Role of Roadway Planting Design in Control of Drifting Snow

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Study and experience have demonstrated that the drifting of snow on highways can be controlled with plants. If plantings for this purpose are to be effective, however, it is essential that the designer has an intimate knowledge of the factors that cause drifting. To get information regarding past experiences, practices, and views, highway departments in the snowbelt were once again subjected to the demands of a questionnaire.

During the 1930's and early 1940's, studies were made which included wind tunnel tests and actual measurements in the field to determine the relationship of various types of barriers to wind velocity and snow drifting. Certain conclusions from these reports were summarized briefly in Highway Research Board Special Report 23, published in 1956. A few States have had considerable experience with snowbreak plantings, and at least one has issued reports on results. However, very few of the replies to the questionnaire indicated any knowledge of these studies. Apparently, empirical methods, rather than research, have governed the limited development recorded in the field of snowdrift control.

Available records do not include data regarding the important factor of quantities of dust or snow suspended in a given volume of air, nor is any reference made to the behavior pattern of falling snow. Studies seem to have been limited to the ability of wind to pick up and transfer loose material from the ground surface. The basic conclusions set forth are that winds of more than minimum velocity at ground level will pick up loose material and hold it in suspension until a reduction in the velocity causes all or part of the material to be redeposited on the surface.

The approximate wind velocity that will pick up snow and cause drifting is 15 to 25 mph, depending on the weight and moisture content of the flakes. This estimate is within the range expressed by most highway department engineers. The capacity of wind to pick up and carry soil particles varies as the square of its velocity. It follows, then, that a 40-mph wind when suddenly slowed to a 20-mph velocity will lose three-fourths of its carrying capacity. Controlling the drifting of snow is therefore a matter of decreasing wind velocity so as to cause deposition at an appropriate location off the traveled way.

Locating problem areas on a given highway is best done at the site during or after winter storms. The planting designer should know enough about potential drift hazards to be able to locate them with some accuracy. His first consideration should be the compass direction of the winds that cause the majority of drift problems. The answers to the questionnaire were surprisingly uniform on this point. From the Rocky Mountains to the Atlantic Ocean, a consensus considers winds from the northwest quarter to be the worst drift hazards. Drift control is most often applied on the northerly and westerly sides of highways. There are occasional storms from other points of the compass, particularly northeast storms in the northeasterly part of the country, but in many cases the wind changes back to the northwest quarter near the end of the storm. A few States in the extreme Northwest seem to have a different wind pattern, with troublesome winds tending to be from the southwest quarter. Topographical and other physical features may cause limited deviations in wind direction.

The second consideration is the type of situation that may cause drifts to form on the highway. The data on wind velocity in relation to loose material indicates that two conditions are required for drifting:

1. Wind of comparatively high velocity, with the opportunity to pick up loose snow.
2. An obstacle that cuts down the wind velocity.

The first condition is met by the type of terrain which gives the wind a free run for some distance on the windward side of the highway. Open fields, whether flat, sloping, or somewhat rolling, usually create ideal conditions for wind velocity to stay high or increase and, therefore, pick up loose snow. Comparatively narrow openings between topographical or other obstacles may also give the wind a free run and may even tend to boost its velocity. Wooded areas on the windward side usually contain the snow and prevent drifting. Wide areas of brush, standing crop plants, or even tall weeds tend to slow the wind at ground level and decrease drift hazards.

The second condition is met in situations where the wind strikes the highway. The folllowing are a few of these situations:

1. Roadway in a shallow cut, at least on the windward side. This is one of the certain trouble spots, as drifts form in the lee of the bank. Banks up to 6 ft in height generally cause the most trouble, but it is unsafe to accept this as an arbitrary limit, though very high cuts tend to create shorter drifts which may not reach the roadway. Flatter grades on cut banks tend to reduce drifting.

