Performance Evaluation of Pavement with Deicing Materials

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As part of countermeasures to slippery roads in Japan, deicing pavement has been investigated. Deicing materials such as chloride and ground rubber were added to the pavement. Deicing pavements are under construction in various districts in Japan, but evaluation methods have yet to be established. The effectiveness of deicing pavement containing a flaked deicing material (Verglimit) consisting primarily of calcium chloride was evaluated, chiefly with a dielectric pavement freezing detector and a fixed camera. As a result, melting action and chloride solution on the pavement with deicing materials were evaluated.

In snowy and cold regions, controlling snow and ice on the roads is of major importance in ensuring safe, smooth traffic flow in winter. In Japan, studded tires have been popular for their convenience and effectiveness. However, the damage that they do to the pavement and related environmental issues pose grave problems. A law prohibiting the use of studded tires in designated areas was enacted in June 1990.

Hokkaido is in the northernmost region of Japan and is affected by comparatively heavy snowfalls and cold climatic conditions, leading to frequently frozen road surfaces in winter. Despite this, few specific snow and ice control practices, such as the application of deicing chemicals, have been followed.

To obtain information supporting optimum snow and ice control measures, deicing materials are being studied. In this survey, the effectiveness of pavement containing a flaked deicing material called Verglimit, which consists primarily of calcium chloride, was evaluated, chiefly with a dielectric pavement freezing detector (DPF) and a fixed camera.

SUMMARY OF SURVEY

Survey Site

Figure 1 shows Otaru, the site of the survey, in the western part of Hokkaido. The mean temperature and average snowfall in February for the past 5 years were −2.8°C (27.0°F) and 800 mm (31.5 in.), respectively; the test road was in a mountainous area.

Average daily traffic during the test was about 2,100 vehicles, 16 percent of which were commercial vehicles. The survey was conducted from December 1991 to March 1992.

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In Sections A, B, and D, 5 percent deicing materials were added to the asphalt mixture. In Section C, deicing material was not added. Section A was paved in 1989, Section B was paved in 1990, and Sections C and D were paved in 1991.

This paper compares and discusses the observations at Sections C and D to evaluate the effectiveness of the deicing material.

Description of Survey

The survey process was as follows:

1. Instrument observation:
   –Regular photographing of the road surface with fixed camera.
   –Monitoring electric capacitance and temperature of the road surface with a DPF.
2. In situ observation:
   –Measuring chloride concentration by sampling packed snow on the road.
   –Measuring reflectivity of snow and ice on the road.
3. Measurement of depth of snow and ice on the road.
4. Measurement of temperature and wind velocity.

Regular Photographing with Fixed Camera

On the basis of photographs, snow and ice conditions on the road surface were identified and road-surface exposure was calculated. Exposure rates were calculated by Equation 1.

$$\text{road surface exposure rate (\%)} = \text{exposed area/total designated area} * 100 \qquad (1)$$

Measurement of Reflectivity of Snow and Ice on Road

With an albedometer, the ratio of light reflected by the snow and ice to the incident light was calculated by Equation 2.

$$\text{reflectivity} = \text{reflected light/incident light} \qquad (2)$$

Measurement of Surface Electric Capacitance and Surface Temperature

The DPF was developed by applying the dielectric characteristics of snow and ice and condenser theory. The device is

