FUNDAMENTAL STUDY ON THE CONTROL OF SNOW ACCRETION AND SNOW COVER ON ROAD RELATED FACILITIES

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1. Introduction

In installing road related facilities in a cold, snowy region, one must consider the issues of snow accretion and snow cover. When snow accretions to road related facilities such as traffic signs, information boards, signals, and delineators, the drivers often find it difficult to discern crucial travel information provided in the form of written words, shapes, illuminators, and reflectors. This situation has triggered accidents in many cases. In addition, snow cover on overhead road structures (e.g., truss bridge, traffic sign, viaduct, pedestrian overpass, tunnel entrance) has caused many fallen-snow accidents.

To control the above-mentioned snow accretion and snow cover, effective measures are considered to be: (1) modification of the structure shape, (2) improvement in surface treatment, and (3) use of external energy such as heat and vibration. This study disregarded (3), and instead attempted basic research of (1) and (2).

2. Snow Accretion Control

Road related facilities that present problems to drivers when snow accretions to the structures are traffic signs, information boards, signals, and delineators. Because plates with larger area tend to have less snow accretion than those with smaller areas,[1)] this study focused on delineators, which are road related facilities with small areas to which snow adheres, and on small traffic signs. The method of modification of structure shape, among items listed in Sec. 1 above was examined as a snow accretion control measure.

2.1 Delineators

Conventionally, delineators have been installed with their reflector planes vertical. However, traffic signs in cold, snowy regions are inclined 10° to 15° forward, to prevent snow accretion. In this study we inclined the delineator reflection planes forward.

2.1.1 Wind tunnel experiment

A wind tunnel experiment was conducted to clarify the relationship between snow accretion and the angles at which discs representing delineators were inclined forward. Figure 1 shows the experimental setup. The disc-shaped test plates were inclined at ten angles: 0°, 5°, 10°, 15°, 20°, 25°, 30°, 35°, 40° and 45°, from left to right. As a test model, waterproof sandpaper (#200) was used, since its surface is rough and tends to catch snow. We arranged these test plates perpendicular to the wind direction in the wind tunnel and maintained the tunnel wind speed at 7 m/s for two hours. We substituted activated siliceous earth for snow.

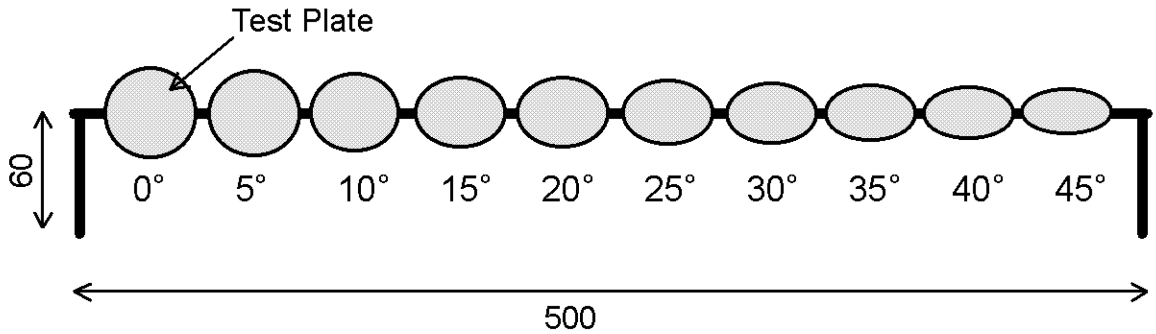

Figure 1 Experimental Setup

Photo 1 shows the states of snow accretion for each test plate, revealing that less snow attached as the angle increased and almost no snow accretion occurred at 40° or over. For this reason, we determined to incline the delineator reflection plane 40° forward.