2. Ends of cuts. Several Midwestern States with much open land referred to this in the questionnaire.

3. Roadway at terminus of up-slope with ratio steeper than 4:1 adjacent to roadway.
4. Obstacles that reduce wind velocity and are close enough to the road to cause snow to be deposited thereon. These include shrubs or trees, buildings, standing crops, and even grass, weeds, or guardrails.
5. Snow banks thrown up by snow plows. In open areas with no other obstacles, these act like cut banks and help create drifts.

Having located the trouble spots, the next consideration is how to prevent drift formation on the roadway. In comparatively open, flat country, it has been found beneficial to raise the roadway slightly above the snow level of the surrounding ground. On fill sections with slopes not steeper than 4:1, if plow banks are kept flattened winds of sufficient velocity often blow the road clear (Figs. 1 and 2). Where this system is used, care must be taken that planting does not interfere with wind flow. For many years 4-ft slat-type wooden snow fence, placed on the windward side, has been standard treatment. A few States have open, level land-use power graders and bulldozers to push up a series of parallel snow banks which act effectively as snow traps.

Interest in planting to control drifting snow appears in literature dating back to the 1920's and 1930's. Comparatively few States have made practical use of plants, although recently there has been a revival of interest in the subject. Five States questioned have extensive experience in the use of plants, several have experimental plantings under way, and others, have expressed interest in the subject. An advantage of permanent plantings to control snow is the elimination of the expense of erecting, dismantling, storing, and periodically replacing slat-type snow fence. This is a problem of no small proportions as indicated by the fact that one division of a State highway department in a northeastern State estimates that an average of 1 mi of snow fence is required for each 3¼ mi of highway maintained. This snow fence costs initially about $0.15 per foot, not including posts and braces. In the same State, a three-row planting of coniferous seedlings is being established at an initial cost averaging about $0.10 per linear foot. Other advantages may include improved aesthetic values and soil conservation. Limited widths of right-of-way and the difficulty of obtaining easements for permanent plantings on abutting property are serious hindrances to live snowbreaks.

