SNOWY AND ICE ROAD COUNTERMEASURES USING ANTI-FREEZING ADMIXTURE

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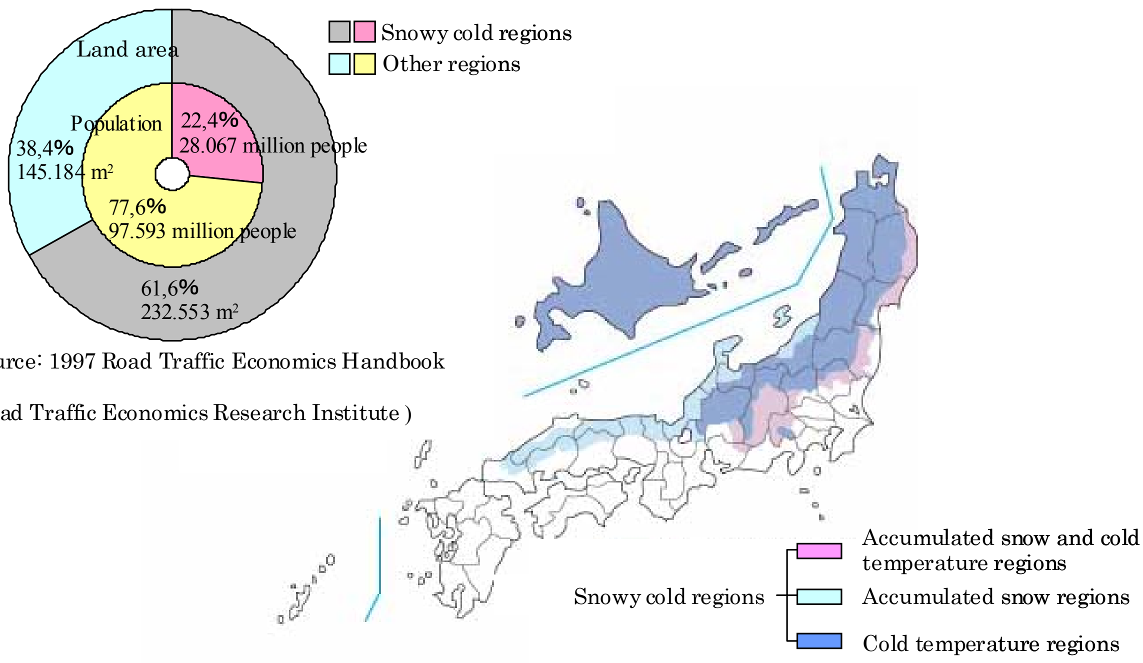
1. Outline

Because the approximately 60% of the national land of Japan that is in special cold snowy regions that are home to approximately 20% of the country's population is subject to road disasters and traffic accidents caused by accumulated snow and road icing, guaranteeing safe and smooth winter road traffic in these regions is a major challenge facing the national government.

The recent spread of studless tires has resolved the problem of dust produced by spike tires. On the other hand, it has resulted in the appearance of slippery road surfaces and new problems with winter road traffic: the rising frequency of traffic accidents at intersections among them. Anti-freezing admixtures are spread as a measure to deal with these problems, but as the volume of winter traffic has risen and in response to public needs, the quantity of



Special snowy cold regions are regions where, "The cumulative annual average of the maximum accumulated snow depth in February is 50 cm or more, or the cumulative annual annual mean air temperature in January is 0° C or lower."

Figure 1. Special cold snowy regions in Japan

anti-freezing admixture spread has also increased and this measure now accounts for a large portion of snow removal costs. Concern with its effects on roadside environments and structures has also appeared.

This report presents change over a period of years in the quantity of anti-freezing admixture spread in the region under the jurisdiction of the Tohoku Regional Bureau and in the anti-freezing admixture spreading cost share of total snow removal expenses. It also reports on the results of the test spreading of anti-freezing admixture in a model region and on the state of development of non-chloride anti-freezing admixtures that inflict little salt damage and provide long-lasting effects to be used to replace the chloride type anti-freezing admixtures that are the major type now in use.

2. Quantity of anti-freezing admixture spread and the anti-freezing admixture spreading cost share of total snow removal expenses

Figure 2 shows the quantity of anti-freezing admixture spread and the anti-freezing admixture spreading share of total snow removal expenses in the region under the jurisdiction of the Tohoku Regional Bureau. Because the Law for the Prevention of Spike Tire Dust was announced in June 1990 and the use of spike tires by all motor vehicles including large trucks prohibited in restricted districts beginning in April 1993, the quantity spread has risen every year regardless of continued light snow. During the past 11 years, the quantity spread peaked in 1999 at a level approximately 3.6 times as high as that for 1989. And although the cost of chemical spreading was 16% of total snow removal expenses in 1989, it had risen to 38% by 1999. It is assumed that the same trend occurred throughout Japan.