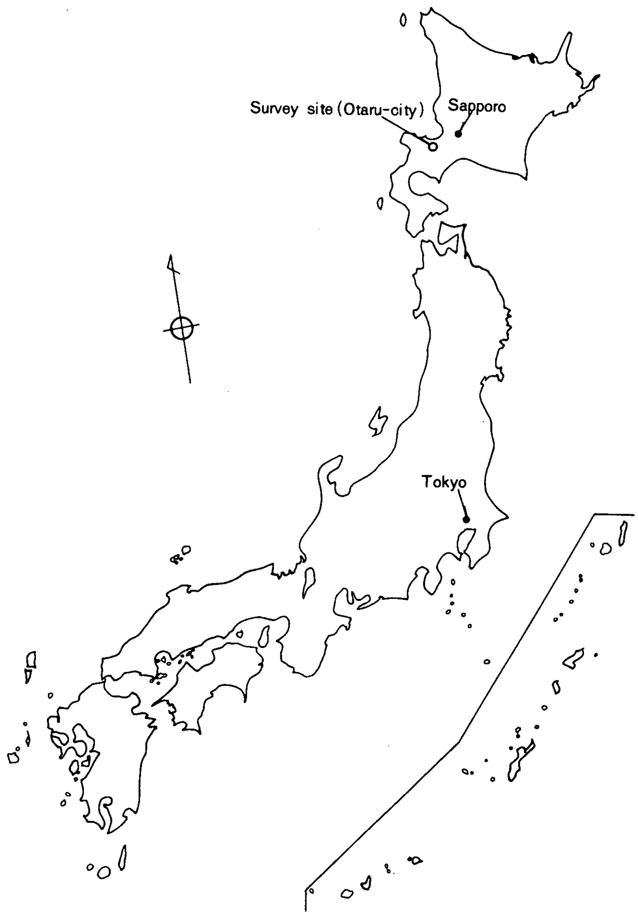

FIGURE 1 Survey site.

used to determine road-surface states on the basis of electric capacitance and temperature. Figure 2 shows a DPF diagram in which the differences in electric capacitance from the dielectric characteristics vary with air, water, and ice conditions. The electric capacitance is determined by Equation 3.

$$C(pF) = 8.854 * \kappa s * A/d \quad (3)$$

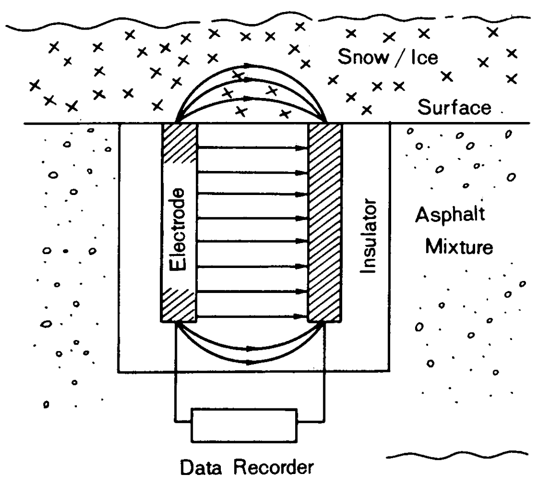

FIGURE 2 Diagram illustrating principle of measurement by DPF.

where

C = electric capacitance,
κs = ratio of dielectric,
A = area of facing pole plates (m^2), and
d = distance between pole plates (m).

The measurement frequency was 72 KHz.

In this survey, the effect of the deicing mixture was evaluated on the basis of the fact that electric capacitance increases with an increase in chloride solution.

Classification of Snow and Ice Conditions on Roads

During winter, the varying properties of snow and ice on the road strongly affect the conditions of the road surface. Snow and ice conditions change with the freeze-thaw cycle, the action of traffic, and other disturbances, and they may be classified as done in Table 1.

ANALYSIS OF PHOTOGRAPHS

The classification of snow and ice on roads and the analysis of road-surface exposure rates were done on the basis of road-surface photos taken from December to February.

Types of Snow and Ice on Roads

The proportions of the different snow and ice conditions are shown in Figure 3. Generally, CS, GS, and IF/IC conditions form slippery and freezing road-surface conditions, whereas SL/WB and DB are relatively safe road conditions.

In Sections C and D, CS is the most common condition (except for DB). In Section C, CS is 63 percent; in Section D, it is 43 percent, or two-thirds that in Section C. The SL/WB

TABLE 1 Classification of Snow and Ice Conditions on Road

Type (Symbol)	Sub-Type (Symbol)
New Snow (NS)	Dry New Snow (DNS)
	Wet New Snow (WNS)
Compacted Snow (CS)	Dry Compacted Snow (DCS)
	Wet Compacted Snow (WCS)
Powder Snow (PS)	Powder Snow (PS)
Grain Snow (GS)	Dry Grain Snow (DGS)
	Wet Grain Snow (WGS)
Slush (SL)	Slush (SL)
Ice Crust (IC)	Dry Ice Crust (DIC)
	Wet Ice Crust (WIC)
Ice Film (IF)	Dry Ice Film (DIF)
	Wet Ice Film (WIF)
Bare (B)	Dry Bare (DB)
	Wet Bare (WB)

