REPORT OF JOINT COMMITTEE ON ROADSIDE DEVELOPMENT

HIGHWAY RESEARCH BOARD AND AMERICAN ASSOCIATION OF STATE HIGHWAY OFFICIALS

LUTHER M KEITH, *Chairman*

Director of Roadside Development, Connecticut State Highway Department

EFFECTS OF TREES ON WIND VELOCITIES

BY FRANZ A AUST

Associate Professor, Landscape Design, University of Wisconsin

SYNOPSIS

The study was made to assemble information regarding wind velocities as affected by barriers, natural and artificial, with the ultimate object of relating such data to the control of drifting snow on public highways

Wind velocities were determined with an automatic recording anemometer and with a small hand anemometer which were calibrated to secure relatively accurate results Five barriers of the planted variety have been studied (1) white pine, (2) willow, (3) Norway spruce, (4) hard maple, (5) evergreen snow fence Maximum reductions in velocity for the various barriers ranged from 52 per cent to 97 per cent of the unobstructed wind velocity With a row of hard maples on each side of the road, there are certain conditions when an increase in velocity is found at the center of the road

The primary aim of this research work is to assemble information regarding the wind velocity as it is affected by natural and artificial barriers For a thorough handling of this problem it has been necessary to take into consideration the kind of barrier studied, its location, extraneous conditions present, and any other information which would aid in interpreting the results of the readings secured While this has been the immediate concern, the ultimate object is to relate such data to the control of drifting snow along public highways

Two types of instruments were used in recording wind velocities: the 4-cup Bronson Automatic Recording Anemometer which indicates velocity and direction of the wind over a period of time, and the small hand instrument with a 2 5-in vane of the type frequently used in heating and ventilating studies All the instruments were calibrated in order to secure relatively accurate results

Five definite barriers of the planted variety have been thus far studied They are:

White Pine Barrier
Willow Barrier
Norway Spruce Barrier
Hard Maple Barrier
Evergreen Snow Fence

Planted White Pine Barrier, Figure 1.

This consisted of three rows of white pine, 600 ft. long, planted on an approximate north and south line. The rows were 18 ft. apart, and the trees were spaced 12 ft. in the row. The trees were approximately 35 ft. high. The age of the windbreak was 30 years. The trees were well branched from tip to base. In the center row natural pruning had removed the branches to a height of 10 ft.

Willow Barrier, Figures 2, 3 and 4. This was a single row of Russian willow, 1800 ft. long, planted on a north and south line. The trees were spaced 6 to 15 ft. apart. Branching was uniform from base to tip. The height of the windbreak was 20 ft., the age 10 years.

Norway Spruce Barrier, Figure 5. This consisted of a single row of Norway spruce spaced one rod apart, located immediately adjacent and on the south side of an east and west roadway. The height of the trees was approximately 45 ft. They were in good condition, well branched from a height of 5 ft. above the ground to the tip. This windbreak was approximately 50 years old.

Hard Maple Barrier, Figures 6 and 7. This barrier consisted of a row of hard maples planted on each side of a north and south roadway. The trees were located 22½ ft. from the center line of the road, and originally spaced one rod apart. The planting was approximately a quarter of a mile long. Occasional failures spacing the trees two rods apart caused some irregularities in velocity observations. The trees were 40 to 45 ft. high; well branched from a distance 10 ft. above the ground to the tips. It had been observed over a period of years that this particular stretch of roadway was always free from snowdrifts. The road grade was about 12 to 18 in. above the adjacent fields.

