STUDY ON A SALTING STRATEGY THAT CONSIDERS PAVEMENT TYPES

S. TANAKA, N. TAKAHASHI & R. ABE
Civil Engineering Research Institute for Cold Region, Japan
s-tanaka@ceri.go.jp

K. TAKEICHI
Department of Civil & Environmental Engineering, Hokkai-Gakuen University, Japan
takeichi@cvl.hokkai-s-u.ac.jp

ABSTRACT RÉSUMÉ

This study aims to establish an effective salting strategy that takes pavement type into account. To this end, we quantitatively clarified sliding-resistance performance of rough-surface pavement on mitigating slippery, icy road surfaces and on enhancing salting effectiveness. We made tests with a laboratory wheel-tracking test machine on ice to assess the coefficient of sliding friction and the bare pavement ratio (hereinafter: BPR) of rough-surface pavement. The test results are as follows. 1) Rough-surface pavement is expected to have superior sliding-resistance performance to dense-graded asphalt mixture pavement. 2) The high sliding-resistance performance of rough-surface pavement is attributed to water drainage and the roughness on the surface, and those effects are highly temperature dependent. 3) The coefficient of sliding friction on rough-surface pavement is increased by repeated salting and wheel passages. These results show that winter road management can be made more efficient BPR and effective by incorporating pavement types into salting strategies.

1. INTRODUCTION

In snowy cold regions, salting is the primary measure against icy road surfaces and an important measure to secure safe and smooth winter road traffic [1]. However, due to recent government budget constraints, further improvements of winter road management efficiency and effectiveness are required.

In Japan, the amount of salt applied in winter road management leaped in 1991, when the use of studded tires was banned [2],[3]. Rough surface pavement, such as drainage pavement and high-performance stone mastic asphalt (hereinafter: high-performance SMA), has been installed on road to increase the surface sliding friction [2]. These types of pavement have been proven by laboratory, outdoor track tests and field tests to have high sliding-resistance performance [4],[5]. However, few studies have addressed the combined effect of salting on rough surface pavement. In addition, salt application is often based on qualitative criteria [1].

In light of this, we have been making studies toward establishing salting methods that take pavement types and their characteristics into account.

In this study, we used a laboratory wheel-tracking test machine on ice owned by the Hokkai-Gakuen University (Figure 1)[6] to make two tests: 1) a water sprinkling and freezing test, to assess the extent to which rough-surface pavement increases the sliding friction, and 2) a salt application test on icy pavement surfaces, to assess the effect of salting on sliding resistance performance. The coefficient of sliding friction, the thickness of the ice and BPR were measured to assess how salting and rough surface pavement, in combination, affected the sliding resistance performance.

In this study when comparing two pavements, the pavement condition that archives a higher coefficient of sliding friction, a higher BPR and a thinner ice thickness is defined as having "higher sliding-resistance performance" than other pavement.

Figure 1 - Laboratory wheel-tracking test machine on ice

2. TEST PAVEMENT

We tested three pavements: dense-graded asphalt mixture pavement, drainage pavement (void ratio: 17%) and high-performance SMA. The second and third types of pavement afford high coefficients of sliding friction due to their rough surface texture.

Drainage pavement whose surface layer is made using a high void ratio mixture provides rough surface texture and high permeability [5] (Figure 2). High-performance SMA has the advantages of the rough texture of drainage pavement and the durability of stone mastic, but it is not permeable (Figure 3).

Table 1 shows the specifications of the test pavements. Measurements were taken by the laboratory wheel-tracking test machine and a circular texture meter. The coefficients of sliding friction are the average of three measurements, and the mean profile depths (MPD) are the mean values at the four measurement locations.

Figure 2 - Cross-section of drainage pavement [5]

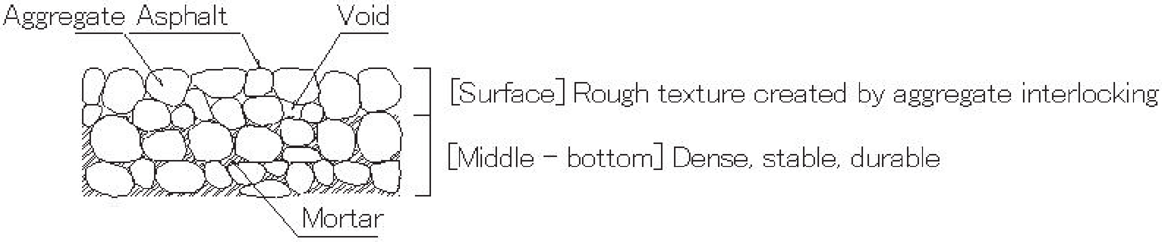

Figure 3 - Cross-section of high-performance SMA [5]