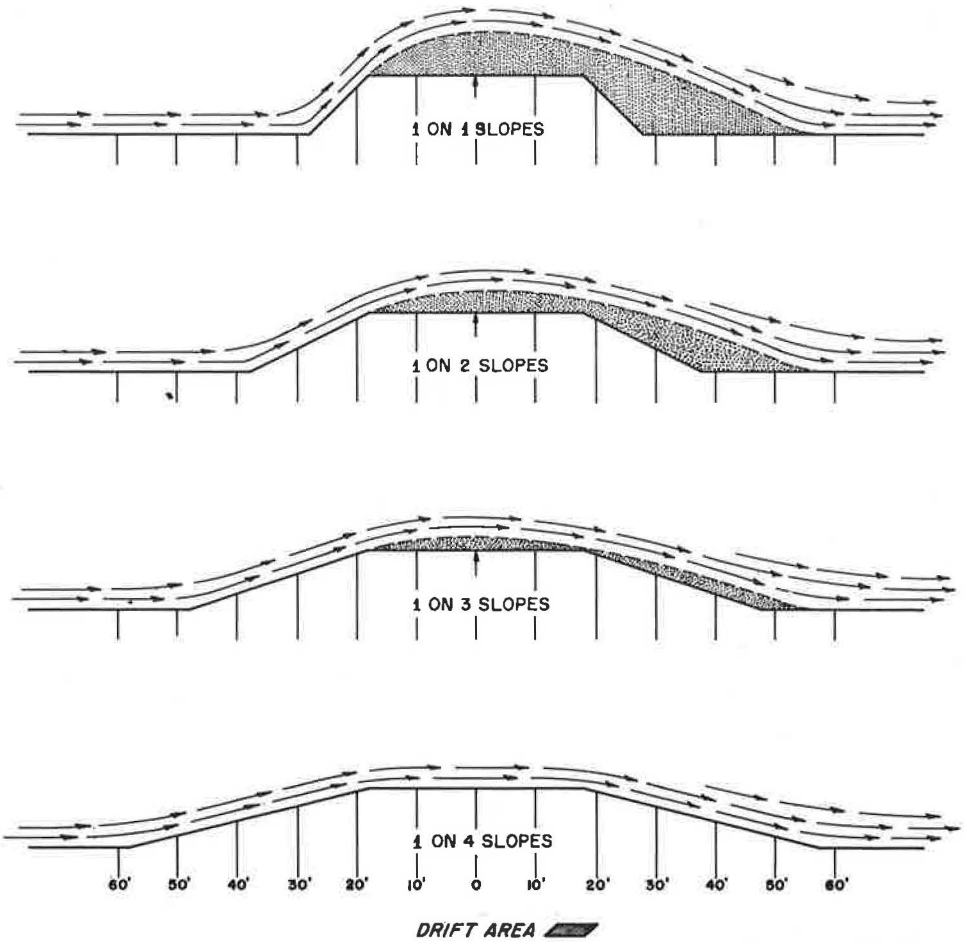

Figure 1. Air flow across a fill embankment.

When plant materials are to be used to prevent drifts from forming on the roadways, their location, composition, and arrangement are of primary importance. The distance at which the barrier is to be placed from the area to be protected has been the subject of many studies. Some of the results of these studies seem to have been partially obscured by careless use of the term "effective area," which seems to be used rather haphazardly to indicate either the length of the area of wind reduction on the lee side of the barrier or the length of the drift formation itself. In some cases, the length of the wind eddy may be as much as 50 times the height of the barrier. However, it is unsafe to assume that the entire area of wind reduction is also always a drift area. Decelerating wind deposits snow, but accelerating wind does not. A gust of wind that has been slowed temporarily will not necessarily continue to deposit snow until it has entirely resumed its former speed. The area of greatest wind reduction is close behind the barrier.

Several observations have been made, indicating that a dense windbreak causes lee drift to a distance of about 15 to 20 times the height of the barrier. This can be used as a rule of thumb, but there may be some doubt as to whether it is the last word on the matter. A question to the States on this subject seemed to show a fairly wide range of differences in actual practice where this measurement is concerned. The States may be divided into two groups: those that place their snow fence 50 to 100 ft from the paving, and those that place it 100 to 150 ft or more away. Generally speaking, the longer distance was used by States