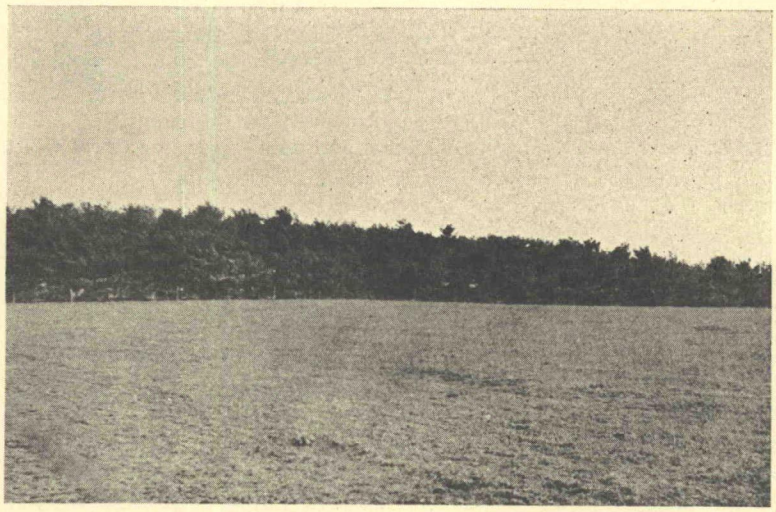

Figure 1. White Pine Barrier, consisting of 3 rows of trees 18 ft. apart, the trees spaced 12 ft. in the row. With wind velocity 34 miles an hour on the windward side, the instruments registered only 5½ miles an hour on the leeward side.

Planted Evergreen Snowfence. This barrier was 700 ft. long, planted 95 ft. north of the centre line of an east and west State trunk highway. It consisted of three rows of evergreens, a mixed planting of Scotch and Norway pine, and Norway

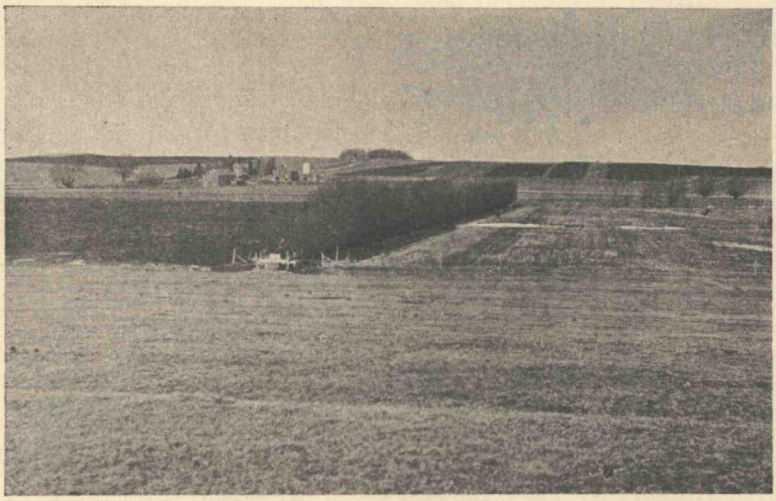

Figure 2. Willow Barrier 1800 ft. long, planted on a north-and-south line; trees 6 to 15 ft. apart

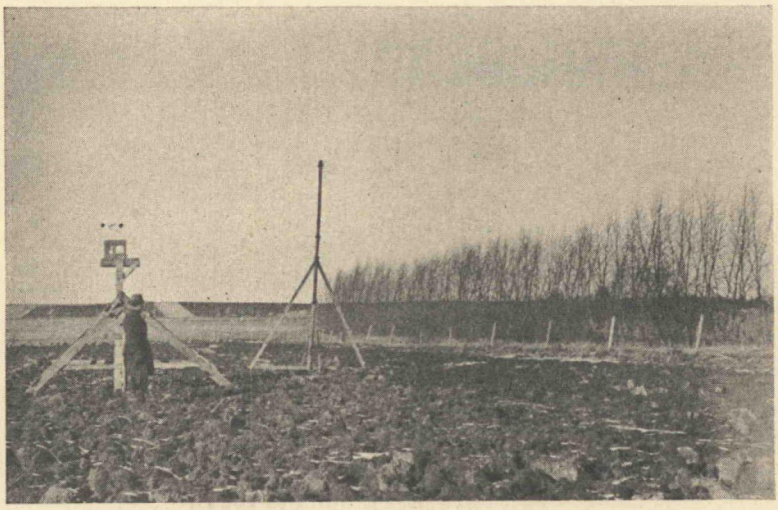

Figure 3. Willow Barrier. At the left, recording anemometer in place. Center, support for anemometers placed at different elevations

spruce. The rows were 6 ft. apart; the trees, planted alternate, 8 ft. in the row. The height varied from 4 to 5 ft. The trees were heavily branched and made a continuous barrier from one end of the planting to the other. Studies were made one year after the windbreak was planted. There were occasional groupings of shrubs planted immediately to the south of the trees. The concrete slab was approximately 18 in. above the adjacent fields. A part of the roadway was through a 2-ft. cut.

