Meteorological conditions for accumulating and falling of snow cover on overhead traffic information sign

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***Abstract*—To study the meteorological conditions under which snow tends to accumulate on and fall from overhead road signs, field observations were performed from December 2006 to March 2007. In this observation, snowfall accumulated on such signs as dry snow which had not contained liquid water with condition of air temperature of below 0 °C. That accumulation accelerated when heavy snowfall occurred during periods when mean wind velocities were below 4 m/s and when mean air temperature approached 0 °C. The fall of accumulated snow tended to occur when it had been melting. When the air temperatures rose above -5 °C, the surface temperatures of overhead road signs rose above 0 °C from solar radiation, and the snow fells off within a few hours.**

I. Introduction

SNOW accumulated on crossbars supporting overhead road signs (hereinafter: crossbars; Fig. 1) can fall and obstruct the view of drivers traveling below or can damage vehicles running below. On national highways in Hokkaido, Japan, the snow is manually removed by workers. However, such work is costly and poses a risk to workers of injury from passing vehicles. Other methods being tested, mainly in the Hokuriku region of Japan, involve placing tilted plates or covers on crossbars, to make the snow fall before it accumulates [1]-[3], or modifying the surface properties of tilted plates to hinder snow adhesion [1], [4], [5]. However, too little is known to identify regions that need such measures and to determine whether such measures are effective in Hokkaido, where weather conditions differ from those of the Hokuriku region. To determine the accumulation countermeasures that are best suited to Hokkaido, field observations were performed to examine accumulation and falling of snow accumulated on crossbars supporting overhead road signs.

Fig. 1. An example of snow accumulated on crossbars supporting overhead road sign.

II. Methodology

A. Location and Period of Observation

Field observations were performed for the 3 months from December 7, 2006 to March 15, 2007 on a full-scale overhead road sign installed at Nakayama Pass (elev.: 835 m), about 45 km southwest of downtown Sapporo, Hokkaido.

B. Observation for Accumulated Snow

Images of snow accumulation were recorded only during the daytime, at one-hour intervals (KADEC EYE II image recorder, Kona Systems Co., Ltd.), and surface temperatures of the crossbars were measured at 10-minute intervals (R060-32, Chino Corp.). Sensors for measuring the surface temperature were installed at the upper and lower surfaces of the crossbars at the back of the signboard (Fig. 2).

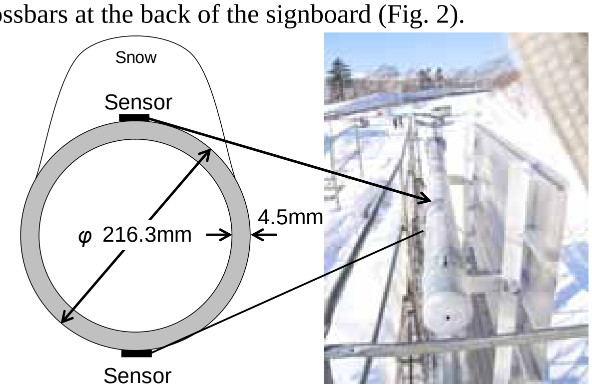

Fig. 2. Installation positions for measuring surface temperature of crossbars.

C. Observation for Meteorological Elements

Meteorological elements were measured every 10 minutes: temperature and relative humidity using a thermo hygrometer (KDC-S02-V-HMP45-D-3.5-S, Kona System Co. Ltd.), solar radiation using an actinometer (MS-43F, EKO Instruments Co., Ltd.). Wind speed, wind direction, and depth of snow cover were obtained at the meteorological observing station of the Civil Engineering Research Institute for Cold Region, adjacent to the observation site.

D. Quantitative Evaluation of Snow Accumulation

From the recorded images, the depths of snow on the crossbars were estimated relative to the heights of railings on the scaffolding used in the observations.

Fig. 3 shows the categories of the accumulated snow. The depths are categorized into five levels, from “free of snow” (Level 0) to “great depth of accumulation” (Level 4). The midpoint between the upper surface of the crossbar and the railing of the scaffolding was used to evaluation the level of snow accumulation. When the depth of accumulation is lower than this midpoint, the depth is level 1; when it is higher than the midpoint but lower than the railings, the depth is level 2; when it is about as high as the railings, the depth is level 3; and when the accumulated snow is substantially higher than the railings, the depth is level 4.

