Snow Accretion on Traffic-Control Sign Boards and its Prevention

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Visual observations of snow accretion on the sign board and continuous measurments of the wind velocity and the air temperature have been made in blowing snow. The flow and velocity distribution of wind around and on the surface of the board, respectively, was measured. The set of results show that snow accretion develops around the wind stagnation point of the board, that at a wind velocity exceeding 4 to 5 m/sec the board is covered even with dry snow which does not contain liquid water and that this dry snow accretion can occur more easily with increasing wind velocity with ascending air temperature and with decreasing area of the sign board. The dry snow accretion can be classified into three types. One of the most frequently observed among them is caused by strong collision of snow against the board. The snow accretion of this type can be explained in terms of snow melting at the contact points of snow and the board by the collision which transforms the kinetic energy of snow into internal energy of it and melted snow adheres to the board. Experiments for preventing snow accretion were carried out by three methods. Among them, the method of altering the wind flow is a comprehensive application of making shift the wind stagnation point, making snow collide against the board at an acute angle so that the snow accretion becomes more difficult. It is the most effective among the three methods and can be expected from the practical point of view.

Snow accretion on sign board, that is, covering it with snow, prevents the drivers from being furnished with traffic information to spoil the traffic safety. On a road covered with snow, the traffic sign boards also play the part of optical guidance besides the snow poles. If these are covered with snow, it will become impossible to discriminate them from the surrounding snow under the poor visibility and, in extreme cases, to recognize even its existence. Snow accretion on sign board increases the poor visibility and often becomes a cause of traffic accident and jam.

Until quite recently, however, it has been almost left out of consideration, because there is no such direct damage as breaking sign board and the covered snow gradually falls off spontaneously. The field observations of snow accretion on sign board and the experiments on its prevention have been made from 1974 in the Ishikari plain Hokkaido

Observational Methods

The circular sign board of 60 cm in diameter, the square of 45 cm in the length of side, the inverted equilateral triangle of 74 cm and pentagon 68 cm high were used for the observation. These sign boards are most frequently applied on highways in Japan.

Glass plates and five polywoods boards of various sizes, which have areas, from 22.5 x 45 cm to 90 x 180 cm, growing in geometrical progression of common ratio 2, were also used. Snow accretion on sign boards were visually observed. The following quantities of the test boards covered with snow were measured: Wind direction and velocity, air temperature and surface temperature of the board with copper-constantan thermocouple.

As indoor experiment, wind flow around and wind velocity distribution on the surface of the model boards were measured in wind tunnel.

The Mechanism of Snow Accretion

The mechanism and aspect of snow accretion on sign board depend on the meteorological conditions such as wind direction and velocity with regard to the board, air temperature and characteristics of snow.

As for characteristics of snow, in particular, there are differences in snow adhesion mechanism between wet and dry snows. For this reason, the snow accretion mechanisms of wet and dry snows will be discussed separately.

Wet Snow

Wet snow accretion occurs through the surface tension of water contained in the snow. Since the surface tension of water is larger enough compare with the spesific weight of snowflake, snow accretion occurs more easily than dry one: The latter appears only in strong wind, whereas the former can be seen even under windless condition. When it is calm or weak wind blows, covered snow is approximately uniform in thickness all over the surface of sign boards.

In the condition of strong wind the sign board perpendicular to wind is covered with snow around a stagnation point in its center and snow accretion finally becomes conical, the cone standing up from the center.

Photo. 1 shows the side view of the snow accretion and it takes such a form as this, because the probability of snow accretion is the highest at a wind stagnation point of sign board and decreases towards the circumference.

Figure 1. Side-view of snow accretion on sign board faced to blowing snow.

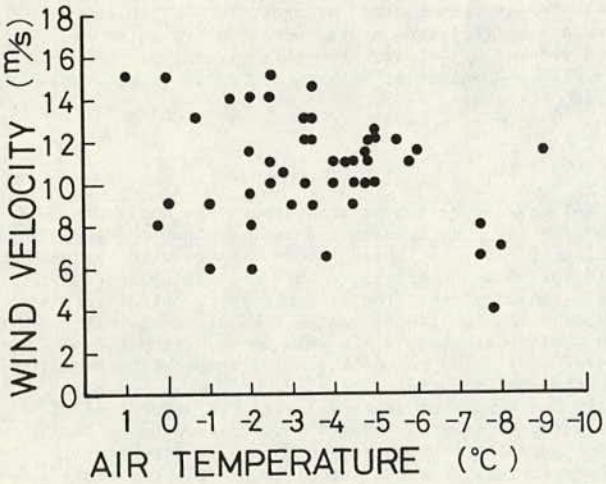
Dry Snow

Also in the case of dry snow which does not contain liquid water, the snow accretion occurs.