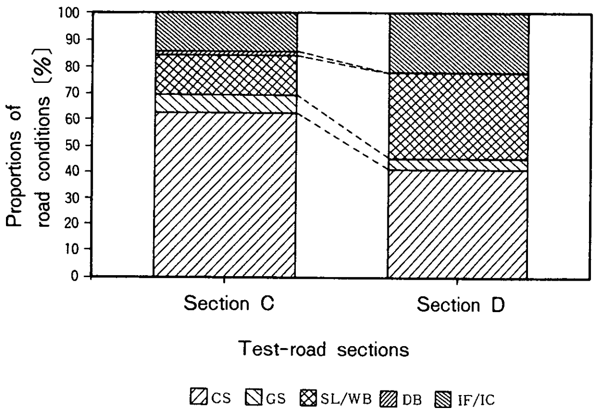

FIGURE 3 Proportions of snow and ice conditions on roads throughout survey period.

and IF/IC conditions in Section C are both 15 percent; in Section D, SL/WB is 29 percent, about twice that in Section C.

Snow and ice on the road by time of day is shown in Figure 4. The SL/WB condition is more common in Section D than in Section C. SL/WB frequencies are highest at 2:00 p.m.: 25.8 percent in Section C and 53.3 percent in Section D. Hence, it is considered that the deicing agent causes the transition from CS (immediately after snowfall) to SL/WB.

In Section D, SL/WB is high at 12:00, 2:00, and 4:00 p.m., and IF/IC is high at 8:00 and 10:00 a.m. This is due to freezing at night, showing that the refreezing of melted snow must be considered when using deicing materials.

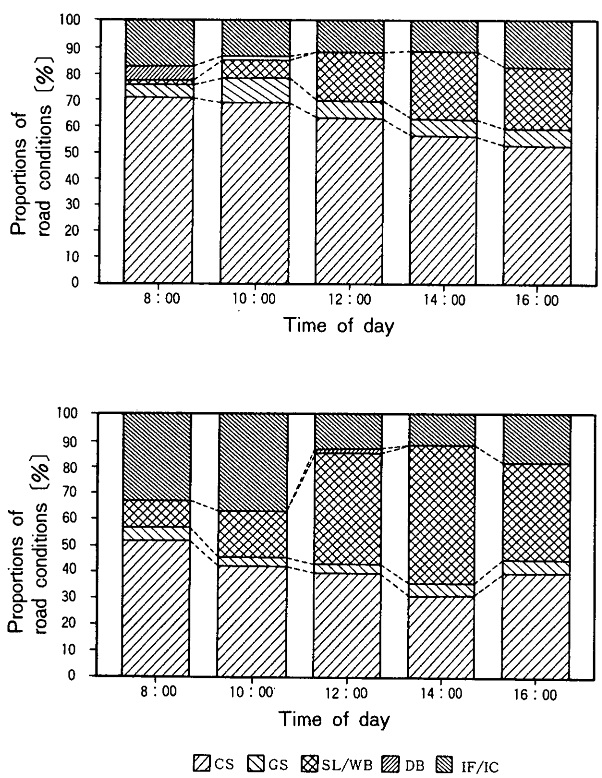

FIGURE 4 Proportions of snow and ice conditions on roads in Sections C (*top*) and D (*bottom*) throughout survey period.

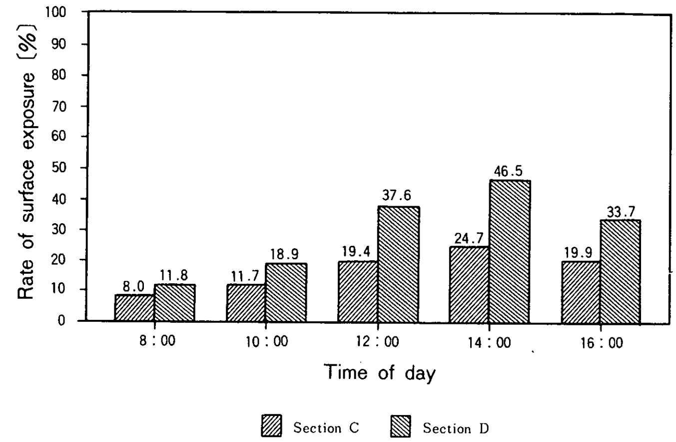

FIGURE 5 Rates of road-surface exposure in Sections C and D throughout survey period.