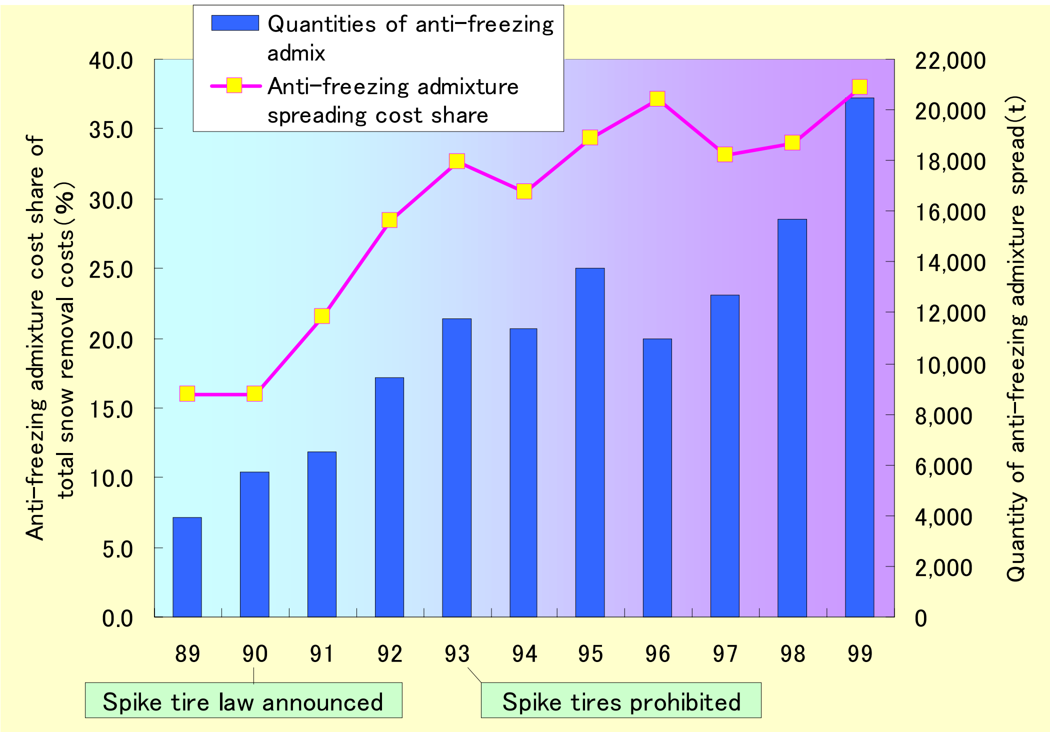


Figure 2. Quantity of Anti-icing Chemical Spread and Anti-icing Chemical Spreading Cost Share of Total Snow Removal Costs

(Source: documents from the Tohoku Regional Bureau)

3. Anti-freezing Admixture Spreading Test on an Actual Road

During this test that was performed on National Highway No. 18 from 20:00 in the evening of January 20 to 8:00 in the morning of January 22, 2000, sodium chloride (NaCl) was spread in one section while CMA40 (a 41:59 mixture of NaCl with calcium magnesium acetate) was spread in another section to evaluate the effectiveness of the spreading in the two sections as the skid friction coefficient during 100% braking.

3.1 Meteorological and road surface conditions

Figure 3 shows changes over time of the hourly snowfall, road surface temperature, and the thickness of the snow and ice on the road surface. No difference in the thickness of snow and ice on the road surface caused by a difference in the kind of anti-freezing admixture spread was observed from the time that the snowfall was 0 cm or from 11:00 in the morning of January 21 when intermittent snowfall was falling until 6:00 in the morning of January 22, but in contrast to this, from 22:00 on January 20 immediately after start of the test until 10:00 in the morning of January 21—a period when snow removal vehicles were dispatched frequently—the snow and ice in the CMA40 spreading section was thicker than that in the NaCl spreading section. In the results of a questionnaire survey of 12 operators driving snow graders and snow removal trucks, more than 80% of the operators answered that more snow and ice remained after removal by the graders and that it was more difficult to remove it from the surface in the CMA40 spreading section than in the NaCl spreading section.

