# Skid Resistance of Porous Asphalt Pavement under Winter Conditions

K. Maruyama
Civil Engineering Research Institute for Cold Region,
Public Works Research Institute, Japan
k.maruyama@ceri.go.jp

K. Fuse
Civil Engineering Research Institute for Cold Region,
Public Works Research Institute, Japan
93180@ceri.go.jp

M. Kumagai
Civil Engineering Research Institute for Cold Region,
Public Works Research Institute, Japan
kumagai@ceri.go.jp

## ABSTRACT

This study investigates whether porous asphalt pavements have higher skid resistance under winter conditions than conventional dense-graded pavements and examines the installation of such pavements as a measure against winter conditions. Evaluation was done by measuring the skid resistance of such pavements in the laboratory, on a test track and on roads in service under winter conditions.

Using skid-resistance measurement devices, the skid-resistance coefficients of porous asphalt pavements (void content: 17%, 20%, and 23%) and that of conventional dense-graded asphalt pavement were measured under winter conditions for comparison. The tests were conducted on artificially-made snow- and ice-covered test pieces, on a test track and on roads in service.

Porous asphalt pavement was found to be effective in mitigating reductions in skid resistance up to a certain level of road freezing (black ice or slush), because its surface texture allows it to retain its roughness. Porous asphalt pavements are expected to show improved skid resistance under the following circumstances: 1) under the road conditions of early and late winter, 2) for roads with a high winter maintenance service level, and 3) in regions with moderate snowfall.

## KEY WORDS

POROUS ASPHALT PAVEMENT / SKID RESISTANCE / SURFACE TEXTURE / WINTER CONDITION

## 1. INTRODUCTION

Maintaining the skid resistance of the road surface in winter is important for securing the safe, smooth flow of traffic in cold, snowy regions. Porous asphalt pavements are being installed on national highways and high-standard highways to improve the safety of wet roads and to reduce noise. The surface texture is also expected to be effective at mitigating reductions in skid resistance on freezing roads.

This paper reports on the effectiveness of porous asphalt pavements in mitigating reductions in skid resistance on freezing roads. Tests were performed in the laboratory and on a winter test track. Field surveys on roads in service were also performed. The skid-resistance coefficients under various conditions of snow and ice were measured to examine the skid performance of porous asphalt pavements under winter road conditions.

## 2. LABORATORY TESTS

### 2.1. Test method

Laboratory tests were performed on conventional pavement and porous asphalt pavement, to determine the skid resistance on artificially reproduced frozen road surfaces. Pavement types for this test are listed in Table 1. Skid resistance at the surface of the 40x40x5-cm (l*w*t) test piece was measured using a portable skid-resistance tester[1)] (Photo 1). In that test, a frozen surface was made by applying water to the surface of the test piece in seven applications, each of 45 ml, at one-hour intervals. Skid resistance was measured five times in the longitudinal direction and five times in the transverse direction for each test piece. The values were averaged to obtain the skid resistance. Measurements were performed after the 1st, 3rd, 5th and 7th applications of water: The first three applications simulate black ice, and the last three applications simulate ice sheet.

Table 1 – Types of test pieces

| Pavement type |
|---|
| Porous asphalt pavement (20% void) |
| Conventional pavement |

Photo 1 – Portable skid-resistance tester

### 2.2. Test results

Figure 1 shows that the skid resistance of porous asphalt pavement decreases with increases in the ice thickness. When the surface condition is black ice, the skid resistance decreases on conventional pavement but remains high on porous asphalt pavement. This is because porous pavement maintains its rough surface texture. However, the skid resistance of porous pavement decreases as the ice thickens from black ice to ice sheet. This demonstrates that as long as porous asphalt pavement retains its surface texture, it also retains its skid resistance, but that when its surface texture is covered by snow or ice, it loses its skid resistance.