Road-Surface Exposure

The average surface exposure throughout the observation period is shown in Figure 5. It is seen that road-surface exposure in Section D is higher than in Section C, particularly from 10:00 a.m. to 12:00 p.m., when the difference increases sharply. The road surface exposures at 10:00 a.m. and 12:00 p.m. in Section C are similar to those at 8:00 and 10:00 a.m. in Section D. This suggests that the deicing mixture hastens the exposure of pavement surfaces.

IN SITU OBSERVATIONS

Reflectivity of Snow and Ice on Road Surfaces

Thawing and contamination of snow and ice were investigated by the reflectivity of the snow and ice on the road surface. Figure 6 shows the results on February 13. Reflectivity is low, and there is more contamination of snow and ice in Section D than in Section C. Reflectivity in Section C remains unchanged throughout the day. The contamination of snow and ice in Section D indicates acceleration of melting by the deicing materials.

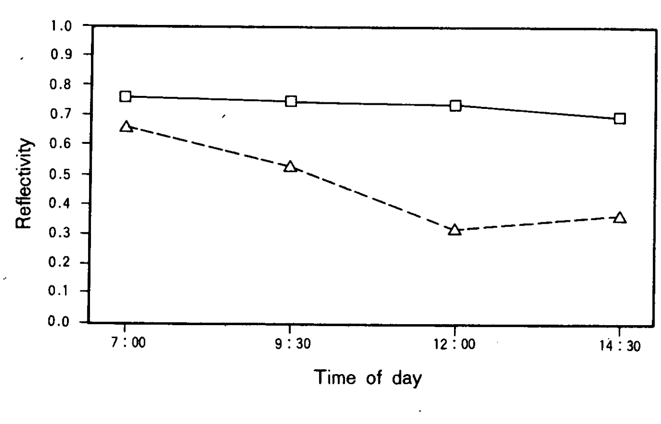

FIGURE 6 Reflectivities in Sections C and D during in situ survey (February 13, 1992).

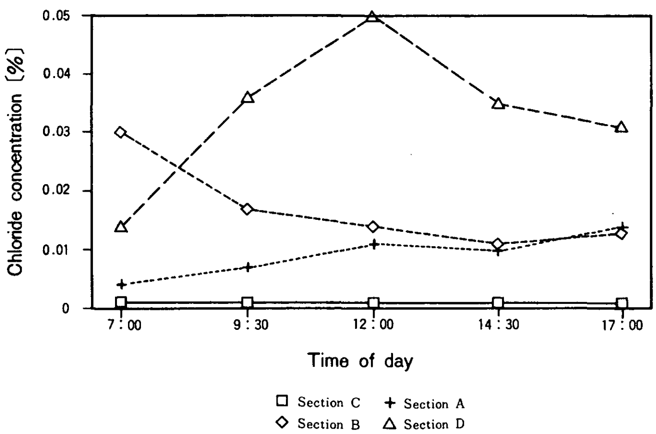

FIGURE 7 Chloride concentrations in Sections A through D during in situ survey.

Measurement of Chloride Concentration

Figure 7 shows laboratory test results on chloride concentration in snow and ice sampled from each section. Section D shows the highest concentration, followed by Sections B and A. Section C, without additives, showed no chloride concentration.

A regression analysis was done on chloride concentrations in snow and ice on the roads, surface temperatures, and electric capacitances as determined with a DPF. The results are given in Table 2. The analysis was conducted on all test-road sections and snow and ice conditions. The variance analysis of the regression for chloride concentration, surface temperature, and electric capacitance showed a highly significant $F0 = 27.38$ related to $F(2,54) = 5.04$ with 57 cases with a risk rate of 1 percent. The correlation coefficient R determined from the regression analysis was .71, which suggests that the concentration of chloride may be determined from the electric capacitance.

EVALUATION OF GENERATED DEICING EFFECT OF DEICING MIXTURE

Chloride concentration and electric capacitance were correlated; without deicing chemicals, no other element affected the electric capacitance. From the DPF data for Sections C and D, the effect of road-surface temperature and electric capacitance was evaluated. In Figure 8, the conditions of the road surface were classified into freezing state (excluding SL, WB, and DB) and SL/WB. The confidence interval of the data was 90 percent.