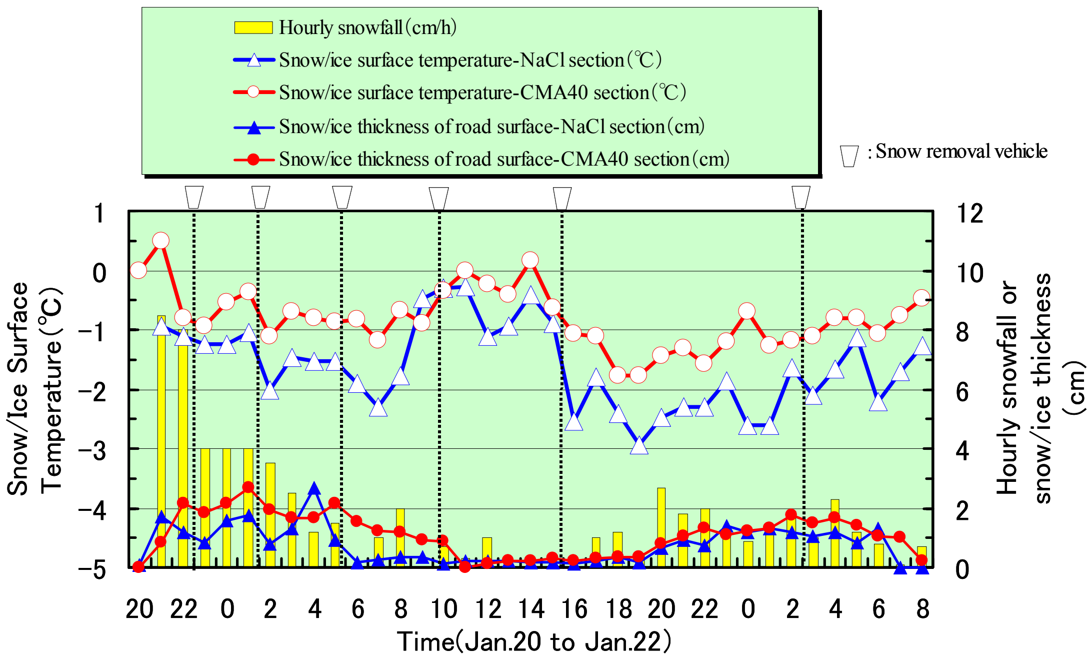


Figure.3 Field Test Results (Route 18, Outbound Lane)
Change Over Time of Hourly Snowfall, Snow/Ice Surface Temperature, and Snow/Ice Thickness of Road Surface

3.2 Skid friction coefficient and residual anti-freezing admixture

Figure 4 shows change over time in the skid friction coefficient (during 100% braking) and the quantity of residual anti-freezing admixture on the traffic lanesurface. The anti-freezing admixture was spread 9 times in the NaCl section and 4 times in the CMA40 section. The quantity of residual anti-freezing admixture on the road surface was obtained by a light refraction type salt concentration meter, and to simplify catching local characteristics, a quantitative evaluation was not achieved with only a single yardstick used. The skid friction coefficient was between 0.19 and 0.47 in the CMA40 section and was between 0.21 and 0.47 in the NaCl section, and varied by between 0.1 and 0.15 according to the time. But overall the skid friction coefficients in the two sections were similar with no clear difference observed.

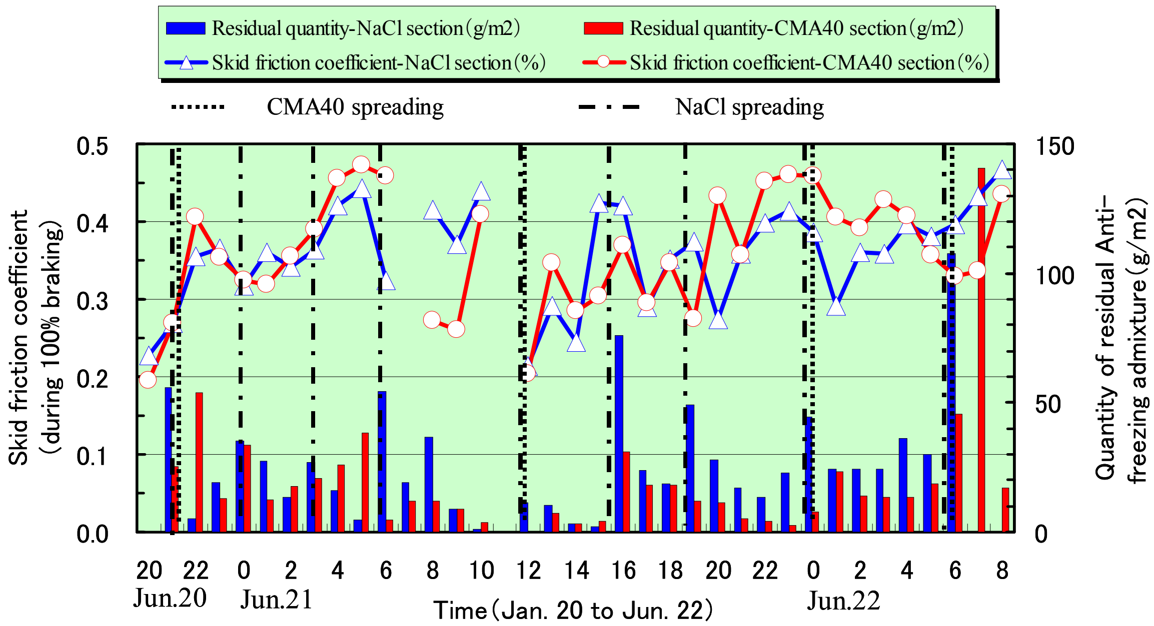


Figure.4 Results of Field Test (Route 18, Outbound Lane)
Change Over Time of Skid Friction Coefficient and Quantity of Residual Anti-freezing admixture

4. Development of non-chloride anti-freezing admixtures

Because the quantity of anti-freezing admixtures used is increasing steadily, its use threatens to harm roadside environments and structures. Therefore, new anti-freezing admixtures that do not cause chloride damage are being developed. This section describes the results of laboratory evaluations of various chemical compounds and newly developed non-chloride anti-freezing admixtures.

4.1 Results of laboratory evaluations of various compounds.

4.1.1 Quantity of ice melted test results

Table 1 presents 11 kinds of material used for the laboratory evaluations. The quantity of ice melted was measured in a low temperature experimental chamber with a temperature of -5°C. Distilled water was placed in a plastic vessel to make ice, then 5 g of each material were spread on its surface and the quantity of ice melted was measured as time passed. The quantity spread per unit of area was equivalent to 370g/m^2.