Table 1 - Specifications of test pavement

Test pavement		Dense-graded	Drainage	High-performance SMA
Coefficient of sliding friction (μ)	Dry surface	0.78	0.77	0.76
	Wet surface	0.75	0.57	0.62
Surface texture (MPD)		0.68mm	2.07mm	1.75mm

3. SPRINKLING AND FREEZING TEST

We made the icy pavement surface by sprinkling water on the pavement surface and causing it to freeze. Using the measured data, we clarified the changes in sliding-resistance performance by type of pavement, amount of sprinkled water, number of wheel passes and temperature.

Equation (1) gives BPR.

BPR (%) = area of exposed pavement surface / area of analyzed image (1)

A thin, transparent layer of ice on the pavement surface is difficult to recognize. In this study, we used laminated polystyrene and white permanent markers [6] to facilitate the clear recognition of the exposed pavement area for calculation.

To calculate the coefficient of sliding friction, it is necessary to know the torque. The mean value of wheel torque measured along the 4 m section at the center of the lane was used for calculations.

3.1. Test conditions

Table 2 shows the test conditions. The tests were made at temperatures of -3, -5 and -8 degrees Celsius. We made a test when the road surface temperature is the same as the air temperature.

Water was sprinkled at 0.5 l/m^2 per sprinkling operation. The braking tests were made under the following two conditions: 1) measurement after water sprinkling and 300 wheel passes, and 2) measurement 30 min. after water sprinkling without any wheel passes. For each condition, we repeated the procedure and measurement five times.

Table 2 - Conditions of the water sprinkling and freezing test

Test pavement	Dense-graded, drainage, high-performance SMA		
Test temperature	-3 degrees C.	-5 degrees C.	-8 degrees C.
Water applied per sprinkling operation	0.5 l/m^2		
Wheel passes	0 passes (measured 30 min. after water sprinkling), 300 passes		
Number of tests (water sprinkling, repeated wheel passes, braking)	5 tests		
Wheel traveling velocity	Repeated wheel tracking test: 5 km/h; braking test: 10 km/h		
Wheel load	5 kN (ground contact pressure: 0.196 MPa)		

3.2. Test results

Figures 4 through 9 show the test results. For the rough-surface pavement, the coefficient of sliding friction and BPR decreased with increases in water sprinkling operations. However, for the dense-graded asphalt mixture pavement, the coefficient of sliding friction was around 0.1 for the entire test and little exposure of the pavement surface was observed.

The drainage pavement had higher coefficients of sliding friction and BPRs than the high-performance SMA did. This may be attributed to the superior permeability of drainage pavement, relative to high-performance SMA. The permeability of drainage pavement measured by onsite permeability test [8] was 1300 ml/15 sec. at normal temperature.

Because of the high permeability, less water was left on the drainage pavement surface than on the high-performance SMA surface; consequently, the drainage pavement had superior sliding-resistance performance than the high-performance SMA did.

Regarding the influence of temperature, when the test temperature was lower, fewer water sprinkling operations were needed to reach a coefficient of sliding friction of 0.1 on the rough surface pavement. (The coefficient of sliding friction of 0.1 is the value that the dense-graded asphalt mixture pavement reached after one or two water sprinkling operations.) Rough surface pavement affords higher sliding-resistance performance than dense-graded asphalt mixture pavement because the former is superior to the latter in permeability and rough surface texture. However, when the temperature becomes lower, the sliding-resistance performance becomes lower. It is attributed to the shorter time taken for the water on the road surface to freeze under lower temperature.

Regarding the influence of changes in the number of wheel passes, regardless of pavement type, both the coefficient of sliding friction and the rough surface exposure ratio were higher without wheel passes than for 300 passes. The reason is considered to be as follows: Water that adhered to the wheel when it traveled on pavement immediately after water sprinkling returned to the pavement surface when the wheel passed on the pavement. The water became a thin ice layer on the pavement and masked the roughness of the surface texture. In contrast, when there were no wheel passes, no additional water was supplied to the pavement surface. This difference is regarded as the reason for the lower sliding-resistance performance of the test with wheel passes than that of the test without wheel passes.