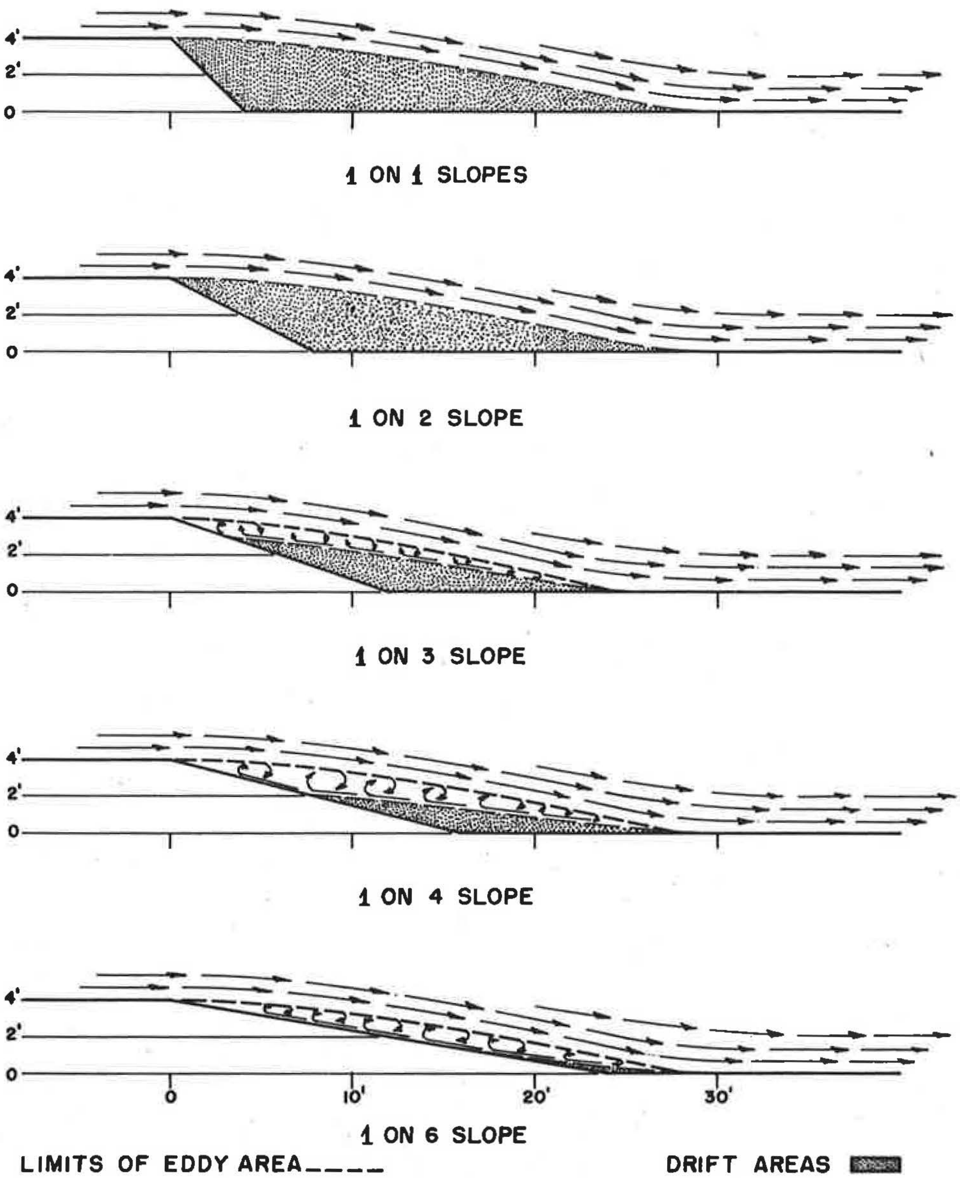

Figure 2. Effect of embankment slope on amount of drifting snow.

that could be expected to have much open land and consequently higher wind veolocities. This distinction was by no means clear-cut, however. Because these figures indicate a variation from 12 to about 30 times the barrier height, according to whether the fence is placed flush with the ground or at the recommended distance of 6 to 12 in. above it, it would be well to be cautious in accepting arbitrary figures on this subject. However, these figures correspond very closely to two European studies of many years ago, both of which indicate a distance of 10 to 30 times the barrier height as the so-called effective area, probably the acutal length of drift in this case.

Many States expressed satisfaction with the 4-ft snow fence. Others sometimes found it too short but were reluctant to use taller fence due to resulting greater stresses. In particularly difficult situations, two or more parallel rows of fencing can be used, rather than an increased height of fencing, though in some cases the fence is raised from time to time during the winter. In a few extreme cases, usually in mountainous country, fences reaching to a vertical height of as much as 12 ft are used.

Studies reveal that the relationships between height of barrier, density of barrier, wind velocity, and drift formation need to be approached with some caution. Some studies fail to cover the interrelationships among all these factors with sufficient thoroughness to give a complete picture. Tests have shown that the percentage of decrease of wind velocity caused by a given barrier grows less as wind velocity grows stronger. Some statistics indicate no appreciable increase in the length of the drift formed as wind velocity increases, whereas others indicate that high wind velocity tends to create shorter drifts than low wind velocity. Finney (2) says of his wind tunnel studies, "With a tight barrier at low velocities the drift would form for the entire length of the eddy area, while at high wind velocities the bulk of the drift would tend to form next to the lee side of the barrier." He further states that widely spaced plants were ineffective in holding the snow at high wind velocities, whereas a tight barrier produced drifting very close to the barrier. This would seem to emphasize the importance of density in a barrier, as well as wind velocity, in causing variations in the height-length ratio.