The dry snow accretion on sign board occurs only when strong wind blows such as when snow storm prevails and according to its mechanism it can be classified into the following three types.

Dry snow accretion on sign board when wind blows perpendicularly to the board. In the same way as the case of wet snow, the snow accretion of dry snow on sign board, to which strong wind blows perpendicularly, forms a conical form which stagnation point of the wind corresponding to a vertex of the cone.

Figure 2. The meteorological condition for snow accretion of dry snow is shown the relation between wind velocity and air temperature.



Differently from wet snow, dry snow of lowere adhesion has a lower growing rate of snow accretion, because dry snow particle can be more easily repelled even when it collides against the board.

Fig. 2 shows, in a form of dependence on wind velocity and air temperature, the meteorological condition for snow accretion of dry snow.

From Fig. 2 it can be seen that snow accretion occurs when wind velocity exceeds 4 to 5 m/sec in falling snow and does not occur when the velocity is lower.

To give an explanation snow accretion occurrence only at a higher wind velocity, the authors assume that when snowflakes carried by wind collide against a sign board, the kinetic energy of them is coverted into the inner energy of snow, which in consequence of the collision is partially melted, adheres to the board and freezes again there. Let us make sure of the assumption by means of a simple calculation as follows:

The kinetic energy of a snowflake, which is carried at a velocity V cm/sec and has a mass mg, is given by the following equation (1).

$$q = 1/2\ m\ v^2$$

Now, suppose that a snowflake of temperature -10°c, mass 15 mg and diameter 1 cm collides against a sign board at a velocity of 500 cm/sec.

On the assumption that all the kinetic energy of the snowflake is converted into thermal, heat of 4.5×10^{-5} cal will be generated. If this quantity of heat is divided by the value of contact area between the board and the snowflake, calculated on the basis of the latter considered to be a disc of 1 cm in diameter. Then it is possible to determine the thickness of the melted snow, which is 7.3×10^{-7} cm. As being known from the researches on friction, however, the true contact area between both in real contact point with each other is only one several hundredth to one several millionth of apparent contact area.

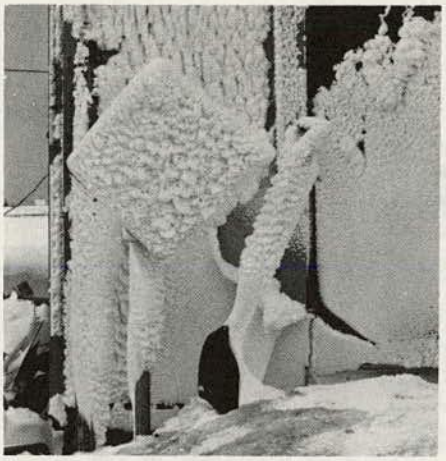
If it is assumed for this reason that the true contact area in the case of snow accretion is equal to one thousandth of apparent area, the thickness of melted snow will be equal to 0.73×10^{-5} cm at the contact point.

While in this calculation, difference in temperature does not so remarkably affect its results as that in wind velocity, heat is emitted in fact to the sign board, the air and the snow and its amount increases with descending temperature. If all of these factors are taken into consideration the thickness will exceed 3000 A even when only several percent of the kinetic energy of a snowflake is consumed. It can be thus supposed that dry snow accretion on sign board is caused by dry snow, whech collides against the board to be melted and then freezes again. Even if the true contact area is only one thousandth of the apparent, the coherence between board and ice is so large as to be able to support a sufficiently grown snow accretion.

Snow accretion due to wake. When wind velocity exceeds 12 to 13 m/sec, snow accretion appears also on another surface of the sign board opposite to the wind direction. This snow accretion is a result of violent collision to the board, of snow which has been swallowed up in eddy wake, formed on the leeward of the sign board by strong wind, and it has approximately a uniform thickness.

Snow accretion occuring in wind shadow. When snow is suspeded by the wind, snow accretion can also appear on sign boards installed in the turbulent eddy, which is formed in urban area and on the leeward of buildings, trees etc. Fig. 3 shows a view of snow accretion on sign board which occurred on the leeward of the observatory.