METHODS

It was planned to study only the prevailing storm winds, namely those from the north and northwest. The recording anemometers used in making the observations were mounted on steel windmill towers (see Fig. 5). The height at which the instruments were placed above the ground was determined in part by the height of the windbreak studied. In some cases, the recording instruments were placed 20 ft. above the ground; in others 10 ft. The hand anemometers which were used in making detailed studies were placed on wooden T-beams

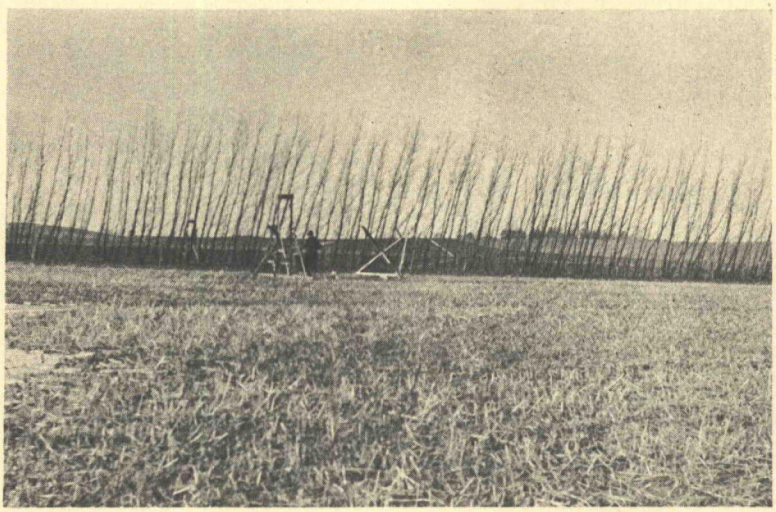

Figure 4. Willow Barrier, showing relative density. The instruments recorded a maximum decrease of 52 per cent and a minimum of 10 per cent

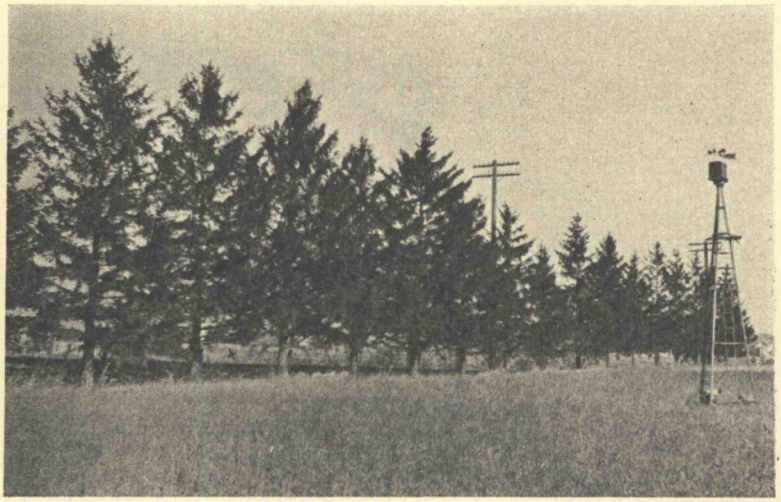

Figure 5. Norway Spruce Barrier. At the right, steel tower supporting recording anemometer. The instruments recorded a maximum decrease of 88 per cent and a minimum of 30 per cent, at a distance 60 ft. from the windbreak.

and so arranged that an instrument could be placed at elevations of 6, 12, and 18 ft. above the ground. For studies close to the ground and for the artificial barriers, the anemometers were placed on 3-ft. wooden supports at varying distances from the barrier. The windward instruments were, in each case, placed far enough from the barrier to be entirely free from its influence. The distance varied from 60 to 160 ft.