In the light of these comments, an explanation is required as to the tendency of some States to place their snow fence at a greater distance from the paving than is customary in other areas. Because of some definite statements that increased wind velocity does cause longer drifts behind snow fence, it probably must be accepted as a fact. This can be reconciled with Finney's test which relates to the factor of density. It may be that standard snow fences contain too high a percentage of openings to stop snow within a short distance where exceptionally high wind velocity prevails. Some of the extra-long distances from the paving may be due to such causes as saturation from too-large quantities of snow or even to what may be a general tendency to set fence at more than the indicated minimum distance just to be on the safe side, even though the effectiveness of the fence tends to decrease if too great a distance is used.

Some of the experimental planting that has been done appears to be based on experience with this slat-type snow fence. Application of the 15 or 20 times height formula to growing plants indicates that a 5-ft high planting placed to control snow would cast a drift on the roadway and beyond it when the plants attain a height of 10 ft. Furthermore, the accompanying diagrams (Fig. 3) by the Lake States Forest Experiment Station of actual drifting caused by various plant groups indicate a range of results that almost defy analysis. Again, height is not the only consideration. Density, thickness, and shape also play important parts.

A few observations may be made concerning the results shown on the diagrams. A loose growth of tall trees, particularly with the lower branches missing, usually results in lengthily extended, though perhaps shallow, drifts. On the other hand, growth that is compact from the ground up generally produces a short, deep drift. Two successively dense barriers with a space between them tend to trap much of the snow in the opening. One of the interesting observations to be made shows that a barrier that is low and dense on the windward side and backed up by sufficient height tends to stop snow in a very short distance. There is a further hint that if plants are placed in successively higher rows from windward to leeward there may be a better chance of creating a reverse eddy which will contain most of the snow within the barrier and throw part of it back to windward, though height and density alone may give the same result. It appears that sufficient density but low on the windward side and sufficient height to prevent clogging with accumulated snow are very important factors. This is borne out by other literature on the subject and seems to conflict again with any rigid height-to-length-of-drift ratio.

It would be a great step ahead in snow control if investigation of the factors of density and height, together with spacing of rows and over-all width of the planting, should result in the design of a barrier that could stop snow within at least the wider rights-of-way; Minnesota has already advanced far along this line. Olson (3) substantiates many of these observations and states that practical experience in that State shows it is feasible to control snow with planting within a 150-ft right-of-way. His illustrations (Figs. 4 through 7) indicate almost complete containment of drifted snow within a six-row barrier, the outer rows of which are only 30 ft apart on centers, after the barrier has grown to sufficient density and height. The height in this case was indicated as 12 to 16 ft, though it is difficult to determine to what degree the effectiveness of the barrier depended on height and to what degree on density.

From the maintenance point of view, a low, compact, deciduous shrub planted on the windward side can be cut back and allowed to regrow when it becomes "leggy." The snow trap arrangement with two