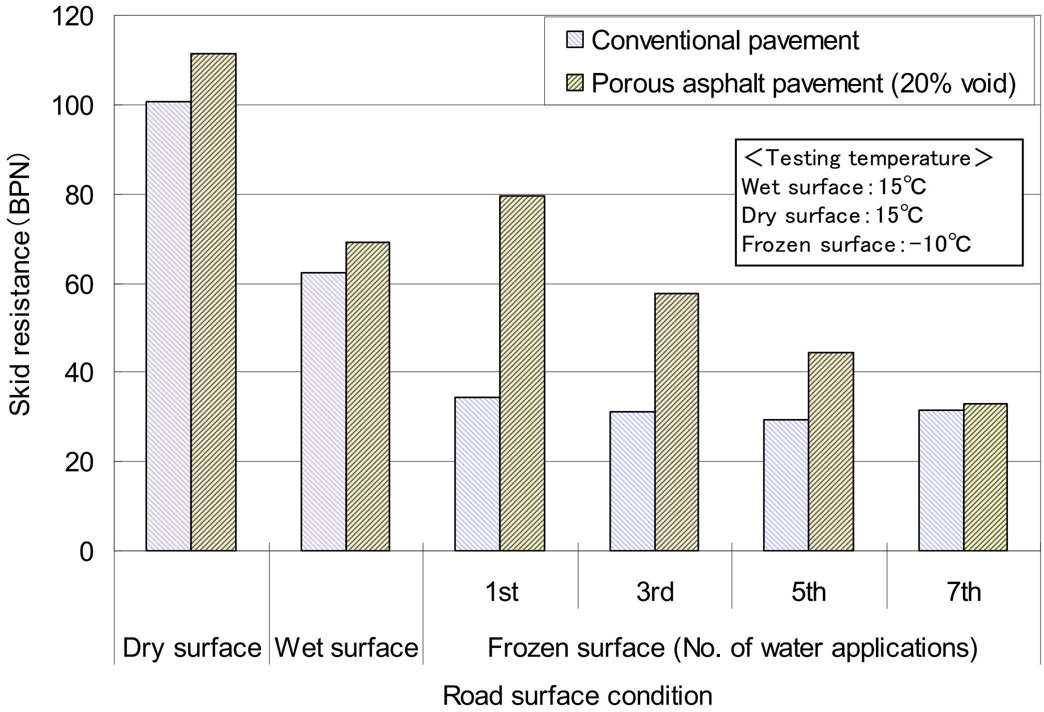



Figure 1 – Results of the skid-resistance test

## 3. TEST TRACK SURVEYS

### 3.1. Test method

To evaluate the skid resistance of porous asphalt pavements under various conditions of snow and ice, skid-resistance tests were performed at a test track. The tested pavements were three types of porous asphalt pavements and one type of conventional pavement.

Table 2 lists the pavements and the tests. Skid resistance on the different types of pavement was measured for three reproduced road surface conditions: black ice, ice sheet and compacted snow. A large skid test vehicle (Photo 2) installed with a skid test wheel was used for measurement. The longitudinal skid resistance of pavement is obtained by dividing the drag force acting on the vehicle's non-rotating test wheel by the constant load applied to that wheel[2).]This simulates skid resistance for the wheels of a travelling vehicle.

Table 2 – Outline of the survey

| | |
|---|---|
| Pavement type | Porous asphalt pavement (17% void) |
| | Porous asphalt pavement (20% void) |
| | Conventional dense-graded pavement |
| Surface condition | Black ice |
| | Ice sheet |
| | Compacted snow |
| Testing speed | 30km/h |
| Tire | Studless winter tire (165/80R-13) |

Photo 2 – Skid-resistance test vehicle

## 3.2. Test results

Figure 2 shows the test results. With black ice, the porous asphalt pavements show high skid-resistance coefficients. Thin ice formed on the conventional pavement in the test. On the porous asphalt pavements, the surface texture roughness was somewhat reduced, but the coarse aggregates were not fully covered with ice. With ice sheet or compacted snow, the skid-resistance coefficients of the porous asphalt pavements were reduced almost to those of the conventional pavement. Under this condition, the surface texture was filled in with ice and snow, and the road surface froze, as was the case for conventional pavements. High skid resistance could not be expected under this condition.