Figure 3. Snow accretion formed in leeside vortex of the observatory.



The snowaaccretion of this type is first thin, then grows to form an uneven surface of snow resembling to cirrocumulus and finally the depressions are filled with snow to produce a uniformaly thick snow layer.

Since in an eddy air-born snow is suspended and its has a falling velocity equal to almost zero, its apparent weight is slight so that snow accretion occur even with very small adhesion.

This is similar to a phenomenon that minute powder and dust adhere to a body. It appears that after snow adheres the adhesion increases with the lapse of time even if it is first slight. For this reason, a fully-grown thick snow can be supported.

Experiments on Snow Accretion Prevention

The authors carried out experiments in order to prevent snow accretion on sign board perpendicular to the wind.

The snow accretion frequency of this type is the highest in Hokkaido Japan and the traffic is also remarkably affected. The results are described in the following.

From the practical stand point, it was decided in these experiments of snow accretion prevention that the sign boards for text themselves would not be changed at all and not heated as far as possible and the experimental methods were fundamentally the following three. Among them the method of altering the wind flow around a sign board will be mainly described.

Method of Utilizing Wind Force

An anemovane is violently swung with in an angle range from 20 to 30 in strong wind. The wind velocity is also variable. The authors hit upon an idea that these are utilized to swing the sign board, which will strike a hammer behind it, and force of the shock at that time may make the snow fall.

Since snow is light enough in comparison with its adhesion and such a force of shock as this scarcely transmitted by it, however, the authors succeeded by this method in obtaining only an effect of quickening falling off of the adhering snow.

Method of Surface Treatment

If there are some materials or transparent paints to which snow does not adhere, it is valuable from the practical point of view.

Since the adhesion of wet snow is owed to the surface tension of water, it adheres only slightly to hydrophobic substances which repel water well.

The authors investigated the possible snow accretion prevention effect of sign board made of teflon and painted with ski wax, which are both known as hydrophobic substance. In comparison with untreated, as a result, such effects as low growing rate of snow accretion were obstained but it is impossible by this method only to prevent snow accretion in such a digree that the sign board can be recognized without hindrance.

Method of Altering The Wind Flow Around a Sign Board

In a strong wind snow accretion is the most remarkable on a sign board perpendicular to the wind.

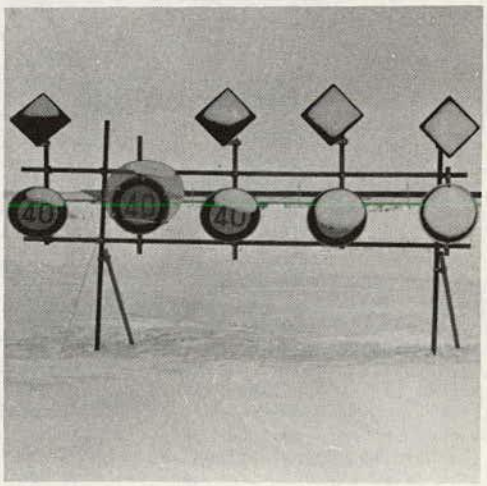
Snow accretion decreases on the board, which approaches more the direction parallel to the wind.

Finally not any snow accretion exists at all on the board parallel to the wind.

This is caused by the facts that snow accretion grows around a stagnation point of wind on the sign board and that a snowflake collides against the board with difficult in a wind blowing along its surface and even if the snow does it is repelled. Baced on these facts, the method consists in removal, if possible, of the wind stagnation point from the sign board or in displacement of the point's position so that even if snow accretion occurs on the board the whole board can be recognized without hindrance.

<u>Providing sign board with a negative angle of depression.</u> The quantity of snow accretion on a downward-inclined sign board decreases with increasing angle of its inclination. Fig. 4 shows a dependence of snow accretion on the angle of inclination. According to the angle increases from 15° to 25°, then 30°, the quantity of snow accretion decreases and snow accretion occurs only on the upper corner of the board.

Figure 4. The dependence of snow accretion on the angle of inclination of sign board.



To know possible cause of this phenomenon, the authors measured the flow and velocity distribution of wind around a sign board model placed in a wind tunnel. Fig. 5 shows such flows of wind in the wind tunnel. This wind tunnel experiment revealed that inclination of the board makes the wind stagnation point shift upward.