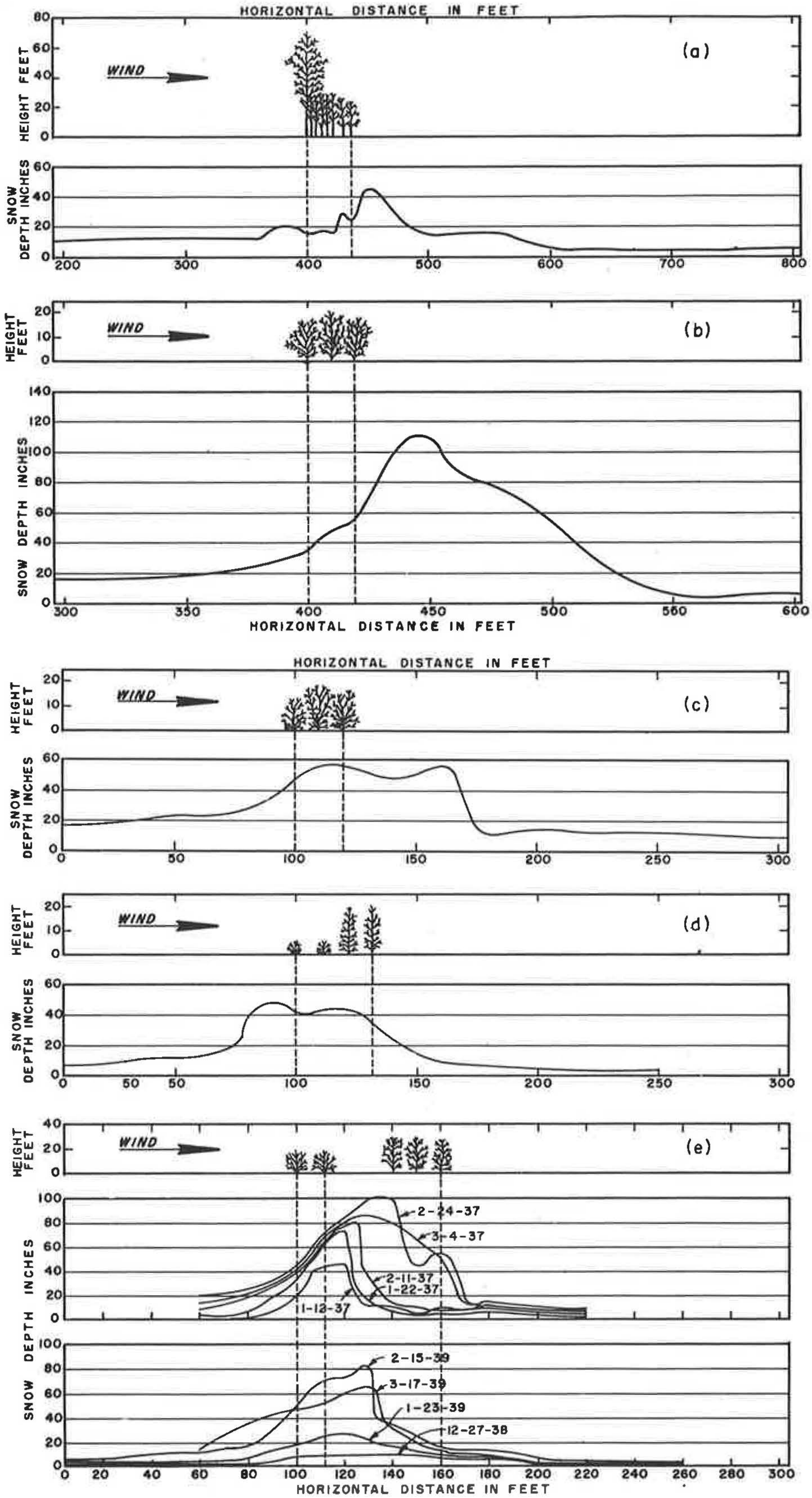

Figure 3. Snow profiles formed by tree and shrub planting (adapted from 1). All plants are deciduous. (a) Wide but loose planting, resulting in long drift; (b) 3-row barrier, now too tight at bottom with deep but rather long drift; (c) same as (b) but dense at bottom with short, deep drift; (d) low, dense planting on windward side backed up by tall plants, excellent snow control; (e) "snow trap" arrangement with most of snow deposited in space between two barriers, showing changes in profile through winter.

Figure 4. Snow conditions before planting.