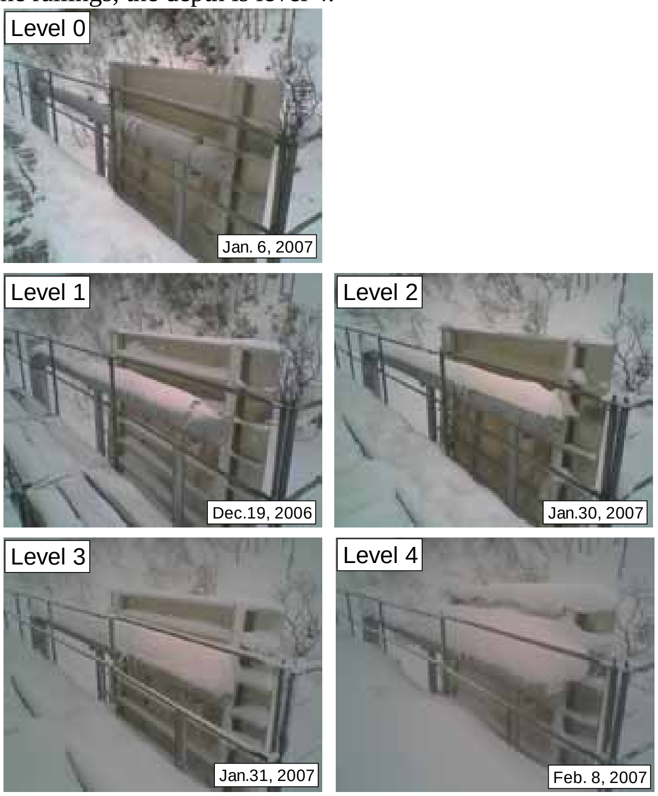

Fig. 3. Categories of snow accumulated on crossbar.

III. Results

A. Meteorological Conditions during the Observation

Fig. 4 shows the meteorological conditions during the observation. During observations, the average air temperature was -7.4 °C, the daily highest temperature was below 0 °C for most of the observation period, and there were only 6 days when the daily highest air temperature exceeded 0 °C. The maximum depth of snow cover on the ground was 242 cm, the average wind velocity was 2.6 m/s, and the prevailing winds were from the west-northwest. Most winds blew perpendicular to the crossbars supporting the signboard.

B. Period with Missing Data

During observation, the depth of snow cover on the ground increased by more than 100 cm in a short two-day period from January 7. Snow continued to fall after this heavy snowfall, and on January 14, the accumulated snow on the crossbars touched the railings. The snow was completely removed on January 27; therefore, the period from January 14 to 27 was excluded from the analysis.

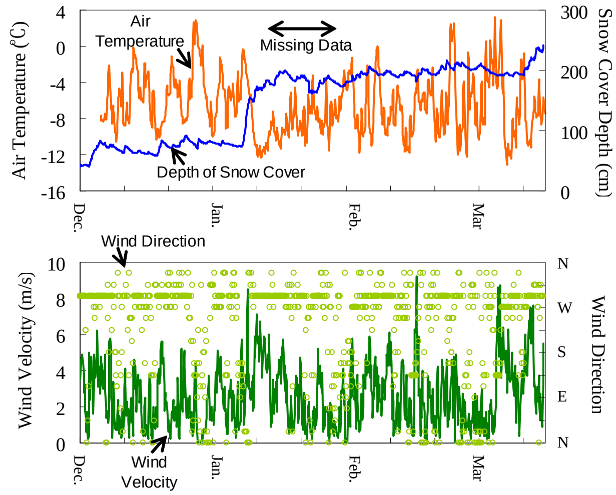

Fig. 4. Meteorological conditions during the observation.