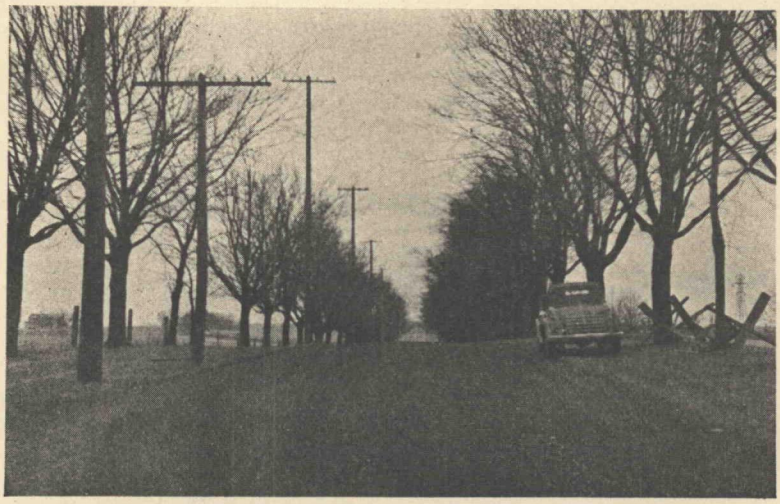

Figure 6. Hard Maple Barrier, consisting of a row of trees on each side of a north-and-south highway; trees located 22 ft. from the center line. These trees caused an increase in the velocity of the wind immediately over the roadbed.

Figure 7. Hard Maple Barrier, showing relative density of the trees. In the center is shown a support for the recording anemometer

Where the recording instruments were

used records were taken for 10 to 12 days Readings were taken on the hand instruments for 5 to 15 minutes

RESULTS

White Pine Barrier. The results of the readings for the white pine barrier shown on Figure 8 indicate that at a distance of 27 ft to the leeward side there is an average decrease of 82 9 per cent over the velocity recorded 160 ft on the windward side At various velocities, this decrease

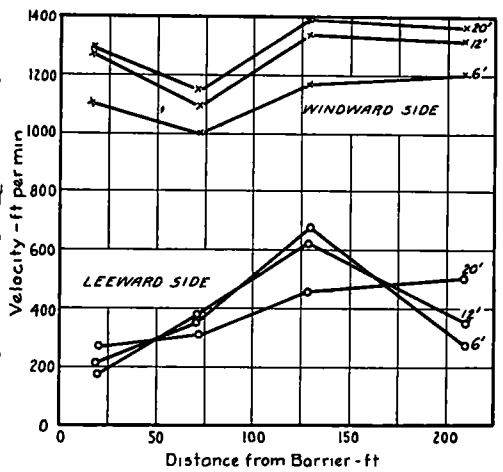

Figure 8. Wind velocity studies at various elevations and distances. The Barrier—A North and South White Pine windbreak 35 ft high Jan. 11, 1934 Average wind velocity 11 miles per hour

reached a maximum of 97 2 per cent and a minimum of 61 7 per cent The least effectiveness was found to obtain at velocities from 9 to 12 miles an hour Both above and below, the rate of decrease of the velocities to the leeward was greater The maximum wind velocity recorded was 34 miles an hour At this velocity there was a decrease of 84 per cent on the leeward side The area of marked influence was approximately 5 to 7 times the height of the barrier Farm buildings located to the east immediately adjacent to the windbreak complicated studies so far as easterly winds were concerned

Willow Barrier. As might be expected, a single row of willow trees offered less resistance to the wind than did the three rows of evergreens The windbreak, being located in a field free of interference other than the plowed ground, provided ideal conditions both to the leeward and windward for wind velocity observations A maximum of 52 per cent decrease was recorded, and a minimum of 10 per cent, while the average decrease was shown to be 23 8 Again the velocities of 9 to 13 miles an hour showed the least percentage of decrease after passing through the obstruction The maximum velocity at the willow windbreak occurred Jan 16 and was 28 miles an hour The decrease on the leeward side due to the obstruction was 30 per cent