Figure 5. Seedling planting with outer row of willow, two years after planting.

dense plant barriers to windward and leeward of an open space would tend to reduce shading out of lower branches and also might require fewer plants than a multiple-row barrier. The open space can be maintained with modern chemical sprays.

Those States, having experience with planted snow barriers seem to prefer evergreens. Ecological factors are an important consideration, as well as density, ultimate height, ease of maintenance, and sufficient flexibility of the branches to prevent breakage under piled snow.

As for plant arrangement and spacing, Finney's wind tunnel tests with single row barriers of small model evergreens showed that a spacing of more than 1.5 times the crown diameter failed to hold the snow, whereas a spacing of 1.1 times the crown diameter appeared to be most effective in causing good drift formation. Double rows were more effective when staggered spacing was used. Best results were

Figure 6. Plant material not sufficiently massed to absorb all drifting. Another two years' growth should be ample.

Figure 7. Ample clearance to road shoulder as no drift reaches beyond massed planting.

obtained with multiple-row barriers when spacing of rows was approximately the same as the spacing of the plants within the row. Closer spacing resulted in clogging and shorter drifts which Finney was trying to avoid, but which may be desirable when only limited space is available, the clogging being overcome by greater height of the trees in the barrier. The results of these tests may be used as a guide only. In actual practice, the question of spacing is complicated by the speed with which results are required. Plants put in as small seedlings for reasons of economy may be spaced closely, with thinning to follow later, or may be widely spaced for a slower effect.

Midwestern States having experience with plant barriers, prefer plantings of three to six rows. For general usage, Minnesota suggests trees spaced 6 to 10 ft apart in rows 5 to 15 ft apart, with deciduous shrubs, if any, spaced at 3 to 4 ft between the trees. Michigan which has plantings so mature that they are now crowded, suggests future plantings of evergreens spaced 12 ft apart in rows 10 ft apart. A depth of planting greater than 3 to 5 rows is suggested as desirable, the extra rows perhaps made necessary by the wider spacing. North Dakota spaces evergreens and willows 10 to 12 ft, with closer spacing for deciduous shrubs. Illinois uses multiflora rose plantings placed in a single line with plants 2 ft apart.

The "snow containment" and "lee drift" approaches to snow control with plants seem to deserve separate study, instead of being lumped together as now seems to be the case. Narrow plant barriers should be placed much like slat-type snow fence with consideration given to the often-quoted ratio of 15- or 20-to-1 length of drift to height. Until better evidence is available, it must be considered possible that increasing the height of narrow barriers may cause too-long drifts. This problem may be avoided by using plants of limited heights or plants that adapt to pruning.

There seems sufficient evidence that multiple-row barriers, if properly designed, particularly as to density, will absorb a considerable amount of snow after reaching sufficient height to overcome clogging. It should be permissible to ignore the height-length ratio where they are concerned. It may be possible, therefore, to place them closer to the roadway, although a snow fence may be needed as a supplement during the growing period.

Olson's observations on planting done in Minnesota deserve detailed study. He describes successful plantings of evergreens placed in four or five rows with 6- by 5-ft staggered spacing. He recommends one or two rows of low, compact, deciduous shrubs on the windward side with 3- or 4-ft spacing. He states that the minimum distance from the first row on the lee side to the centerline of the roadway should be 40 ft, with the planting extending to a width of about 30 ft, bringing the outer row 70 ft from the centerline. On very difficult sites this type of planting is well tested and has proved capable of containing the snow and keeping it off the highway (see Figs. 4 through 7).

Bates and Stoeckeler (1) of the Lake States Forest Experiment Station discuss deciduous or mixed deciduous-evergreen plantings and suggest that the first row on the windward side be planted 80 to 100 ft from the edge of the road. They state that shrubs on the windward side should be spaced 2 to 3 ft apart; that succeeding shrub rows should be spaced 3 or 4 ft apart; that low deciduous trees and evergreens should be 4 to 6 ft apart; and that rows may be spaced 6 to 10 ft apart, except that evergreens should be kept 12 to 16 ft away from tall-growing deciduous trees. Here, the distance from the roadway would seem to indicate a somewhat less effective barrier than produced by the predominantly evergreen planting used in Minnesota.