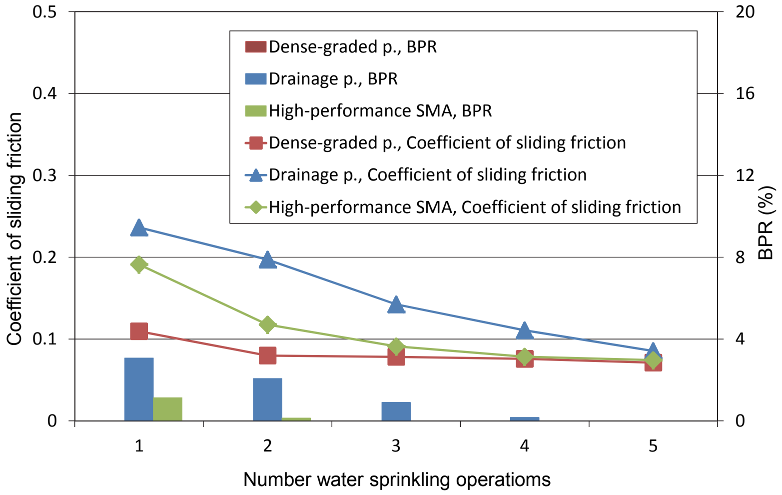

Figure 4 - Test results with air temperature of -3 degrees Celsius and 300 wheel passes

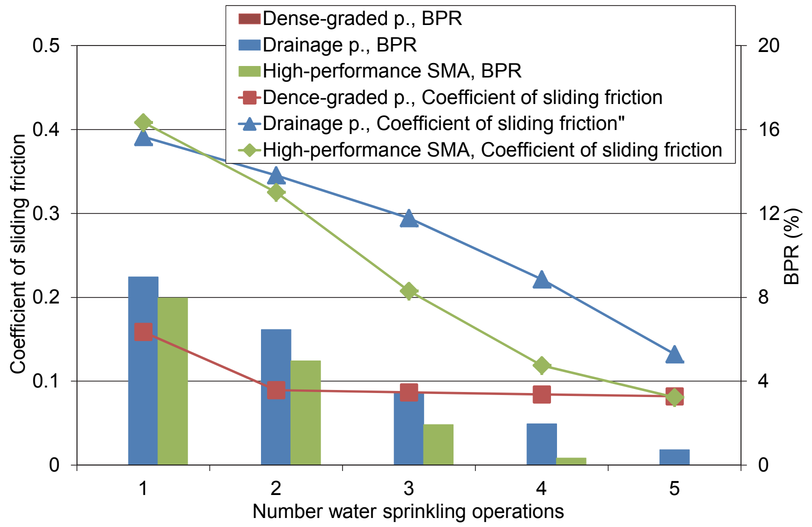

Figure 5 - Test results with air temperature of -3 degrees Celsius and no wheel passes

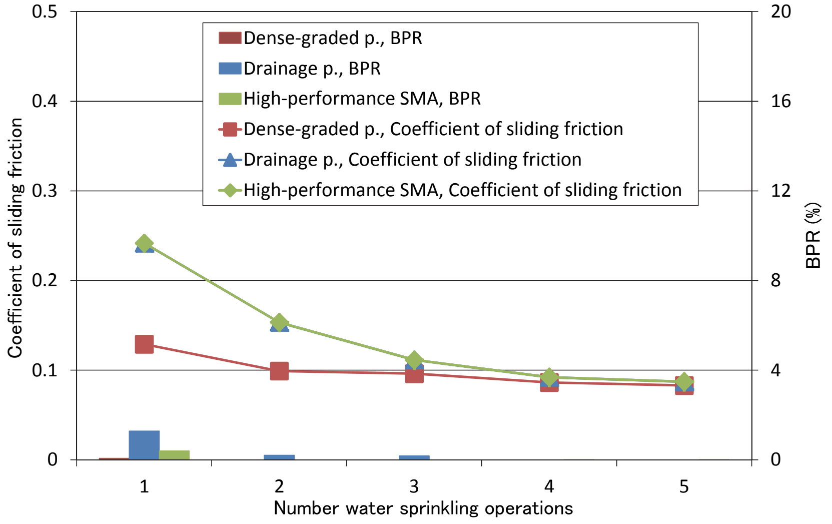

Figure 6 - Test results with air temperature of -5 degrees Celsius and 300 wheel passes