C. Meteorological Conditions on Snow Accumulation

Occurrence of snow accumulation was judged from images recorded by the camera system. However, since the images were only recorded during the daytime and the images are unclear during heavy snowfall, it is difficult to determine when snow accumulation started. Therefore, it was decided to identify the meteorological conditions under which snow started to accumulate by examining the conditions and snow accumulations every day. Snow accumulation in this field observation is defined as a snow cover with a depth on the crossbar observed at 0900 of the Japan Standard Time (JST) but no snow existed at 0900 JST of the previous day. Ten cases met this definition during the survey period.

Fig. 5 shows the relationship between mean air temperature and increase in depth of snow cover on the ground from the previous day for cases in which there was accumulation on the crossbars. In this figure, most of snow accumulation occurred when the air temperature was below 0 °C and snow was dry which had not contained liquid water. In particular, snow accumulated even when the air temperature fell below -10 °C.

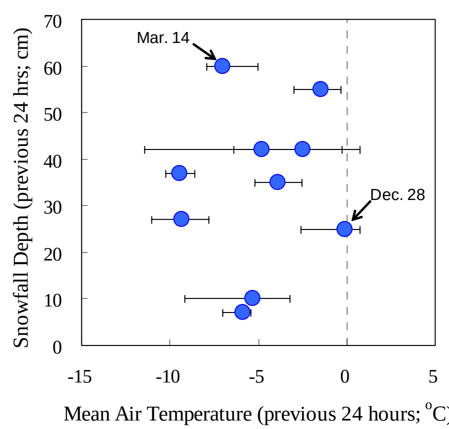

Fig. 5. Relationship between mean air temperature and increase in depth of snow cover on the ground from the previous day for snow accumulation. Horizontal bars show the maximum and minimum temperatures.

Fig. 6 shows the relationship between mean wind velocity and increase in depth of snow cover on the ground from the previous day for cases in which there was accumulation on the crossbars. Snow accumulation occurred under the mean wind velocities of less than 4 m/s. Within this range of wind velocity, under low winds, snow accumulation occurred regardless of the amount of snowfall, whereas under high winds, snow accumulation occurred only when snowfall was heavy. Therefore, under high wind velocities with little snowfall, snow accumulation would do not occur, because wind blew the snow off from the crossbars.

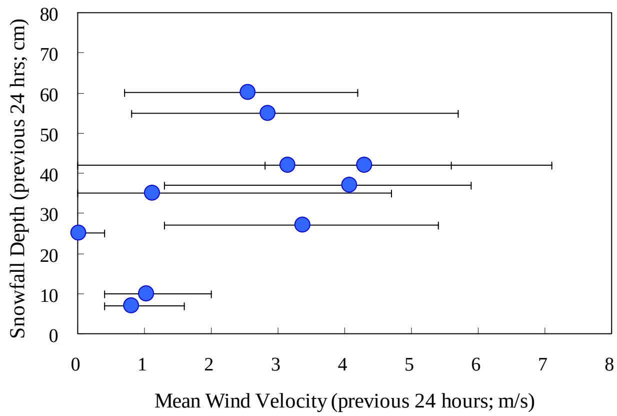

Fig. 6. Relationship between mean wind velocity and increase in depth of snow cover on the ground from the previous day for snow accumulation. Horizontal bars show the maximum and minimum wind velocity.

D. Meteorological Conditions on Accumulated Snow Fall Off

During the field observation, the falling of accumulated snow from the crossbars tended to occur when the snow was melting. For example, Fig. 7 shows recorded images, air temperature, solar radiation, and surface temperature of the crossbars on December 25, 2006. The air temperature was below -5 °C, but the surface temperature rose above 0 °C from solar radiation. Notably, from around 1200 JST, the temperature at the upper surface of the crossbar on which snow accumulated was a relatively constant 0 °C, but the tempera-ture at the lower surface of the crossbars continued to rise, and differences in temperature became significant. At this time, the camera image shows that the snow had moved to the far side of the crossbars, and so accumulated snow would melt from the bottom. At 1300 JST, the temperature at the upper surface of the crossbar became higher than at the lower surface, and it is believed that snow had fallen immediately before this period.