Table 1. Materials used for the laboratory evaluation tests

No.	Type	Form
1	Sodium chloride	Solid
2	Calcium chloride (dehydrate)	Solid
3	Calcium magnesium acetate + sodium chloride	Solid
4	Urea + sodium chloride	Solid
5	Sodium acetate	Solid
6	Potassium acetate	50% solution
7	Calcium magnesium acetate	Solid
8	Calcium magnesium potassium acetate	Solid
9	Urea + sodium acetate	40% solution
10	Urea	Solid
11	Sodium formate	Solid

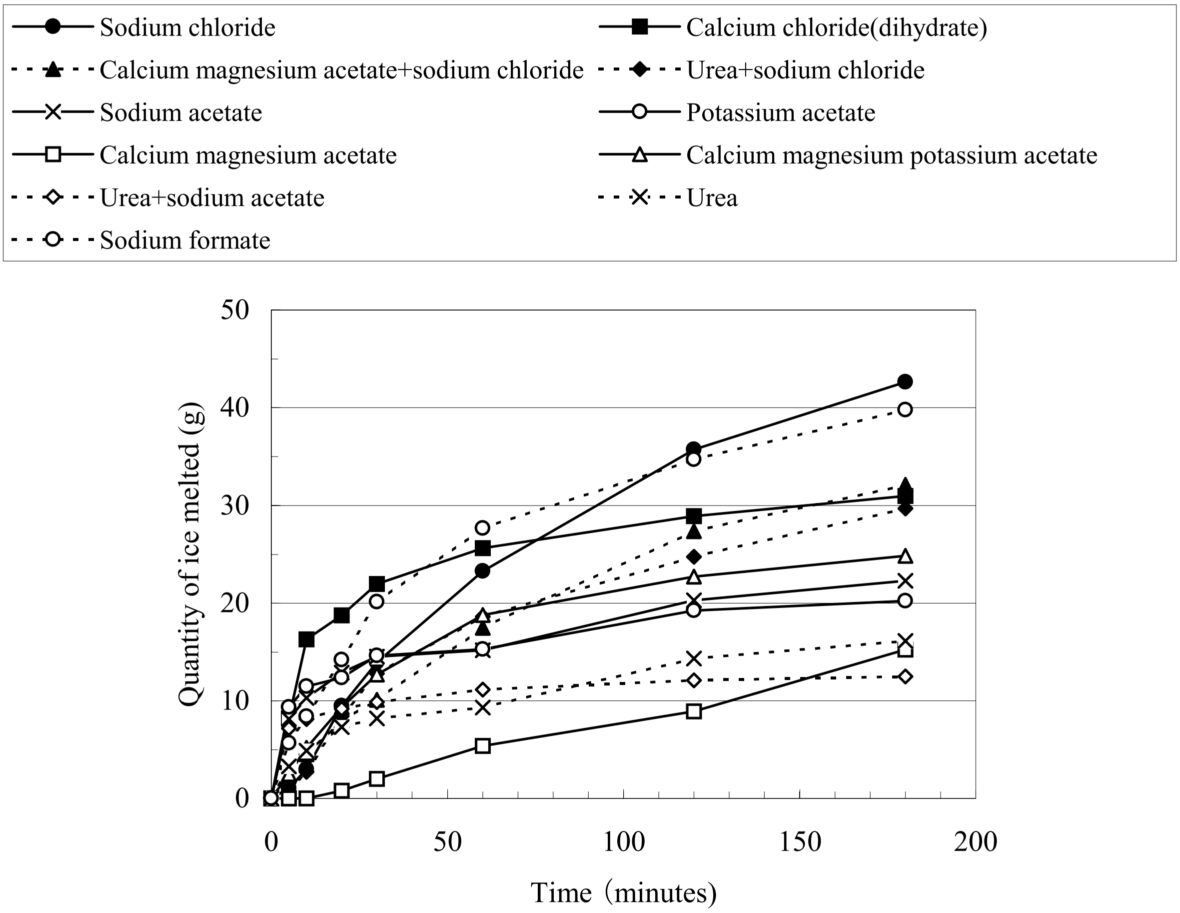


Figure 5. Results of measurement of quantity of ice melted (-5℃、5g)

Figure 5 shows the results of the measurement of the quantity of ice melted. Calcium chloride melted the most for the first 30 minutes after spreading, but it peaked at 60 minutes. After 60 minutes, sodium chloride melted the most ice. Among the non-chloride chemicals, sodium formate provided the best ice melting capability that is considered equal to that of the chloride compounds. The next best melting capability was that provided by mixtures containing chloride compounds. The results confirmed that the ice melting capability of sodium acetate, of potassium acetate, and that of calcium magnesium potassium acetate are all equivalent to compounds including chloride. This test showed that the ice melting capability of urea and of calcium magnesium acetate are both relatively low.