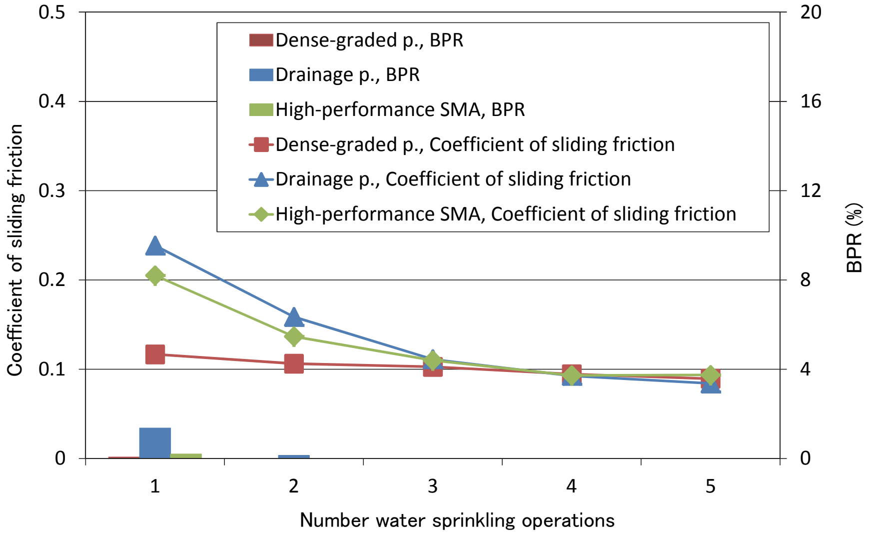

Figure 7 - Test results with air temperature of -5 degrees Celsius and no wheel passes

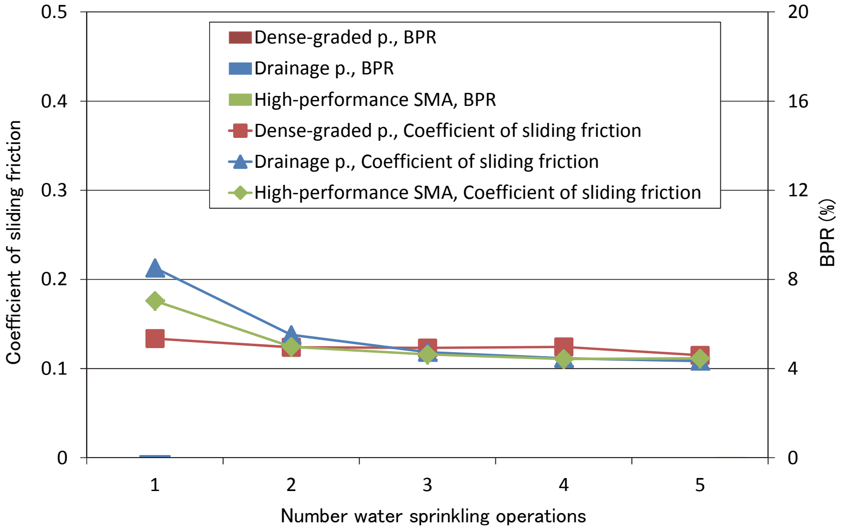

Figure 8 - Test results with air temperature of -8 degrees Celsius and 300 wheel passes

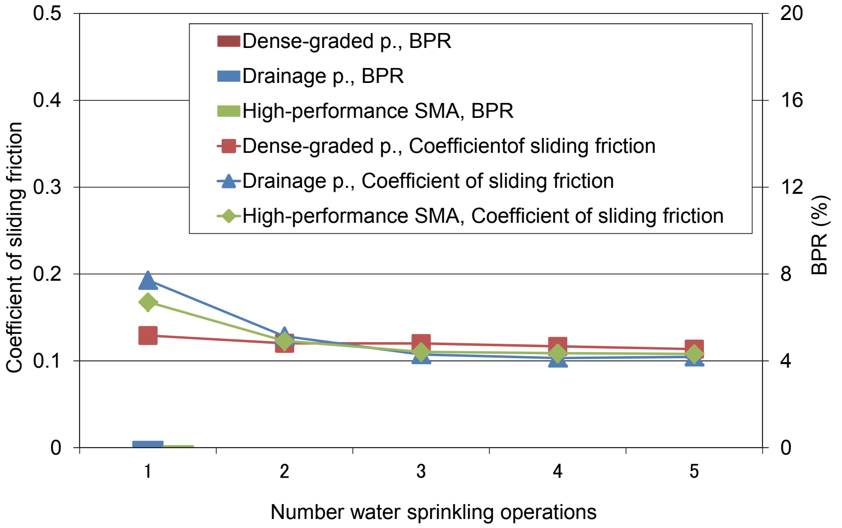

Figure 9 - Test results with air temperature of -8 degrees Celsius and no wheel passes