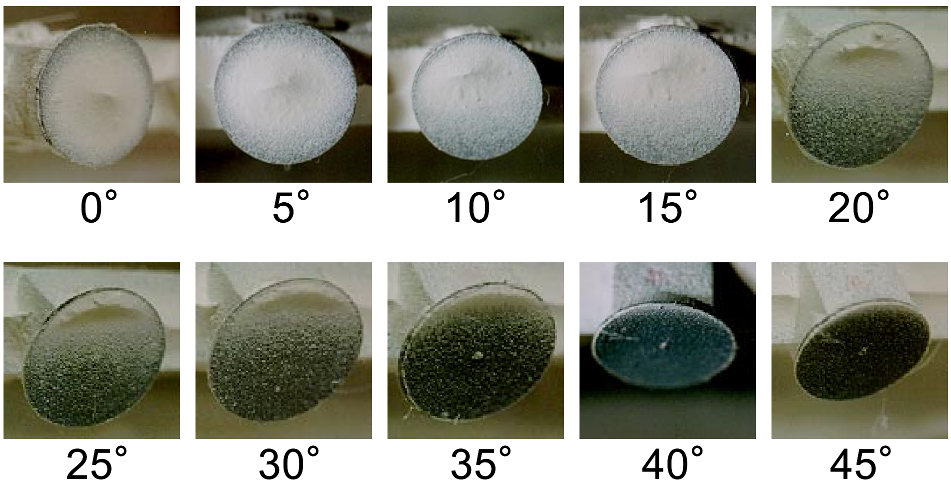

Photo 1 Snow Accretion in the Wind Tunnel Experiment

2.1.2 Outdoor exposure experiment

A delineator is a device that locates the roadside for night drivers through the retro-reflection of incident light flux. However, inclining the conventional reflector 40° forward prevented the reflection of light. Therefore, the test model was made with a lens structure that retro-reflected the light straight to the luminous source direction (Photo 2). Its shape was made elliptical so that the device would appear circular, which is the same shape of a conventional delineator with ψ100, when viewed from straight on. Regarding the reflection luminance, the test model satisfied the requirement of the delineator installation standards and explications.[2)]

Photo 2　Test Model

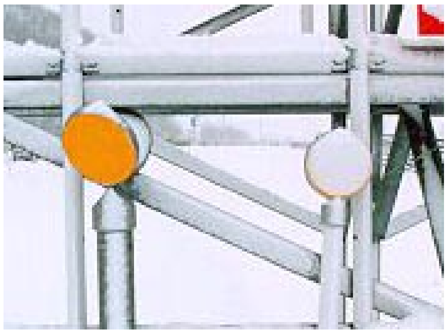

Photo 3　Experiment

We installed both the test models and the conventional delineators outside, and observed the progress of snow accretion.　The experimental conditions are described below, and Photo 3 shows the experiment in progress.

- Test site: Snowy Country Product Research Institute, Sekisui Jushi Corp., Mikasa City, Hokkaido
- Period: December 13, 1996, to March 14, 1997
- Time: 07:00 to 16:00 (819 observation hours)
- Installation height: 1.5 m
- Orientation: WNW
- Observation method: unmanned observation, with industrial television (ITV) camera recording the process in time-lapse video

We defined the state of snow accretion as that when snow covered over 50% of the delineator reflector, and evaluated the test model by measuring the total hours of snow accretion in which snow accretion was observed during the research period. Figure 2 shows the total hours of snow accretion for the conventional delineator and that for the test model. The total snow accretion hours of the test model was nearly one-fortieth that of the conventional one.　The test model's significant snow accretion control effect was verified in this outdoor exposure experiment.

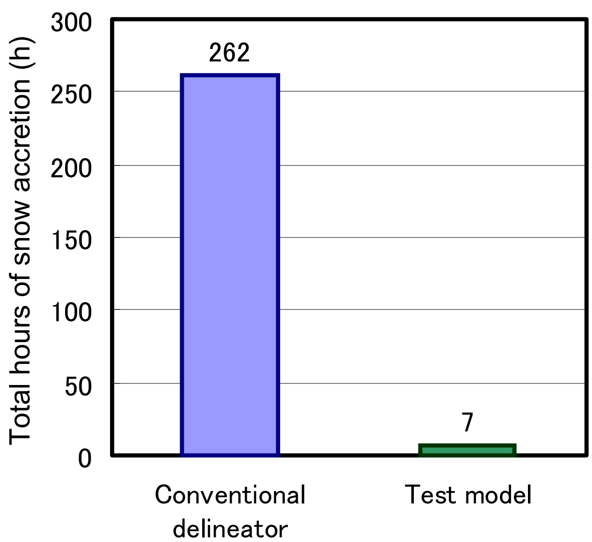

Figure 2　Total Hours of Snow Accretion

2.2 Small traffic signs

As a small traffic sign, we chose to use distance posts installed on expressways. The most common type measures 400 mm wide by 180 mm high. They provide written information for night drivers by retro-reflecting incident light flux. A reflective sheet is applied to the sign. As with the case of the delineator, the sign inclined 40° forward was indiscernible during the daytime and retro-reflected little light at night. Thus, inclination of somewhere around 15° seemed appropriate. We considered inclining the sign 15° forward and attaching an eave to the top. Based on the delineator’s test result, the eave's angle was fixed at 40°, which was proved to produce the optimum snow accretion control. In the experiment, we evaluated the size of the eave.