4.1.2 Steel plate corrosion test results

Corrosion testing using steel plate (JIS G 3141 cold rolled steel plate) was performed. Solutions with a concentration of 1mol/1 of each of the chemical agents listed in Table 1 were prepared. The steel plates were alternately submerged for 12 hours in the chemical solutions then left standing in the atmosphere of the laboratory for another 12 hour period. These alternating steps were continued for 7 days (7 cycles), then the products of the corrosion were dissolved with a weak acid and the weight loss of the steel plate was measured.

Figure 6 shows the steel plate corrosion rates obtained. The corrosion rates of the sodium chloride and calcium chloride were between 80 and 90 mdd. Among the mixtures including a chloride substance, the corrosion rate of the mixture of urea and sodium chloride was highest at 130 mdd. The corrosion rate of the sodium formate was about 40 mdd, that is approximately equal to that of the chemical made by mixing calcium magnesium acetate with sodium chloride. Those containing only an acetate compound caused almost no corrosion.

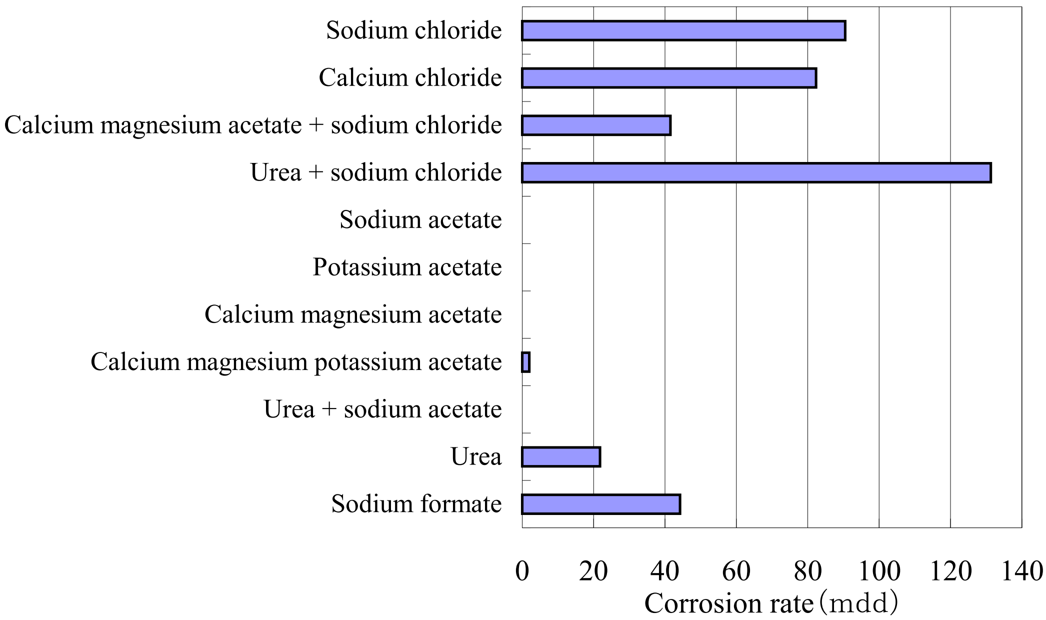


Figure 6. Steel plate corrosion test results

4.2 Non-chloride anti-freezing admixtures

The above laboratory evaluation results show that the non-chloride chemical with the highest ice melting capability was sodium formate that has a relatively small molecular weight, but concerns remained regarding its metal corrosiveness, environmental safety, and stability of supplies of this chemical. Based on an overall judgement, acetate compounds are the most suitable candidates for use as non-chloride anti-freezing admixtures. The non-chloride anti-freezing admixtures with acetate compounds as their principal constituents shown in Table 2 were trial manufactured, and the products used for the spreading experiment described in the next section of this report.

Table 2. Non-chloride anti-icing chemical candidates

Code	Principal constituents	Form
A	Calcium magnesium acetate	Solid
B	Calcium magnesium sodium acetate	Solid
C	Calcium magnesium potassium acetate	Solid
D	Sodium acetate	Fluid
E	Sodium acetate, calcium magnesium acetate	Solid
F	Sodium acetate	Solid
G	Potassium acetate	Fluid

5. Field verification tests of non-chloride anti-freezing admixtures

Field verification tests of the effects of spreading both existing chloride compound type anti-freezing admixtures and non-chloride anti-freezing admixtures on a street in Arai City were performed five times in order to develop practical anti-freezing admixtures that provide sustained effectiveness and have little harmful impact on the environment. This section reports on the results of the "Fifth field verification test" performed to study the effects of advance spreading.

5.1 Outline of the tests

Table 3. Testing Dates

Time	Observations	Survey dates and times (24-hours clock time)	Total Survey Time (Hours)	Weather Conditions
First	Began	17:00, Feb. 12,2001	12.0	Cloudy
	Ended	5:00, Feb. 13,2001		
Second	Began	20:00, Feb. 15,2001	9.0	Clear, later cloudy
	Ended	5:00, Feb. 16,2001		
Third	Began	17:00, Feb. 25,2001	13.0	Snow, later cloudy
	Ended	6:00, Feb. 26,2001		
Fourth	Began	14:00, Feb. 26,2001	9.5	Snow, later clear
	Ended	23:30, Feb. 26,2001		
Fifth	Began	15:00, March 11,2001	14.0	Snow, later clear
	Ended	5:00, March 12,2001		
		Totals	57.5	

The tests were performed during the time periods shown in Table 3 on the Tokaichi-Nagamori Road that is a city road in Arai City in Niigata Prefecture. The effects of spreading anti-freezing admixtures (two chloride chemicals (sodium chloride and calcium chloride) and seven non-chloride chemicals(acetate compounds A to F)) in this section were evaluated based on the results of measurements of the skid friction coefficient by a road surface skid measurement vehicle and on the results of measurements by field observers (of snow/ice surface temperature, concentration of the residual chemical on the road surface, appearance of the road surface, etc.).