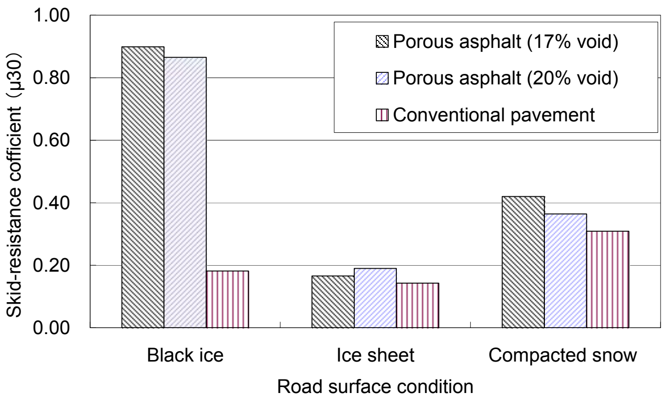



Figure 2 – Skid-resistance coefficient on test track

# 4. FIELD SURVEY ON ROADS IN SERVICE

## 4.1. Outline of the field survey site

A field survey on roads in service was conducted at two field survey sites: Site A and Site B. Figures 3 and 4 outlines the plan view of the sites. Three road sections were installed with porous asphalt pavements (porosity of 17%, 20%, and 23%) and one conventional dense-graded pavement section was installed in the same lane for comparison at Site A. One porous asphalt pavement (porosity of 17%) and one conventional dense-graded pavement were installed at Site B.

The survey location, tested pavements and measurement method are listed in Tables 3 and 4. Porous asphalt pavements were compared with conventional pavement at the same locations in terms of skid resistance under winter conditions. Skid resistance was measured by skid-resistance test vehicle. The effectiveness at mitigating reduction in skid resistance was examined for four road surface conditions: compacted snow, slush, black ice and ice sheet. The survey conditions are shown in Table 5 and Table 6. The texture depths were measured with a mini texture meter.

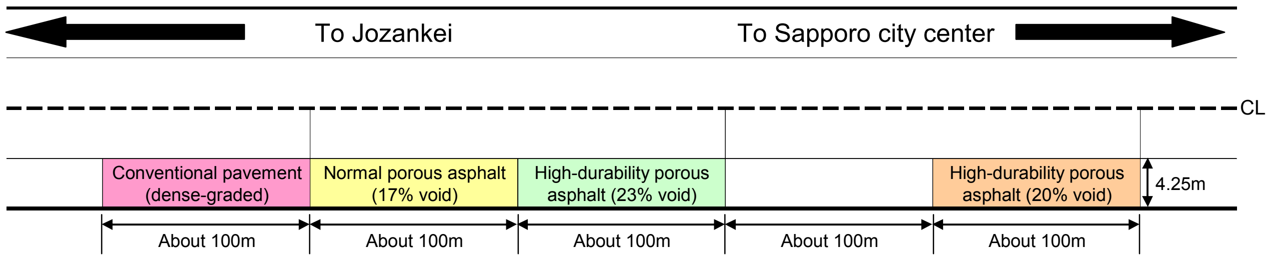



Figure 3 – Plan view of field survey site A

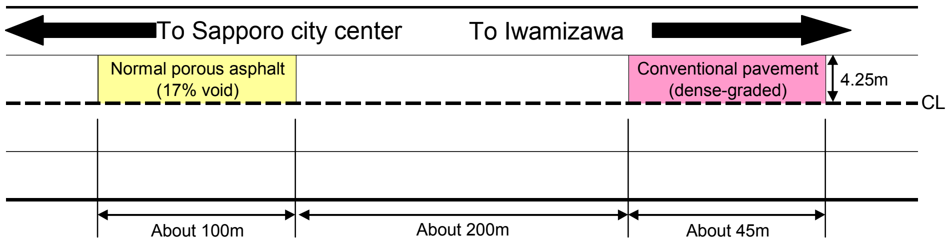



Figure 4 – Plan view of field survey site B

Table 3 – Outline of the test (Site A)

| | |
|---|---|
| Test location | Nat'l Highway 230 (Ishiyama-dori St.), Sapporo City |
| Survey period | Dec. 2005 to March 2006 and Jan.2008 to March 2008 |
| Pavement type | Conventional dense-graded pavement |
| | Porous asphalt pavement (17% void) |
| | Porous asphalt pavement (20% void) |
| | Porous asphalt pavement (23% void) |
| Test method | Test speed 30km/h |
| | Tire: studless winter tire (165/80R-13) |