2.2.1 Wind tunnel test

The states of snow accretion on the conventional traffic sign and that with eaves were observed in the wind tunnel test. Figure 3 shows the experimental setup: a conventional traffic sign (No. 1), a sign inclined 15˚ forward (No. 2), signs with eaves of various sizes on top (No. 3 to No. 5), a sign with eaves inclined backward (No. 6) and a sign with a spacing between the sign and the eaves (No. 7). The experiment was carried out in the same manner as that in Section 2.1.1.

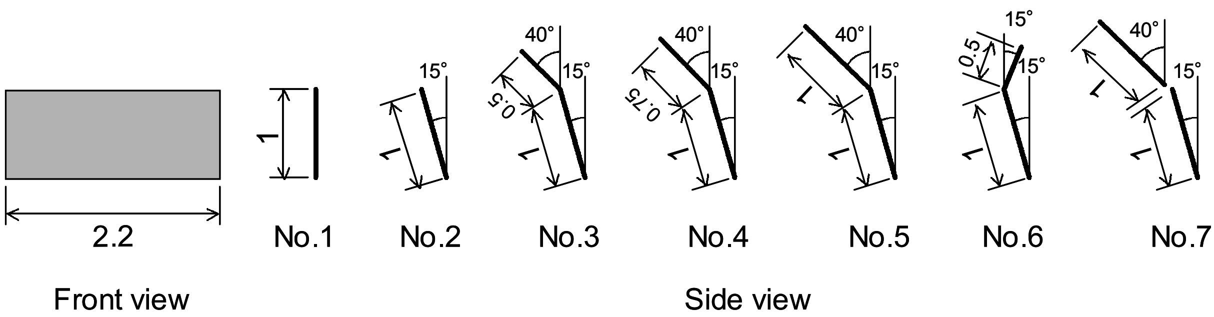

Figure 3 Experimental Setup

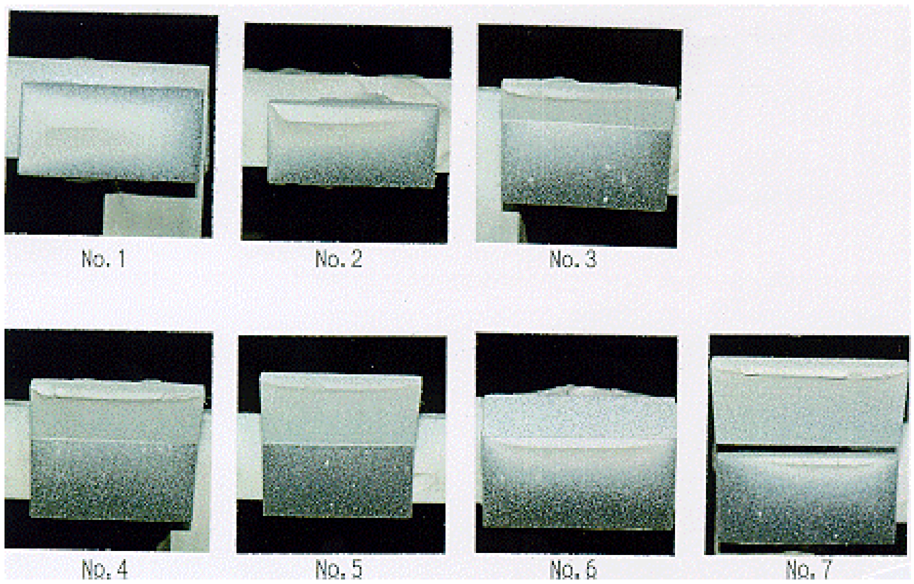

Photo 4 Snow Accretion in the Wind Tunnel Test

Photo 4 shows the states of snow accretion for each test model, revealing that the signs with the eaves inclined 40° forward (No. 3 to No. 5) showed less snow accretion. The one with the widest eaves (No. 5) had least snow accretion.