On the wide right-of-way of the Interstate highway, there is often room to establish snow control plantings inside the right-of-way, even allowing for the usual lee drift. Wide medians often recreate the same situation as a normal roadside and require the same measures. With a comparatively narrow median, planting used for headlight glare control or for other purposes may cause trouble in a situation where the roadway is designed to blow clear, although it is doubtful that it will be a drift hazard where roads are regularly plowed and plow banks of normal height established, because the plow banks themselves usually cause drifting.

Although plantings need to be of uniform density to control snow properly, they need not be too mechanical in appearance. There are many ways to relieve stiffness and monotony. Where a solid evergreen planting is desirable, ecological factors are usually such that two or more contrasting varieties may be used. A variation of outline and silhouette may be obtained by occasionally introducing groupings of somewhat taller plants. At certain breaks in the terrain, groups of deciduous trees can be inserted. Deciduous ornamentals may often be grouped in front of the evergreen background. Dense growing deciduous plants may themselves be used for the barrier. Some good ornamentals make acceptable snow barriers; they may be varied as to size and variety, particularly on the side toward the highway, which can be landscaped informally. A few conifers added either within or in front of a deciduous barrier will lend variety.

Ecological considerations and growth forms should govern the selection of species. Too much stress may sometimes be placed on matching the local background. Although this is an important guiding principle, it must be remembered that the local background is not always the last word in aesthetic excellence, and that continued uniformity leads to driver hypnosis. Snow control plantings can add variety to an otherwise tiresome landscape, though they may in themselves become monotonous if done in a frequently repetitive manner.

The function of snow control may sometimes be combined with other functions. A live snow barrier will eliminate the necessity of mowing in the area it occupies, and may thus reduce maintenance costs if designed so that the planting itself requires a minimum of maintenance. Snow control plantings may have many of the characteristics of plantings used for screening, noise abatment, headlight glare control, or even crash barriers. Plantings used for these functions may also contribute to drift control, if carefully designed. In order that plantings for these various purposes may contribute to snow drift control, it is essential that the designer give proper consideration to wind direction and existing drift hazards.

The problem of shade-induced icing can usually be disregarded as a factor associated with snowbreak plantings. Along the north or northwest borders of the roadway, plantings will not cause serious shading, and evergreens placed on westerly areas will cause trouble only after reaching considerable heights and as a result of being planted too close to the roadway.

In summary, the planting designer should thoroughly understand the factors that cause snow drifting and should consider them not only in designing snow control plantings but in designing other types of planting as well. He should combine snow control with other plan use where feasible and, above all, he should avoid planting that causes undesirable drifting on the highway. He should determine the wind direction responsible for most drifting in the area under consideration, and study the terrain to locate drift problems, supplementing these stuides whenever possible with actual observation of snowfall. Narrow plant barriers should be somewhat taller than 4 ft in areas of heavy snow and should normally be located 15 or 20 times their height from the paving to be protected, but it should be kept in mind that loose barriers may not retain snow within this distance under conditions of high wind velocity.

With the use of closely spaced, multiple-row plantings, it appears that the recommended distance of 80 to 100 ft from the pavement should be reasonably effective. It should be remembered, however, that a closely spaced evergreen barrier no more than 40 ft from the centerline has successfully controlled drifting snow. It would be desirable to initiate experiments with plantings of varied height, spacing, and density in an attempt to develop a barrier that would control drifting snow in the shortest possible distance, and thus allow planting closer to the paving and within the limits of a comparatively narrow right-of-way. If these factors are considered realistically by the designer, roadside plantings can contribute materially to the control of drifting snow.

ACKNOWLEDGMENTS

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