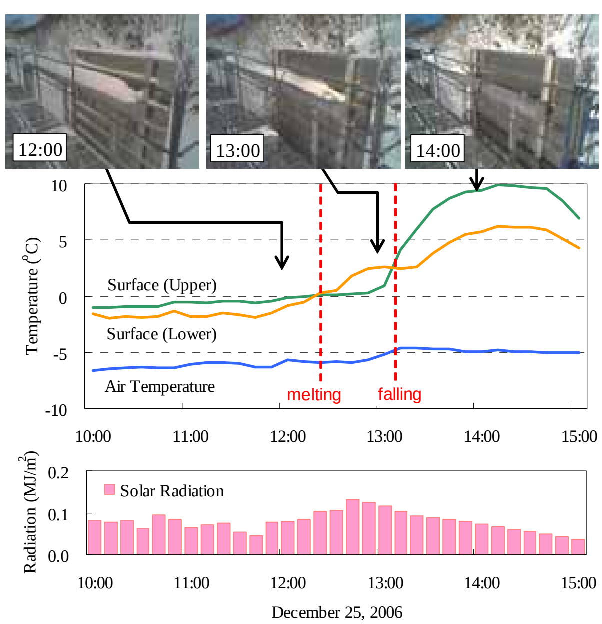

Fig. 7. An example of recorded images, air temperature, solar radiation, and surface temperature of the crossbars for falling of accumulated snow.

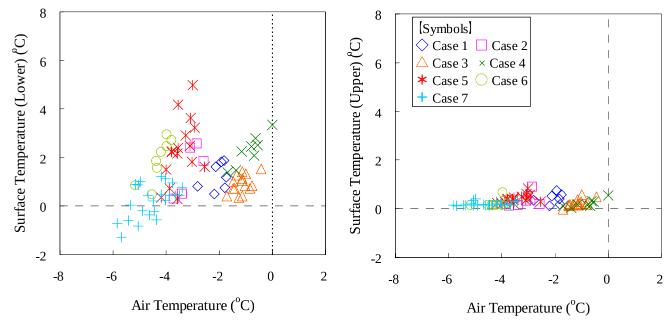

Fig. 8. Relationship between air temperature and surface temperatures on lower (Left) and upper (Right) of crossbar for falling of accumulated snow.

From the above example, the accumulated snow will starts to melt and then fall during the period from when temperatures at the upper and lower surfaces of the crossbars both rise above 0 °C to when the temperature at the upper surface become higher than that at the lower surface. Fig. 8 shows the relationship between air temperature and surface temperatures. In this figure, the temperatures at the upper surface are all between 0 and 1 °C, but the maximum temperature at the lower surface is 5°C. The air temperatures at which the surface temperature rises above 0 °C are about -5 °C and above. Fig. 9 shows the temperature differences between the upper and lower surfaces and the time from the start of snow melting to the occurrence of falling. The mean temperature difference between the upper and lower surfaces is 0.5 to 2 °C, and heat corresponding to this temperature difference will be expended in melting the bottom of the accumulated snow. Furthermore, the accumulated snow tended to fall within 3 hours of when the surface temperature rose above 0 °C.

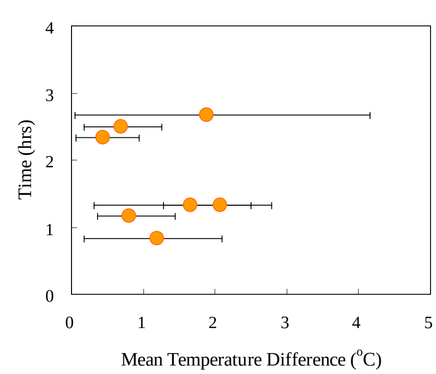

Fig. 9. Mean temperature difference between the upper and lower surfaces and time from the start of snow melting to the occurrence of falling. Horizontal bars mean the maximum and minimum of temperature differences.

IV. Discussion

A. Air Temperature Dependence of Snow Accumulation

Snow accumulation is generally thought to occur when snow falls at air temperatures of slight above 0 °C [6] and become to contain a little liquid water [7], but the observations in this research showed that most of the snow accumulation occurred when air temperature was below 0 °C and snow was dry.