2.2.2 Examination through computer simulation

By using the following analytical methods, we predicted the airflow around the test models that are illustrated in Figure 3. To perform the quantitative analysis, we employed the finite difference method to linearly express the Navier-Stoke partial differential equation that is the basic equation for fluid motion. Figure 4 shows typical equivalent wind velocity rate diagrams. The area with slanted lines represents a stagnation area where the wind velocity rate was 0.4 or less. In the case of the conventional traffic sign (No. 1) and the one inclined 15° forward (No. 2), the stagnation area extended throughout the plate. In contrast, those with eaves (No. 3 and No. 5) had a stagnation area that converged at the top of the eaves, preventing snow accretion to the sign.

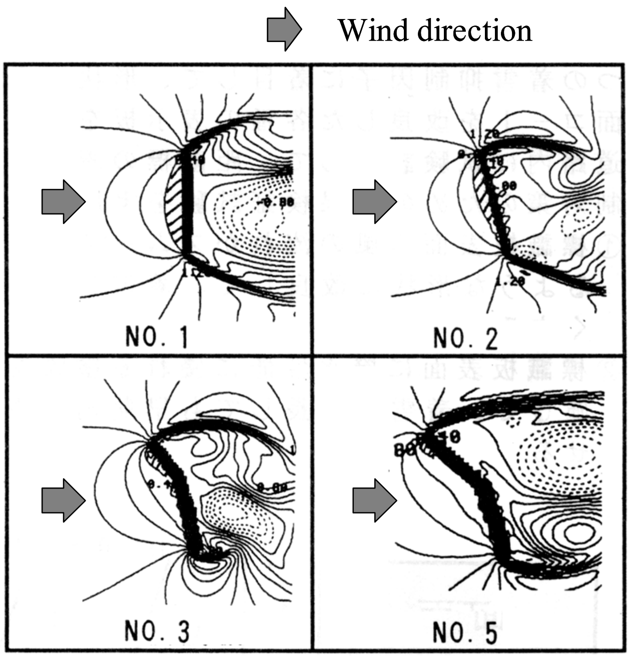

Figure 4 Equivalent Wind Velocity Rate Diagrams

2.2.3 Outdoor exposure experiment

Following the wind tunnel test and computer simulation, in which the snow accretion control effect of test models No. 3, 4 and 5 was highly evaluated, the two-winter outdoor exposure experiment was conducted on those test models. Test model No. 1 was included as a control. The experimental conditions are described as follows.

- Test site: Snowy Country Product Research Institute, Sekisui Jushi Corp., Mikasa City, Hokkaido
- Period: December 10, 1996, to March 10, 1997 (Phase I)
  December 6, 1997 to March 24, 1998 (Phase II)
- Time: 07:00 to 16:00
- Installation height: 1.5 m
- Orientation: WNW
- Observation method: unmanned observation, with ITV recording the process in time lapse video

We defined the state where snow covered more than 50% of the sign as snow accretion, and the time factor of snow accretion was evaluated with the value of test model No. 1 indexed as 100%. The time factor of snow accretion is obtained through the following formula:

time factor of snow accretion = (total snow accretion hours of a given test model / total snow accretion hours of test model No. 1)×100

Figure 5 shows the calculation result. There is noticeable snow accretion control effect for the eaves-equipped test models, versus the case of test model No. 1. Regarding the size of the eaves, test model No. 5 (eaves : sign = 1 : 1) demonstrates the highest snow accretion control effect. If the shape of test model No. 5 is introduced to actual traffic signs, then snow accretion can be reduced to 33% (Phase I result) or 50% (Phase II result) of the test model No. 1 value.

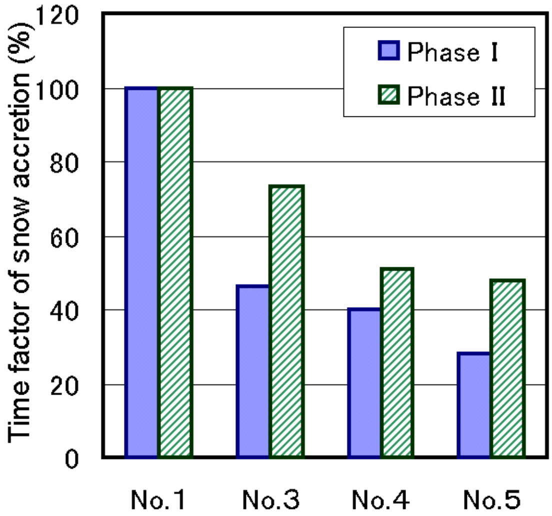

Figure 5 Time Factor of Snow Accretion

2.3 Summary

Snow accretion control for the delineator, which is a small road accessory, and for the small traffic sign has been envisioned by modification of their shapes. We obtained the following experimental findings.