4. SALTING TEST

In this test, first we made the icy pavement surface. Then, we applied salt and conducted the wheel tracking tests. We measured the coefficient of sliding friction, BPR and the ice thickness for each type of pavement to clarify the effectiveness of salting.

This test assumes the winter road maintenance conditions of ice control by salting after road surface icing.

4.1. Test conditions

Table 3 shows the conditions of the salting test. The test temperature was set at -5 degrees Celsius. Ice layer was made by sprinkling water at 2.0 l/m^2. Wet salt (sodium chloride) was used for salting, with an application rate of 20g/m^2. The wet salt was made by mixing solid salt with a salt solution. The mixing ratio, by mass, of solid salt to salt water was 9:1. Wheel passes were repeated up to 2,000 passes.

Table 3 - Conditions of salting test

Test pavement		Dense-graded, Drainage, High-performance SMA
Test temperature		-5 degrees C.
Road surface conditions		Icy pavement surface Amount of sprinkled water: 2.0l/m^2
Salt		NaCl 20g/m^2 applied wet
Test item	Road surface exposure ratio	Measured at 100, 300, 500, 1000, 1500 and 2000 wheel passes
	Sliding friction coefficient	Measured at 500 and 2000 wheel passes (braking test)
	Thin layer of ice (black ice)	Measured at 100, 300, 500, 1000, 1500 and 2000 wheel passes
Wheel traveling velocity		Repeated wheel tracking test: 5 km/h Braking test: 10 km/h
Wheel load		5 kN (ground contact pressure: 0.196 MPa)

4.2. Test results

Figure 10 gives BPR by number of wheel passes, and Figure 11 gives the coefficients of sliding friction measurements.

Regardless of pavement type, BPR increased with increases in the number of wheel passes. BPR was higher for the dense-graded asphalt mixture pavement than for the rough surface pavement at the beginning of the test. The coefficient of sliding friction for the dense-graded asphalt mixture pavement was around 0.1 (very slippery), and it did not increase with increases in the number of wheel passes, whereas that for the rough-surface pavement greatly increased after 500 passes.