Fig. 10 shows images of snow accumulation under different temperatures. On December 28, when air temperature was relatively high (average air temperature: -0.8 °C), snow accumulated on the railings of the scaffolding and signboard with narrow width, and developed over the width of these objects. On the other hand, on March 14, when air temperature was relatively low (average air temperature: -7.7 °C), the width of snow accumulation was less than that of the crossbar on which the snow accumulated, and the snow accumulation had a triangular cross section.

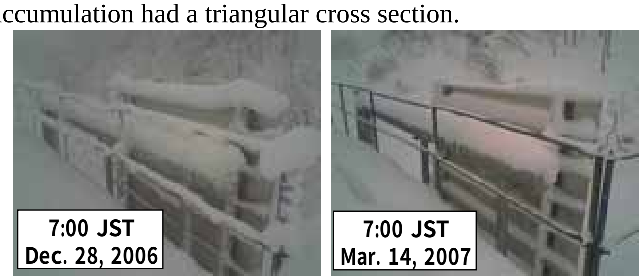

Fig. 10. Examples of snow accumulation in this field observation. Left and right shows cases when air temperature was relatively high and low during snowfall (see Fig.5).

Fig. 11 plots the relationship between the amount of snowfall and the air temperature, with the size of the plotted circles reflecting the depth of accumulation on the crossbars. The greater the amount of snowfall was, the higher the depth of snow accumulated. The figure also shows that at a given snowfall, the higher the air temperature was, the greater the amount of snow accumulation was. As the temperature approaches 0 °C, the snowfall particles becomes large [8] and structures catch the snow at a higher rate [9]. Therefore, it is believed that snow is more likely to accumulate on crossbar of signboards under higher temperatures.

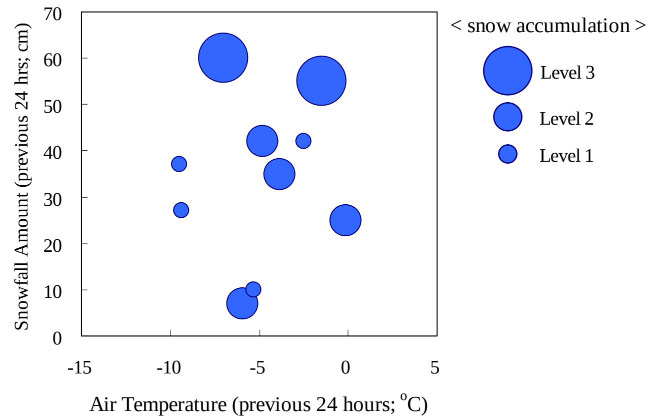

Fig. 11. Relationship between amount of snowfall and mean air temperature for snow accumulation. The size of the plotted circles reflects the depth of accumulation on the crossbars.

When the air temperatures is below 0 °C, the angle of repose for dry accumulated snow tends to be small [10] and the depth of accumulation on a narrow structure is limited by that angle [11]. In this research, the crossbars supporting the signboard had a diameter of 21.6 cm, which is wide enough to catch dry snow [11]. This width would probably allow the depth of accumulation to increase even when the snow was dry.

B. Wind Velocity Dependence of Snow Accumulation

Reference [12] have reported that the threshold wind velocity below which snow starts to accumulate on building rooftops is about 4 m/s. Accretion of dry snow on power cables also tends to occur at wind velocities below 4 m/s [13].

Fig. 12 plots the relationship between the increases in depth of snow cover on the ground and the mean wind velocity, with the size of the plotted circles reflecting the depth of snow accumulation on the crossbars. Snow accumulation occurs when the wind velocity is below 4 m/s. Snow accumulations greater than Level 2 tends to occur when wind velocity is below 3 m/s. This indicates the possibility of a threshold wind velocity for crossbars supporting overhead road signs, similar to those for other structures, below which dry snow accumulates on signboards.