Fig. 6 schematically shows a relation between the snow accretion inclined boards and the corresponding wind flow and shift of stagnation point.

Figure 5. Flow around the sign board in wind tunnel.

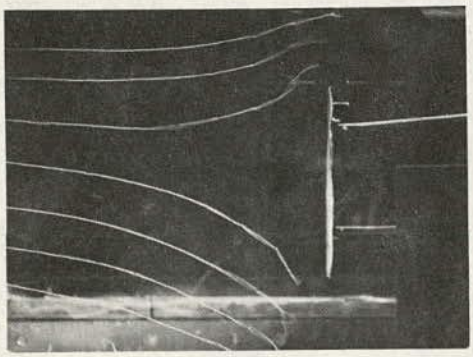
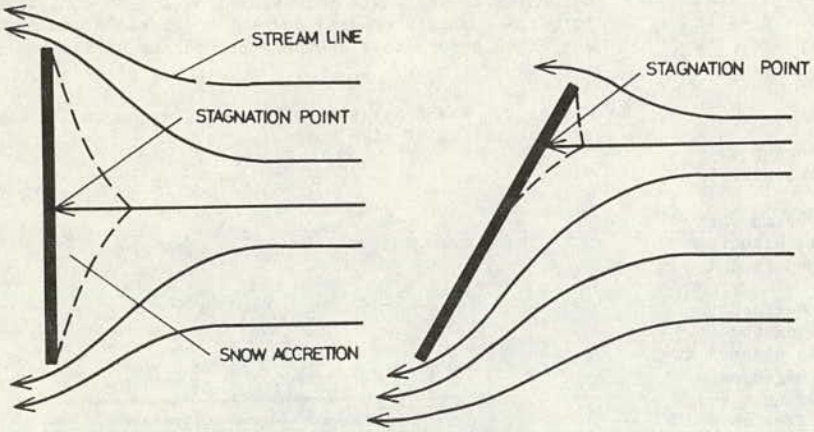


Figure 6. Schematic drawing of relation between snow accretion on inclined sign boards and the corresponding wind flow and shift of stagnation point.



Shielding sign board with a transparent cover having a negative angle of depression of its front. Though based on the same principle, a sign board is not inclined but shielded by a transparent cover having an angle of inclination: The fourth sign board from the right in Fig. 4 is fitted with a transparent acrylic cover as this contributes to shift of the stagnation point to a part of the cover, protruding above the sign board and although snow accretion occurs on this part the sign can be recognized without any hindrance at all. This method can be also applied to reflector.

Dimension of Sign Board and Quantity of Snow Accretion

The stream of snowflake is bent on the circumferential zone of a larger sign board in the direction of wind streamline and collides against the board at an acute angle, so that the snowflakes are repelled. For this reason, snow accretion becomes more dificult with increasing dimension of the board. The authors investigated the dependence of snow accretion omount on the dimension of the sign board. For this purpose, the authors used five painted poly wood venner boards, which are of rectangle with a ratio of the larger to shorter sides 2 : 1 and have areas from 22.5 x 45 to 90 x 180 cm in geometrical progression with a common ratio 2. Fig. 7 shows the views of snow accretion on the boards of various dimensions.

Figure 7. The amount of snow accretion depends on the dimension of the sign board.

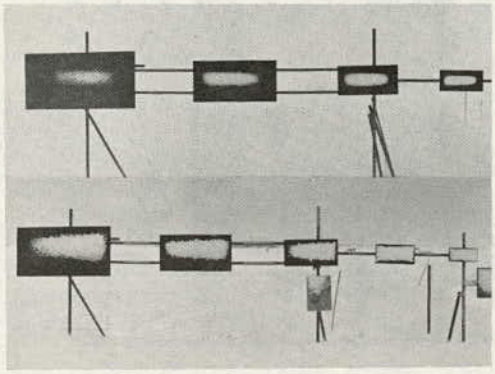


Fig. 8 is a diagrammatic representation of the relation between the shorter side of board and corresponding snow accretion ratio which is defined as a ratio of the area of its part covered with snow to that of its whole. It can be seen from Fig. 8 that the snow accretion ratio decreases linearly with increasing dimension of the board up to 64 cm of its shorter side and beyond it the ratio does similarly but with gradually decreasing rates. Fig. 9 reveals a tendancy that the rate of decrease in snow accretion ratio with increasing dimension of the board is lowered with increasing wind velocity and air temperature. Fig. 9 shows the snow accretion rate on the test board of 90 x 180 cm as a function of wind velocity and air temperature.