- Snow accretion on the delineator can be reduced to one-fortieth of the conventional installation, by modifying the shape of the reflection plane and inclining it 40° forward.
- For the small traffic sign, snow accretion can be reduced to between one-half and one-third of the conventional installation, if the sign is inclined 15° forward and if eaves equal in size to the sign are inclined 40° forward.

3. Snow Cover Control

As snow, after having accreted to or covered on the overhead road structure, grows and then falls off, it is very likely that vehicles and pedestrians passing below will incur damages. The problem is becoming more serious, since many roads have been elevated and structures have become larger. As a countermeasure against snow cover, a roof is built on the road structure. Photo 5 shows examples of roofed traffic signs. In this study, we examined the second idea, the improvement of the roof surface treatment, which is (2) of the countermeasures listed Section 1. A preliminary experiment on the angle of gradient and the surface treatment of the roof had been carried out. Based on those experimental results, we developed a new surface treatment and confirmed its snow cover control effect in the manner similar to the preliminary experiment.

Photo 5 Roofed Traffic Sign

3.1 Preliminary experiment on the angle of gradient and the surface treatment of the roof

To clarify the basic requirements for the roof, we evaluated snow cover conditions in the outdoor exposure experiment, by changing its gradient from horizontal to vertical and by changing its surface treatment. We used aluminum plates 300 mm by 300 mm as a test model.

The angle of gradient of the aluminum plate to horizontal was set at 0° (horizontal), 15°, 30°, 45°, 60°, 75° and 90° (vertical).

Regarding the surface treatment, three types were employed: aluminum base material (contact angle: 78°); super water-repellent coating which is commonly used for snow cover control (contact angle: 151°); and hydrophilic coating (contact angle: 20°).

The experimental conditions are described below, and Photo 6 shows the experiment.

Photo 6 Experiment

- Test site: Snowy Country Product Research Institute, Sekisui Jushi Corp., Mikasa City, Hokkaido
- Period: December 15, 1998, to March 20, 1999
- Time: 07:00 to 16:00
- Orientation: WNW
- Observation method: unmanned observation, with ITV recording the process in time lapse video

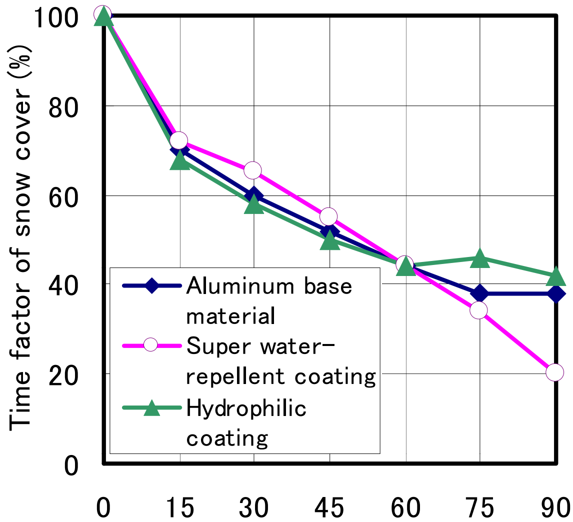

Figure 6 Time Factor of Snow Cover

We defined the situation where snow covered over 50% of the aluminum plate as snow cover, and the time factor of snow cover was evaluated against the 0° (horizontal) value. The time factor of snow cover is obtained through the following formula:

time factor of snow cover = (total snow cover hours of a given test model / total snow cover hours of 0° (horizontal) test model)×100

Figure 6 shows the results. As the angle of gradient increased, the time factor of snow cover tended to decrease. Regarding surface treatment, the super water-repellent coating demonstrated the minimum time factor at the angle of 90° and 75°. At the angle of 60°, the values were almost the same among the aluminum base material, the super water-repellent coating and the hydrophilic coating. In contrast, the time factor of snow cover for the hydrophilic coating was the lowest at the angle of 45° to 15°.