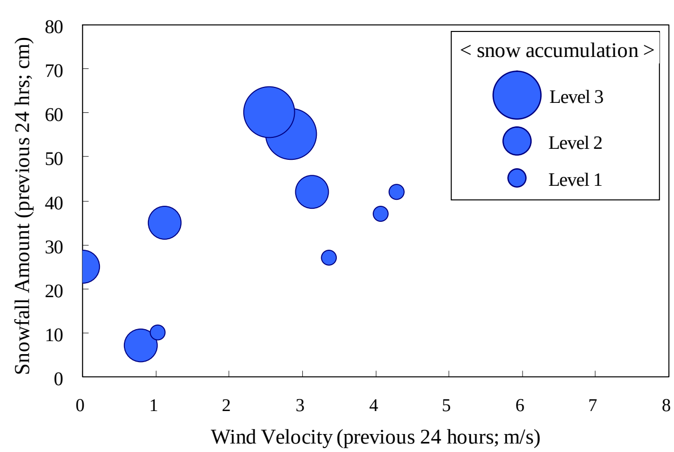

Fig. 12. Relationship between amount of snowfall and mean wind velocity for snow accumulation. The size of the plotted circles reflects the depth of accumulation on the crossbars.

C. Conditions under which Snow Melts and Falls Off

There were some cases in which accumulated snow did not fall even when the surface temperature rose above 0 °C. Fig. 13 plots the relationship between cumulative solar radiation and cumulative temperature differences between the upper and lower crossbar surfaces during the snowmelt period. The size of the plotted circles reflects the depth of snow accumulation on the crossbars for cases in which the snow fell off and for cases in which the snow did not fall off, when the surface temperature rose above 0 °C. The greater was the difference in cumulative surface temperature, the more likely it was for the accumulated snow to fall off, for a given cumulative solar radiation (Fig. 13). It was found that the depth of snow accumulation in case that snow fell were smaller than that in case that snow did not fall. Therefore, snow would fell when the depth of snow accumulation was reduced by repeated melting. In relation to this, the formation of an ice film between the accumulated snow and the crossbars was confirmed by examining cross section of accumulated snow.

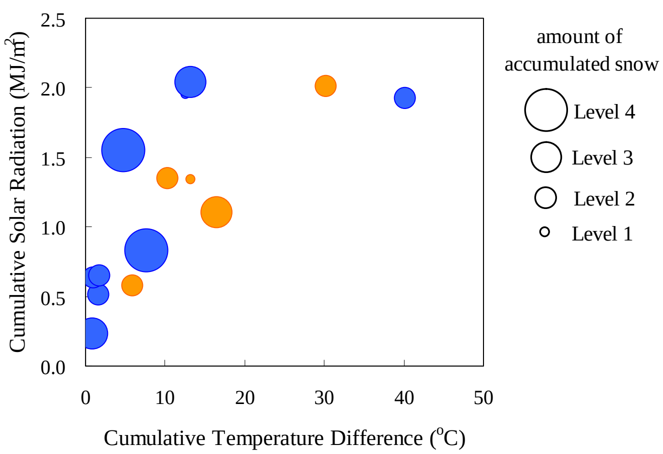

Fig. 13. Relationship between cumulative solar radiation and cumulative temperature differences between the upper and lower crossbar surfaces during the snowmelt period. The size of the plotted circles reflects the depth of accumulation on the crossbars for cases in which the snow fell off (colored on orange) and for cases in which the snow did not fall off (colored on blue).

It is known that when snow accumulated on a structure does not melt for air temperature is below 0 °C, its adhesion to the structure tends to increase with duration [14]. This will allows snow accumulation depth to increase with subsequent snowfall.

V. CONCLUSION

Field observations were performed to study meteorological conditions under which snow tends to accumulate on and fall from crossbars supporting overhead road signs. In this observation, the dry snow which had not contain liquid water tended to accumulate on the crossbars when wind velocities were below 4 m/s and air temperatures approached 0 °C during heavy snowfall. The fall of accumulated snow was caused by melting of snow. When air temperatures rise above -5 °C, the surface temperatures of crossbars supporting overhead road signs rise above 0 °C from solar radiation, and snow falls of within a few hours.

The field observations were to be continued until April 2007 to gain further information on snow accumulation from snowfall at temperatures around 0°C and on falling of accumulated snow. Based on the findings, the authors intend to study measures against the falling of accumulated snow from overhead road signs.

VI. AKNOWLEGMENT

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VII. REFERENCES

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