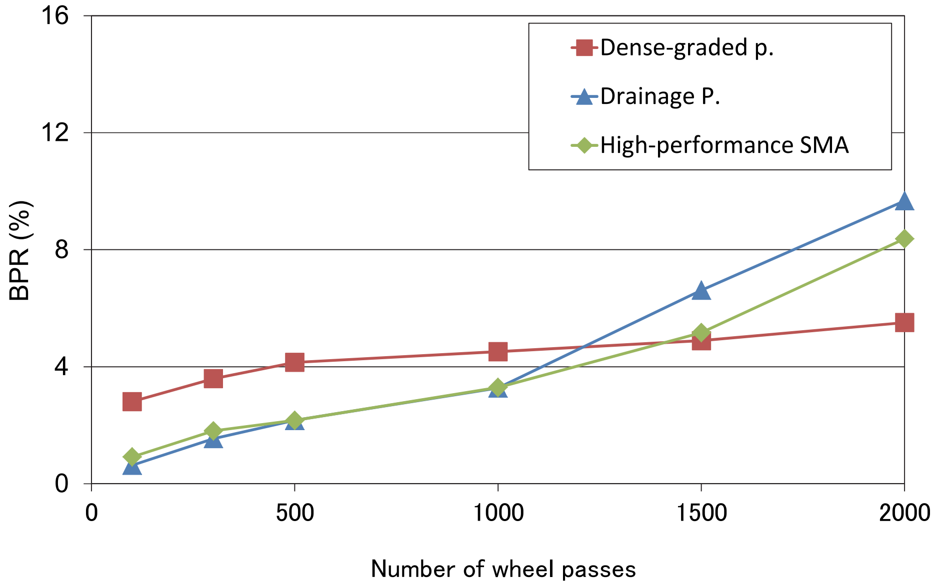

Figure 10 - BPR vs. number of wheel passes

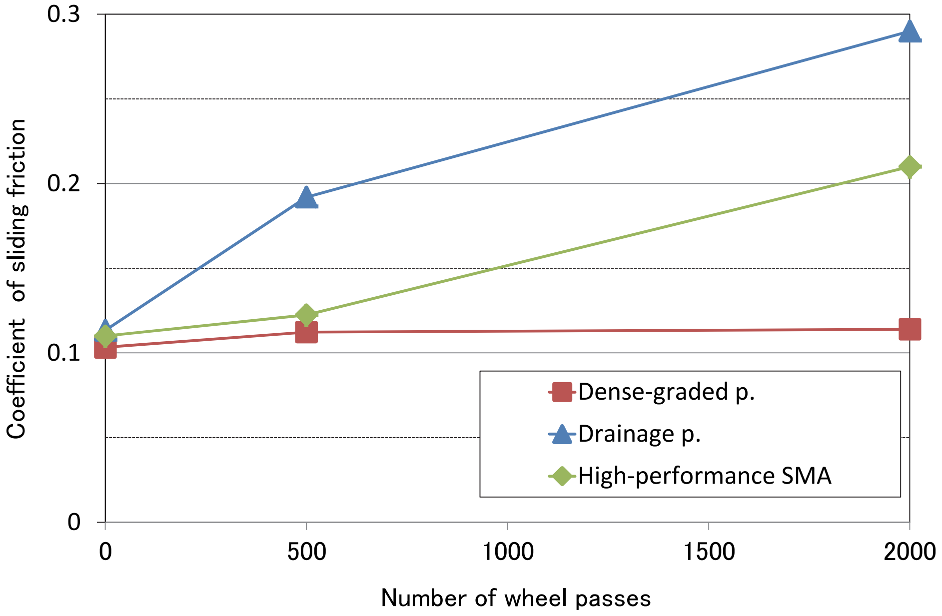

Figure 11 - Coefficient of sliding friction vs. number of wheel passes

Figure 12 shows the relationship between ice thickness and number of wheel passes. The thickness of the ice layer was measured with a simplified digital film thickness gauge (Figure 13). Measurements were taken at four arbitrary locations on the pavement. For rough-surface pavement, measurement locations were selected on convex protuberances of the pavement surface. Measurements were taken at the same four locations throughout the test.

The ice that formed on the rough-surface pavement was thinner than that on the dense-graded asphalt mixture pavement, by 0.5 mm before the wheel passes started and by 0.8 mm at 2,000 wheel passes. The thickness of ice after salting was decreased by melting effect of the salt and by abrasion from the wheel passes. The decreases in ice thickness for rough-surface pavement were greater than those for dense-graded asphalt mixture pavement. This is because the ice abrasion rate by wheel passes and the effect of salting were greater for the former than the latter [9]. Such differences are attributed to the rough texture of rough-surface pavement.

The drainage pavement had higher values of BPR and coefficient of sliding friction than high-performance SMA had. These differences are attributed to the differences in the amount of water on the pavement due to their differences in permeability.

The results of tests under this study suggest the possibility of more effective salting by tailoring the salt application amount and the number of salting operations to the pavement type.

