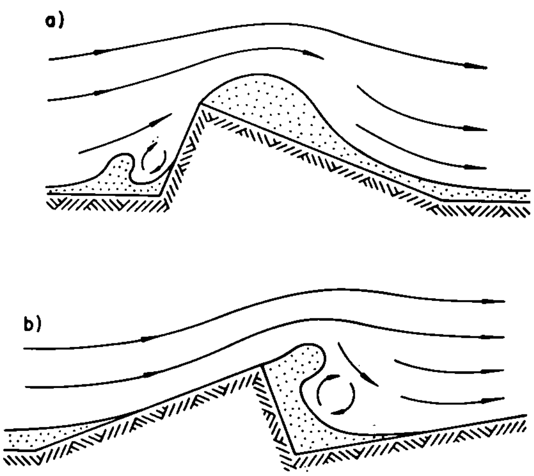


Figure 4. Wind gap between two hills.

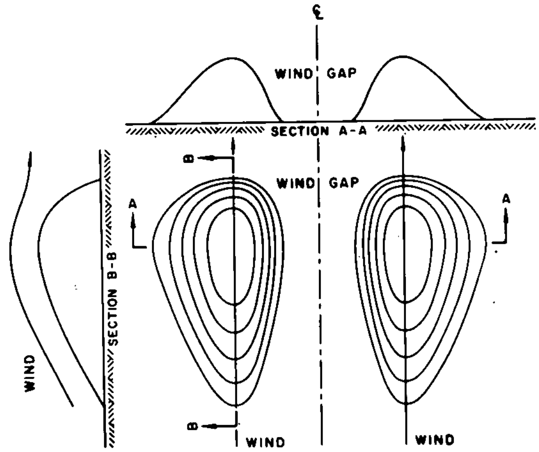


Figure 5. Road section along the windward slope of a hillside prone to snow drifting.

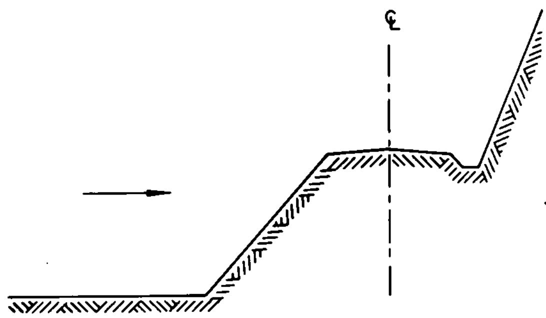
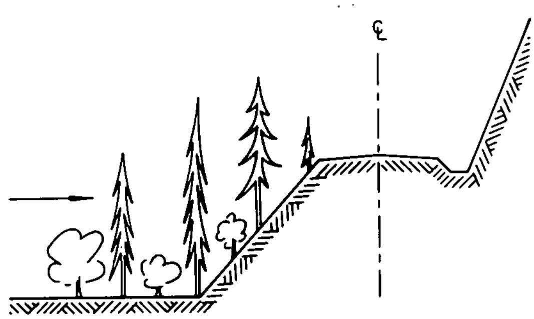


Figure 6. Good position of a road protected from wind by trees.



well as in solving problems of snow retention and conservation for agricultural use and as a water supply resource.

3. The physical, mechanical and thermal properties of the snow and the soil are important factors in snow-drifting processes. Therefore, it is necessary to understand the snow-drifting processes in a geomorphological environment under various climatic conditions.

4. To cope effectively with snow-drifting problems, a comprehensive theoretical and experimental research on geomorphological and climatic factors is suggested in this article. Reliable parameters for practical use, classification of snow drifting, and regional snow drift maps delineating the regimen of the snow cover, are aimed at in these researches. Such research should find an important place in the programs of various institutions, agencies, and transportation boards, authorities and departments administering snow-drifting control work on roads, as it deserves.

5. With reference to the suggested research as outlined above, some geomorphological aspects pertaining to snow drifting on roads are discussed in this article.

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