Detailed studies were made of the wind velocity at various elevations and distances The results are shown in Figure 9 The elevations which were used were 6, 12, and 18 ft Observations were taken at these different elevations and for distances of 10, 45, 70, 100, and 130 ft both to the windward and leeward side of the windbreak Observations were taken as nearly at the same time as possible and a day was chosen when there was little variation in wind velocity The results show that with average wind velocity of 11 miles per hour there is a consistently marked decrease on the leeward side for the elevation of 6 ft The effectiveness varies indirectly with the distance from the windbreak When one compares the velocities at the height of 12 and 18 ft to the leeward with corresponding distances and elevations to the windward, it is observed that at a distance of 50 ft there is a decided peak in the curve. On the windward side the veloc-

ity is greater at this point than the average velocity beyond the range of influence of the barrier On the leeward side there is little or no effect At a distance of 100 ft from the barrier there is a depression in the curve especially on the windward side This is true for all the elevations· namely, 6, 12, and 18 ft From this point there is a gradual rise in the curve until we reach a distance of 150 to 175 ft where conditions on the windward side are again normal giving

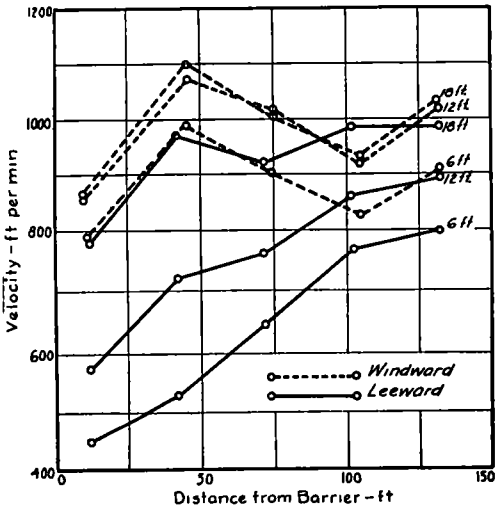

Figure 9. Wind velocity studies at various elevations and distances at the Willow Barrier —A North and South row of Willows 20 ft. high. Jan 11, 1934 Average wind velocity 11 miles per hour.

rise to the average wind velocity and on the leeward side a consistent rise until one leaves the area of influence of the barrier

Additional observations were taken with a higher wind velocity and the curves here obtained approximate in form those shown on Figure 9

Norway Spruce Barrier The irregular gaps in the tops of the Norway spruce barrier as well as the open spaces at the base of the trees, resulted in erratic readings Nevertheless the average decrease in velocity as shown on Figure 10 was 55 2 per cent, a substantial reduction in the leeward over the windward readings The maximum decrease was 88 and the minimum 30 per cent The maximum wind velocity occurred on January 28, when it reached a peak of 43 miles an hour from the northwest There was a decrease of 47 per cent at a distance of 60 ft on the leeward side

Hard Maple Barrier An interesting feature of the hard maple barrier lies in the fact that while a substantial reduction in velocities occurred on the leeward side of the barrier with either an easterly or a westerly wind, an actual increase was recorded at the center line of the road This action of the wind has been observed in many similar situations It is apparently explained by the fact that the openings at a level below the branches above tend to constrict the passage besides offering resistance to the passage of the air through the barrier This apparently builds up the velocity immediately over the roadbed See Figure 11 The average increase above the roadbed for velocities of 10 miles per hour was 9 3 per cent The average decrease for selected readings 60 ft to the leeward of the hard maple barrier was 44 8 per cent See Figure 12 The maximum wind velocity of 57 miles per hour occurred on January 28 This gale was decreased by 57 per cent on the leeward side of the windbreak

Planted Evergreen Snowfence A detailed study was made of the wind velocities in connection with this barrier Velocities were recorded at eleven selected intervals for a distance of 250 ft to the leeward side of the windbreak and 3 ft above the ground level as shown on Figure 13 The assumed normal reading was taken 100 ft to the windward side

The data secured indicated that the greatest decrease occurred at a point 50 ft from the barrier, with two other low-points at 125 and 225 ft Directly over the roadbed and at distances of 150 to 175 ft the barrier had little or no effect