When a roof is built on a road structure, it is expected that there will be a wide range of gradient angles. From the results above, it seems that the super water-repellent coating, which is commonly used for snow cover control, is not a perfect solution for this kind of roof. We believe both hydrophobic and hydrophilic characteristics are required for the surface treatment to enhance the effects of this kind of roof.

3.2 Development of new surface treatment and examination of its snow cover control effect

Based on the results above, we developed a coating that included both hydrophobic and hydrophilic characteristics (hereinafter, the new coating), and its snow cover control effect was tested in the outdoor exposure experiment. The test models were aluminum plates 300 mm by 300 mm to which the new coating was applied. The angles of gradient of the plates were set at 0° (horizontal), 10°, 20°, 30°, 40°, 50°, 60°, 70°, 80° and 90° (vertical). The experimental conditions are described below.

- Test site: Snowy Country Product Research Institute, Sekisui Jushi Corp., Mikasa, Hokkaido
- Period: December 1, 2000, to March 31, 2001
- Time: 07:00 to 16:00
- Orientation: WNW
- Observation method: unmanned observation, with ITV recording the process in time lapse video

As with the evaluation in Section 3.1, the effect was assessed using the time factor of snow cover. Figure 7 shows the results, indicating that the time factor of snow cover declined as the angle of gradient increased. When compared with the results in Figure 6, the values for the new coating were lower than those for the aluminum base material, the super water-repellent coating, and the hydrophilic coating at all angles between 15° and 90°. The new coating could reduce snow cover to between one-third and two-thirds of the aluminum base material. Hence, significant snow cover control effect of the new coating was confirmed.

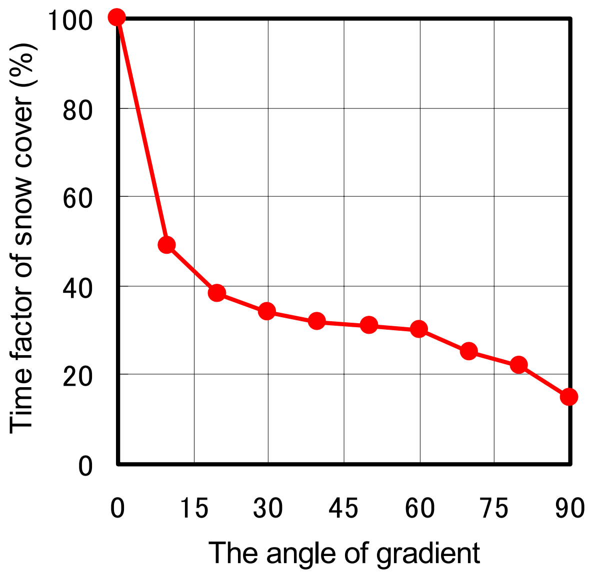

Figure 7 Time Factor of Snow Cover

3.3 Summary

We improved the surface treatment of the roof built on the road accessory structure, and examined the effectiveness of its snow cover control. The findings follow.

- The time factor of snow cover tended to decrease as the angle of gradient increased.
- In comparison among the aluminum base material, the super water-repellent coating, and the hydrophilic coating, the super water-repellent coating demonstrated the highest snow cover control effect at an inclination greater than 60°, while the hydrophilic coating showed its effectiveness at a lower angle.
- When the new coating was applied, snow cover could be reduced to between one-third and

two-thirds of the aluminum base material at all angles of gradient between 15° and 90°.

4. Conclusions and Future Issues

As a snow accretion control measure, we modified the shapes of delineators and small traffic signs. As a result, snow accretion on the proposed delineator and small signs was reduced by one-fortieth, to between one-half and one-third of the conventional installation, respectively. We assume that the effects would be enhanced by use of the new coating, which we examined in Section 3.2.

As a snow cover control measure, we attempted to improve the roof surface treatment. As a result of applying the new coating to the roof, snow cover was reduced to between one-third and two-thirds of the aluminum base material.

To strictly control snow accretion and snow cover, the use of external energy such as heat and vibration needs to be considered. However, the idea is less feasible, for the following reasons.

- Heavy initial investment
- High operation costs
- Counter to energy saving
- Troubles caused by system malfunction

References

1) Masao Takeuchi, Snow accretion to the road traffic sign and its prevention, Seppyo No.40, Vol.3, pp15-25, 1978.
2) Japan Road Association, the delineator installation standards and explications, pp9.