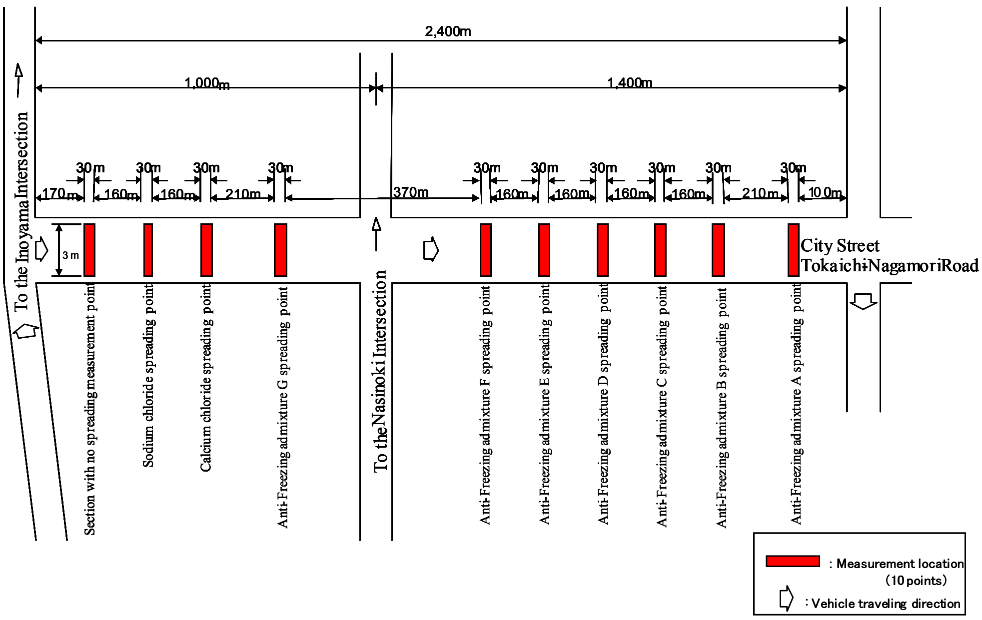


Figure 7. Measurement Locations (10 points) and Spreading Sections for the Field Verification Test

The tests began in the evening and ended in the morning while the Arai City street, Tokaichi-Nagamori Road was closed to traffic. The measurements of the skid friction coefficient by the road surface skidding measurement vehicle were done every hour at the measurement locations where the 9 chemicals were spread as shown in Figure 7. And assuming that passing traffic agitates anti-freezing admixtures that have been spread, five standard passenger cars were continually driven in a single direction through the test section (2.4 km) during the test preparation period and during a period extending from the start to the end of each test. The quantity of anti-freezing admixtures spread was set at 40 g/m^2. During the fifth field verification test (advance spreading effects test), because of a shortage of the test material for anti-icing section D, it was not spread and this section was treated as a non-spreading section where only the friction coefficient was measured.

5.2 Test results

5.2.1 Meteorological conditions and road surface conditions

When the fifth field verification test (advance spreading effectiveness test) was performed on March 11, an intermittent light snowfall of less than 1 cm/hour began just after the start of the test at 17:00 and ended at 22:00, but the sky cleared and after it did, radiation cooling dominated. The air temperature was – 0.2°C shortly after the test was started at 17:00, but as time passed, it decreased, reaching – 4.5°C when the test was ended at 4:00 in the morning of the next day.

(1) Road surface temperature

The road surface temperature was 0°C to 1°C in all sections of the road at 17:00 before the anti-freezing admixture spreading, but as time passed, it fell, apparently following the change in the air temperature during the test period. The road surface temperature in the sodium chloride section fell far lower than the road surface temperature in the other sections at 18:00 after the anti-freezing admixture was spread as a result of the action of a decline of the freezing point.