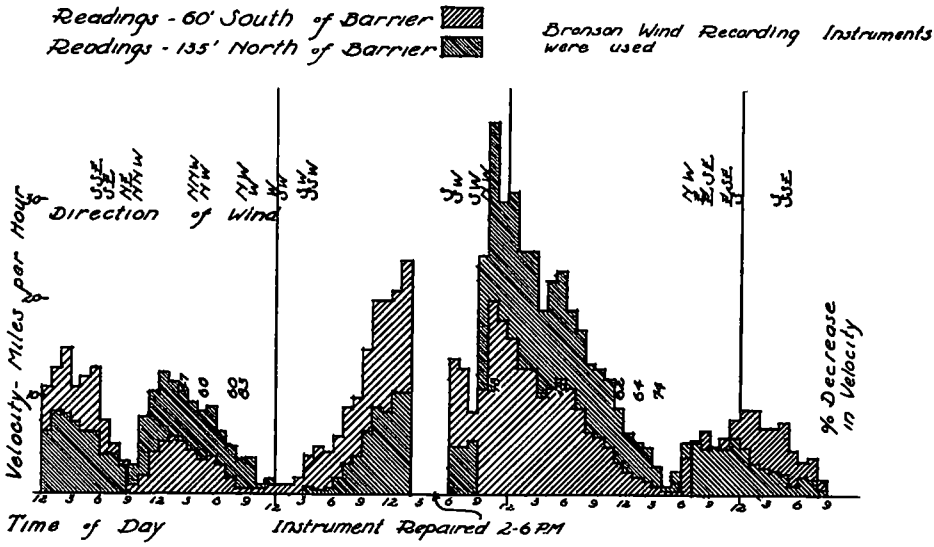

Figure 10. Wind Velocities at the Norway Spruce Barrier

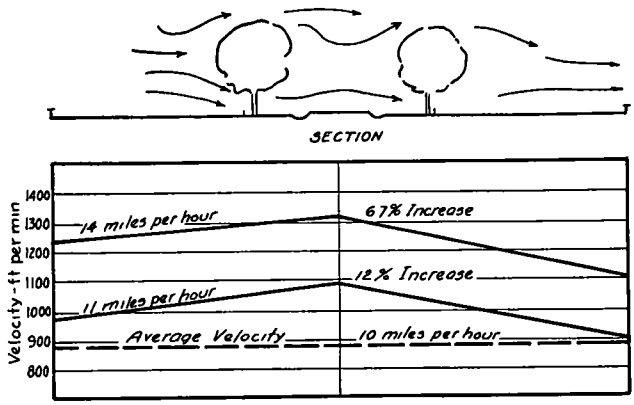

Figure 11. Results of observations on double row of Sugar Maples near Mendota. Wind velocities were measured on center and 100 ft. on each side of road

SUMMARY OF FINDINGS

1 Natural wind barriers studied in the experiment may be ranked for their effectiveness in the following order. (1) Triple row of white pine, (2) single row of Norway spruce, (3) double row of hard maple, (4) single row of Russian willow

2 The Russian willow windbreak shows that there is a decided increase in the velocity of the wind on the windward side of the break at a point 50 ft from the

barrier, and a decided decrease in the velocity on the windward side at a point 100 ft from the barrier

3 The continuous record charts seem to indicate that the percentage of decrease in wind velocity on the leeward side over the windward side of the barrier became greater as the actual wind velocity increased above 12 miles per hour It also increased as the actual wind velocity decreased below 8 miles an hour Thus the minimum percentage of decrease in wind velocity for any particular barrier studied occurred when the actual wind velocity was between 8 and 12 miles an hour