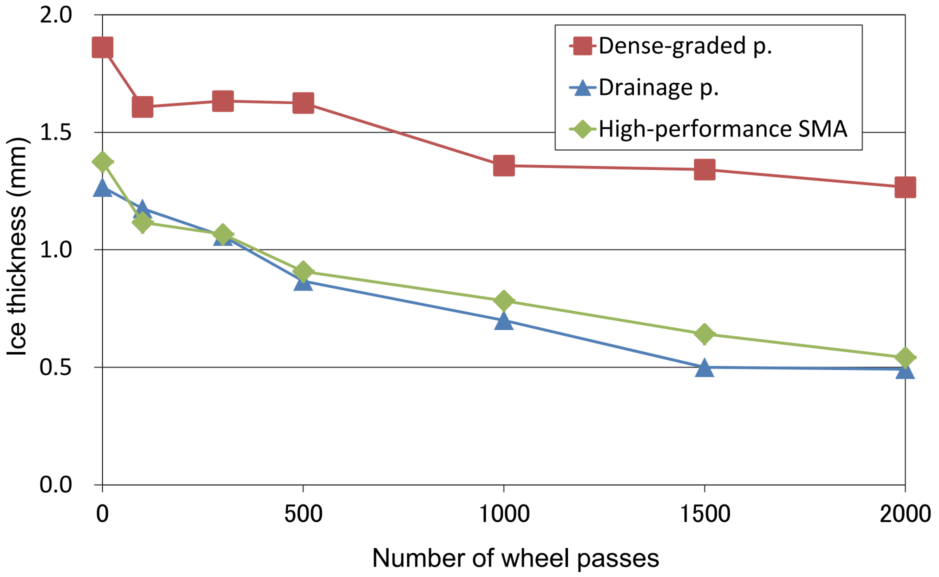

Figure 12 - Ice thickness vs. number of wheel passes

Figure 13 - Simplified digital film thickness gauge

5. SUMMARY

The followings are the results and knowledge obtained by this study.

Sprinkling and freezing test:
1) Drainage pavement and high-performance SMA were proved to have high sliding-resistance performance. However, in the field application of rough-surface pavement on actual roads, durability and maintenance of permeability need to be considered.
2) The drainage pavement has higher sliding-resistance performance than the high-performance SMA has. This is because drainage pavement has a higher permeability than high-performance SMA and, thus, the former has less water remaining on the pavement than the latter has.
3) The permeability and rough surface texture of rough-surface pavement contribute to the high sliding-resistance performance; however, that performance declines with decreases in temperature.
4) The sliding-resistance performance is higher when no wheel passes (left for 30 minutes after sprinkling water) than when wheel traveled for certain times. This is attributed to the supply of water from the wheel. However, further study is needed.

Salting test:
5) The coefficient of sliding friction for the dense-graded asphalt mixture pavement was around 0.1 (very slippery), and it did not increase with increases in the number of wheel passes, whereas that for the rough-surface pavement greatly increased after 500 passes.
6) The ice on rough-surface pavement is thinner than that on the dense-graded asphalt mixture pavement, by 0.5 mm before the wheel passes and by 0.8 mm at 2,000 wheel passes. This suggests that rough-surface pavement has a higher sliding-resistance performance than dense-graded asphalt mixture pavement. The surface condition recovered due to exposure of the rough texture of the pavement.
7) The drainage pavement afforded a higher sliding-resistance performance than high-performance SMA. This is because the drainage pavement has less water remaining on the surface than high-performance SMA has.

6. CONCLUSION

The characteristics of three types of pavement were clarified by laboratory tests, and the effectiveness of salting in increasing the surface friction of these pavements was assessed.

Currently, criteria for deciding salt application are more qualitative than quantitative, but it is important to quantitatively assess the sliding-resistance performance of different types of pavement.

Our future study will include outdoor track tests and field tests toward establishing effective salting methods for winter road management and maintenance.

REFERENCES RÉFÉRENCES

1. Hokkaido Regional Development Bureau (1997). The Winter Road Surface Management Manual (draft).
2. Snow Research Center (1997). Examples of Winter Road Maintenance and Management. pp.159-206
3. The Committee on Pavement Engineering, JSCE (2011). Pavement in Cold and Snowy Regions. Pavement Engineering Library 6, pp.156-207
4. Yuichi K., Tetsuya T., Roberto T. (2012). Study on the Salting Effects. Proceedings of the 55th Hokkaido Development Technology Conference, Sapporo, Japan.
5. Manabu C., Jun T. Ryuji A. (2006). Skid Resistance of Open-Graded Asphalt Pavements under Snowy and Icy Conditions. Proceedings of 22nd Cold Region Technology Conference, Vol.22, pp.209-213
6. Shunsuke T., Kiyoshi T., Yukiei M., Naoto T. (2011). Study on Properties of Skid-Resistance on Freezing Pavements and Quantitative Evaluation Method of Antifreezing Effects. Proceedings of JSCE, Vol.67/E1, pp.53-64
7. Japan Road Association (2007). Guides for Pavement Inspection and Testing Methods, Vol.1. pp.104-116
8. Japan Road Association (2006). Assessment of Pavement Performance –Mandatory and Other Major Performance Indicators-. pp.47-53
9. Shunsuke T. (2012). Study on the Sliding-Resistance in Relation to Bare Pavement Ration of Icy Road Surface. Doctor Thesis of Hokkai-Gakuen University. pp.30-46, pp.51-54