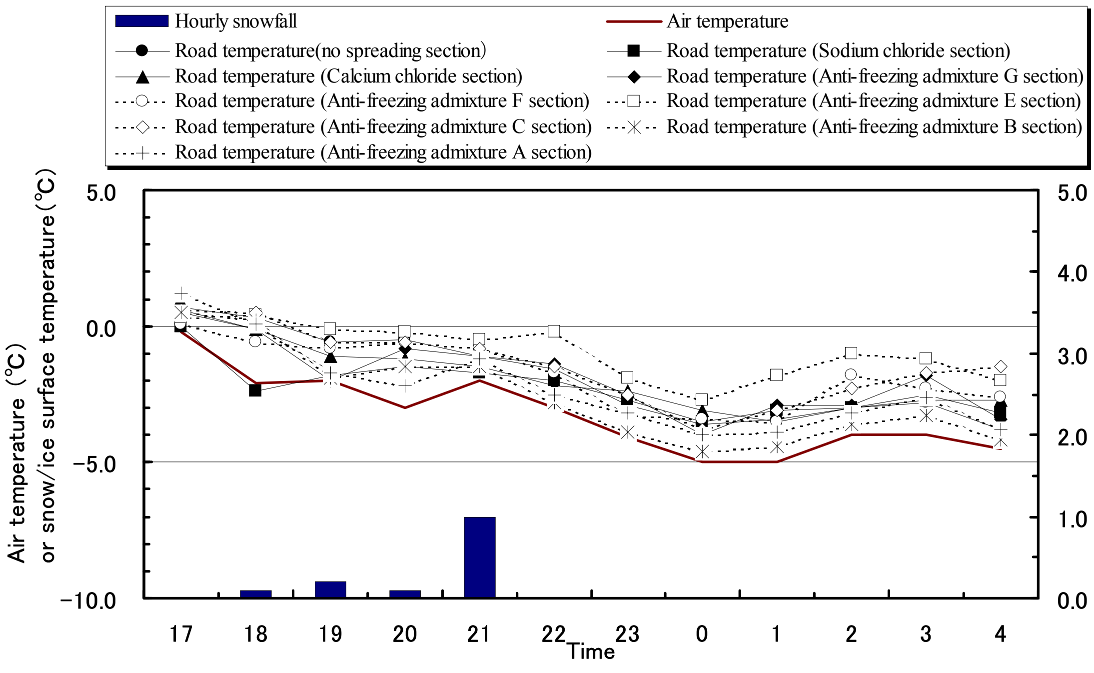


Figure 8. Change Over Time of the Air Temperature,Hourly Snowfall and Snow/Ice Surface Temperature (17:00 on March 11 to 4:00 on March 12)

(2) Road surface condition

For two hours after the test began, the road surface in the section where no chemical was spread was wet in both the parts with ruts and the parts without ruts, but as the air temperature and road surface temperature both declined, ice and snow formed on the surface. In the sections where anti-freezing admixtures were spread, differences were observed in the road surface condition between parts with ruts and parts without ruts, but the wet condition tended to continue for about two hours longer than it did in the section where no anti-freezing admixture was spread. The depth of the snow and ice in the parts with ruts was between 0 and 0.5 cm.

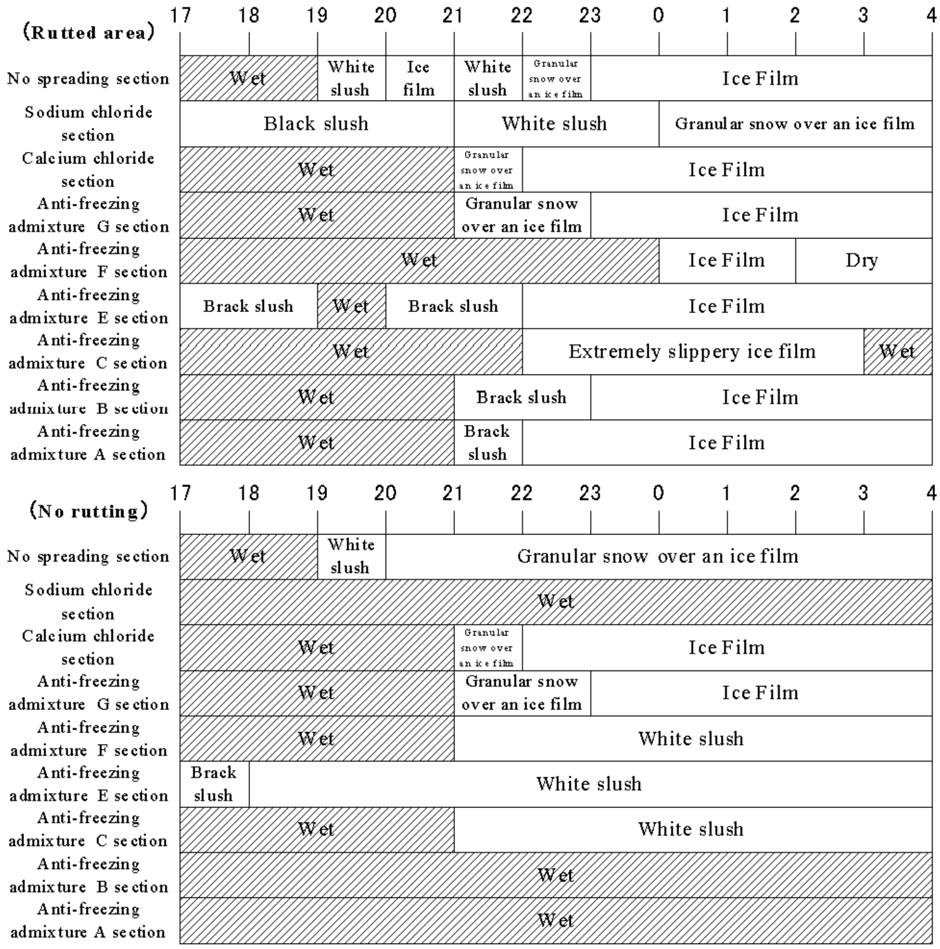


Figure 9. Change Over Time of Road Surface in Sections With Rutting and No Rutting
(17:00 on March 11 to 4:00 on March 12)

(3) Skid friction coefficient

The skid friction coefficient in the sections where no chemicals were spread was between 0.41 and 0.74 under the wet condition that continued for about 2 hours after the start of the test, but it was between 0.14 and 0.30 after the road surface condition changed to snow and ice cover. In the sections where anti-freezing admixtures were spread on the other hand, scattering appeared between the different sections, but it was between 0.29 and 0.78, and maintained a skid friction coefficient between 0.15 and 0.48 higher than that measured in the section without chemical spreading.