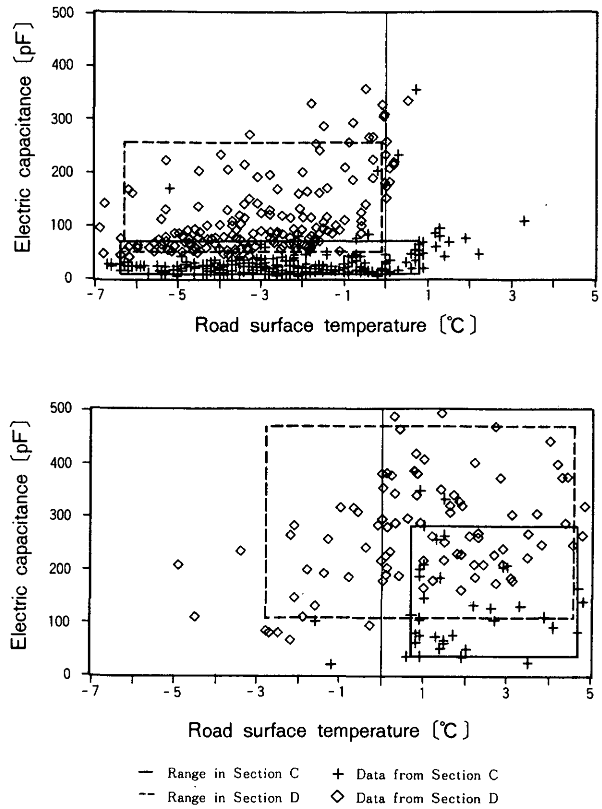

FIGURE 8 Ranges of freezing state (*top*) and SL/WB (*bottom*) in Sections C and D from DPF data.

The road-surface temperature range of the freezing state was −6.4 to 0.8°C (20.5 to 33.4°F) in Section C and −6.3 to −0.1°C (20.7 to 31.8°F) in Section D, indicating that the freezing state in Section D occurs at 1°C (1.8°F) lower than it does in Section C. The electric capacitance was between 9.0 and 70.0 pF in Section C and 49.5 and 256.3 pF in Section D, which indicates high electric capacitance in the snow and ice of Section D because of the deicing materials.

The road-surface temperature range of SL/WB was 0.7 to 4.7°C (33.3 to 40.5°F) in Section C and −2.8 to 4.6°C (27.0 to 40.3°F) in Section D, which indicates that SL/WB in Section D occurs at 3.4°C (6.1°F) lower than it does in Section C,

TABLE 2 Multiple Regression Analysis on Road-Surface Temperature, Chloride Concentration, and Electric Capacitance, and Analysis of Variance

Result of Multiple Regression Analysis		
Number of cases	Multiple correlation (=r)	R-Square 0.5035 (=r²)
57	0.7095	0.5035

Analysis of Variance	D.F.	Sum of Square	Mean Square	F-Value(F0)
Regression	2	1,166,020.00	583,011.00	27.38 ≥ 5.04=F(2,54)
Residual	54	1,150,030.00	21,296.80	
Total	56	2,316,050.00		

showing that freezing is restrained. The electric capacitance was between 34.3 and 280.3 pF in Section C and 107.8 and 468.8 pF in Section D, indicating high electric capacitance caused by deicing materials as in the freezing state.

In Section C the transition between the freezing state and SL/WB occurred at about 0.7 or 0.8°C (33.3 or 33.4° F). In Section D, the electric capacitances of the freezing state and SL/WB overlapped at between 100 and 250 pF with road surface temperatures of between −3 and 0°C (26.6 and 32.0°F). This is thought to occur when, and indicate that, the bond between snow and ice and pavement is broken. In such circumstances, snow can be removed quickly.

CONCLUSIONS

- Pavement with deicing material added leads to more slushy and wet bare road conditions, resulting in higher road-surface exposure rates. However, refreezing of thawed snow must be considered.
- Chloride concentration, road-surface temperature, and electric capacitance are correlated, and chloride concentration may be determined from the electric capacitance.
- The minimum surface temperature of slush and wet bare road conditions was about −3°C (26.6°F) in Section D, with deicing pavement, and 1°C (33.8°F) in Section C, without deicing pavement.
- Deicing pavement enables faster snow removal because of the destruction of the bond between snow and ice and the pavement surface, even though snow and ice conditions remain.

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