4 With the planted snowfence, obser-

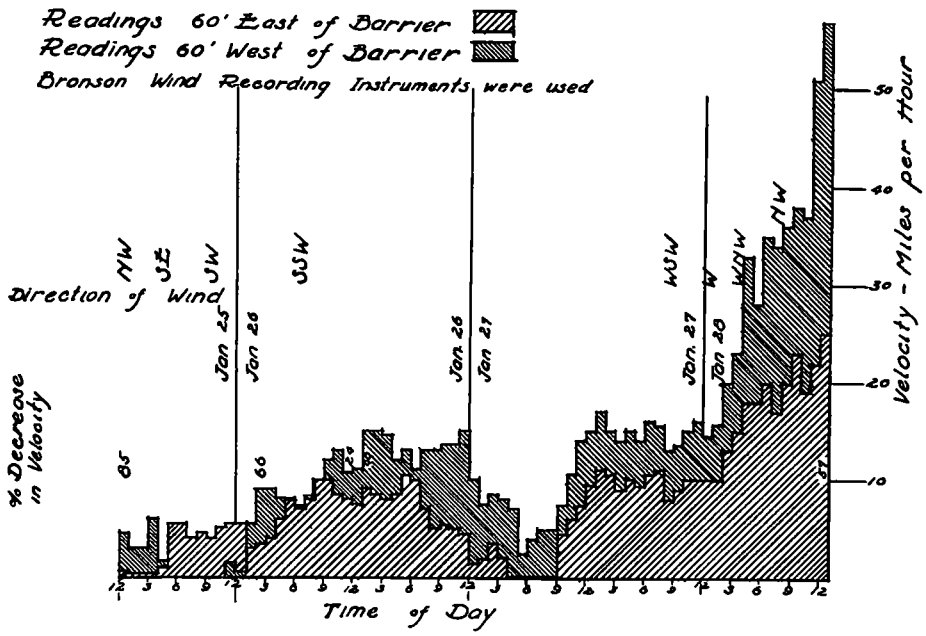

Figure 12. Hard Maple Barrier—Double Row—North and South Highway, Mendota, Wisconsin Jan. 25–28, 1934

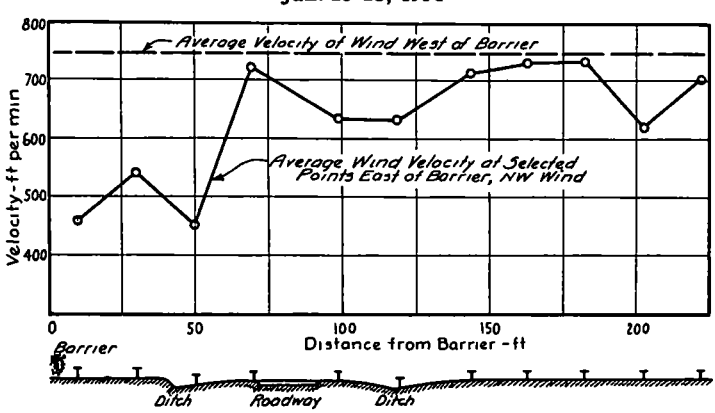

Figure 13 Observations at planted Evergreen Barrier. The cross section shows the points at which velocities were determined 3 ft above the ground

vations seem to indicate that the ditch lines or any other irregularity of the soil greatly affect any decrease in wind velocity The distance to the leeward side where there was any appreciable decrease in velocity was dependent upon the height of the windbreak

5 In the case of the two rows of the sugar maple it seems that there was a decided increase in the wind velocity midway between the two rows directly over the roadbed This is of significance in any problem of snow drift control where roads are lined with trees

SUGGESTIONS FOR FUTURE STUDY

Any conclusions arrived at from these studies cannot be considered as final The work is rather of the nature of a reconnaissence survey It is hoped that these studies may be continued at a future date and that the time selected for such studies may provide opportunity for more complete correlation of the wind velocities with the actual form and position of the snow drift in relation to the barrier

The studies should not be limited to snow fences The very fact that trees do have a very marked effect in decreasing wind velocities would rather indicate that we should have more trees and strips of woodland bordering our highways If we are to consider the comfort of the driver and the wellbeing of the traveler, our highways must provide not only for comfort, safety, and directness of travel, but also for their mental and spiritual needs A complete study and analysis of the effect of trees on wind velocities is certain to improve and benefit the work of the landscape engineer quite as much as the person charged with problems of maintenance