The results of the test performed to evaluate the effectiveness of advance spreading revealed that in contrast to the steep decline in the skid friction coefficient accompanying icing caused by the falling road surface temperature in the sections without chemical spreading, in sections where the acetate compound type non-chloride anti-freezing admixtures

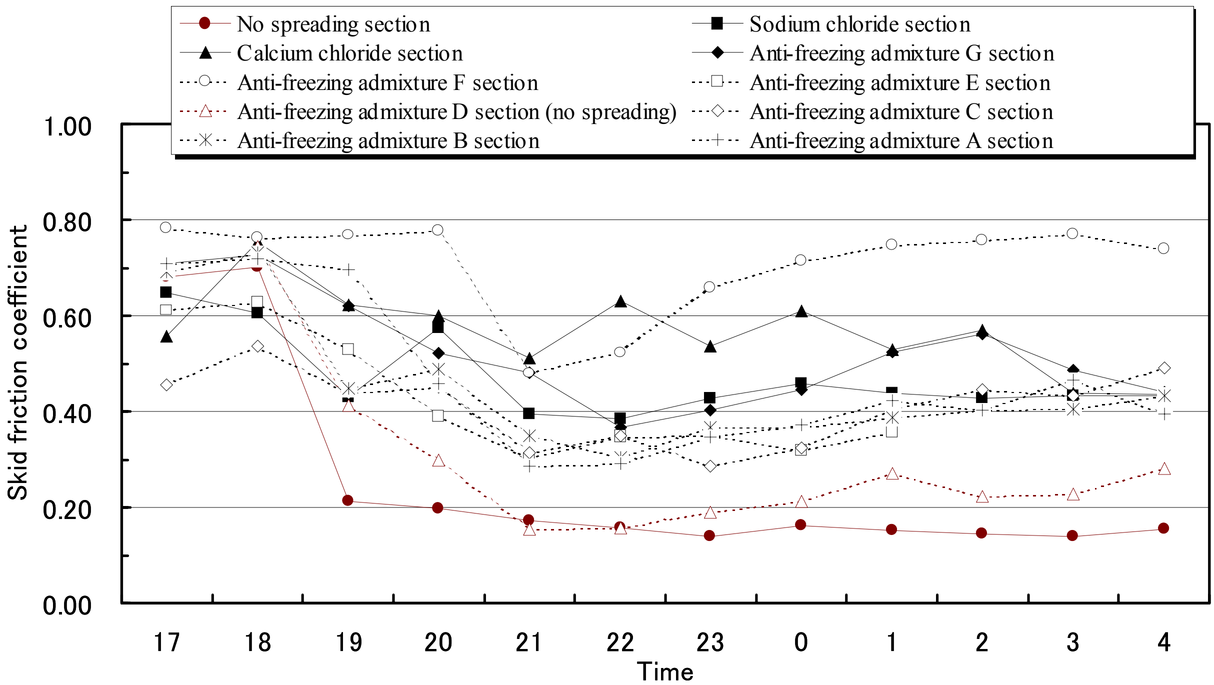


Figure 10. Change Over Time of the Skid Friction Coefficient (17:00 on March 11 to 4:00 on March 12)

were spread, this spreading guaranteed a skid friction coefficient equal to that in the sections where existing chloride type anti-freezing admixtures were spread. These test results were obtained under limited meteorological and road surface conditions, so it is necessary to accumulate data for various kinds of meteorological and road conditions. It is also necessary to conduct future studies of the spreading of non-chloride Anti-freezing admixtures that account for their effects on road structures and roadside environments.

6. Summary

Since the 1990 prohibition of the use of spike tires, the quantity of anti-freezing admixture spread to guarantee safe winter road traffic in Japan has risen steadily. The principal chemicals used for this purpose have been sodium chloride and calcium chloride, because they are the most effective and economical available. The appropriate use of these chemicals is an extremely effective winter road traffic safety measure. Because in heavy snowfall regions, anti-freezing admixture that has been spread on the roads is removed along with snow during the frequent snow removal operations performed in these regions, in order to limit the rise in the quantity spread, it is necessary to clarify the actual state of the spreading of anti-freezing admixture in order to study and develop more effective and more efficient spreading methods.

With regards to non-chloride anti-freezing admixture, the effectiveness of acetate compounds in advance spreading has been confirmed, but it is necessary to continue to evaluate their effectiveness by studying more cases where road surface conditions and meteorological conditions differ.