Since the larger value of snow accretion ratio means the occurrence and growth of snow accretion being easier, it can be said in general that snow accretion occurs more frequently with increasing wind velocity and air temperature.

Figure 8. The relation between the shorter side of board and corresponding snow accretion ratio shows that the snow accretion ratio decreases linearly with increasing dimension of the board up to 64 cm of its shorter side.

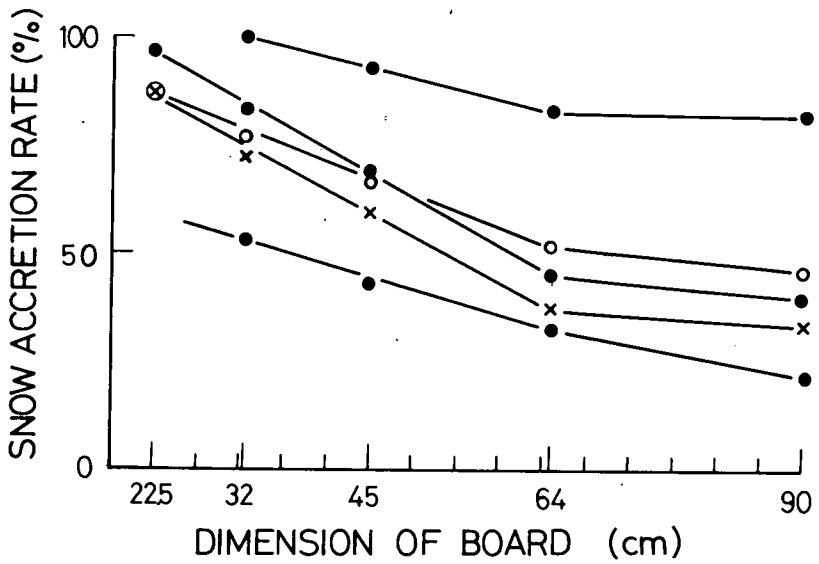
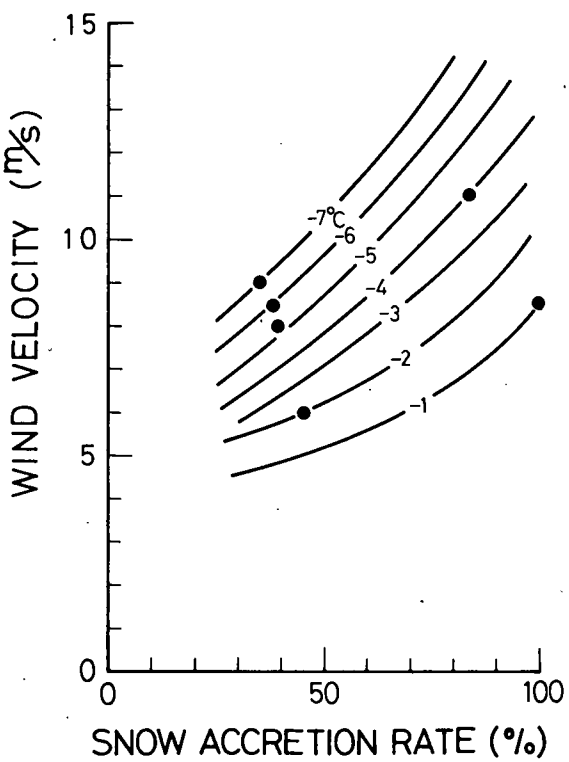


Figure 9. The snow accretion rate on the test board of 90 x 180 cm is shown as a function of wind velocity and air temperature.



Conclusion

As a function of wind direction, velocity, air temperature and characteristics of snow, the authors observed the snow accretion on sign board and discussed possible mechanism of snow accretion occurrence. In a strong wind, the snow accretion on sign board occurs more frequently with increasing wind velocity and, in the case of dry snow, increasing air temperature.

It appears that dry snow accretion is a phenomenon, in which the kinetic energy of air-born snow is converted into the inner one of it through its collision against the sign board to melt a part of it and after adhesion of this melted snow to the board the melted snow refreezes.

As for snow accretion prevention, experiments were carried out on the basis of the following three ways.

(1) Utilization of wind force,
(2) Surface treatment and
(3) Alteration of wind flow.

It was found that among them the alteration of wind flow is the most effective method.