Table 4 – Outline of the test (Site B)

| | |
|---|---|
| Test location | Nat'l Highway 12 (Oyachi), Sapporo City |
| Survey period | Jan. 2008 to March 2008 |
| Pavement type | Conventional dense-graded pavement |
| | Porous asphalt pavement (17% void) |
| Test method | Test speed 30km/h |
| | Tire: studless winter tire (165/80R-13) |

Table 5 – Survey conditions (Site A)

| | Air temp. | Surface temp. | Conventional pavement | Porous asphalt (17% void) | Porous asphalt (20% void) | Porous asphalt (23% void) |
|---|---|---|---|---|---|---|
| Case 1 | 1.8℃ | -4.5℃ | Compacted snow | Compacted snow | Compacted snow | Compacted snow |
| Case 2 | -0.2℃ | -7.0℃ | Shallow slush | Shallow slush | Shallow slush | Shallow slush |
| Case 3 | -1.0℃ | -10.0℃ | Black ice on some parts of the pavement | Mostly dry | Black ice on some parts of the pavement | Mostly dry |
| Case 4 | -0.6℃ | -2.0℃ | Ice sheet | Ice sheet | Black ice | Ice sheet |
| Case 5 | -3.0℃ | -6.2℃ | Granular snow | Granular snow | Granular snow | Granular snow |
| Texture depth (mm) | | | 0.27* | 0.78 | 0.83 | 0.92 |

*Texture depth of conventional pavement is from data obtained at the CERI winter test track and is for reference only.

Table 6 – Survey conditions (Site B)

| | Air temp. | Surface temp. | Conventional pavement | Porous asphalt (17% void) |
|---|---|---|---|---|
| Case 6 | -8.4℃ | -10.7℃ | Black ice | Black ice |
| Case 7 | -3.7℃ | -4.5℃ | Ice sheet | Ice sheet |

### 4.2. Field survey results

Figure 5 shows the skid-resistance coefficients for the three kinds of porous asphalt pavements and the conventional dense-graded pavement under Case 1. The air temperature was +1.8ºC, the road surface temperature was -4.5 ºC, and the road surface condition was compacted snow on all road sections. Since the surface textures of porous asphalt pavements were covered with snow, the surface was not exposed and did not act to mitigate the reduction in skid resistance. Therefore, the skid-resistance coefficients were in the range of 0.3 to 0.4, which were similar to those for the conventional dense-graded pavement.

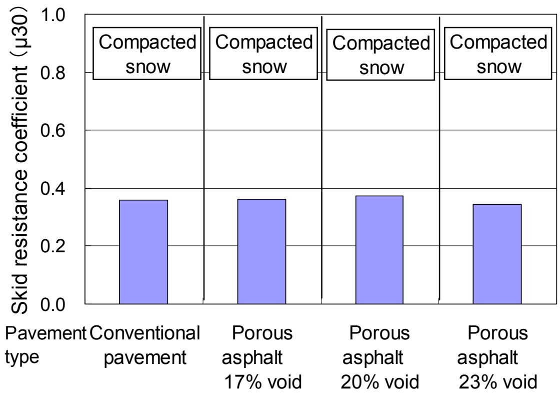
Figure 6 shows the skid-resistance coefficients under Case 2. The air temperature was -0.2ºC, the road surface temperature was -7.0ºC, and the road surface condition was shallow slush. When the road surface condition was shallow slush, the surface texture acted to mitigate the reduction of skid resistance because it allowed draining, and the skid-resistance coefficients were about 0.5.However, on the conventional dense-graded pavements, the water in the shallow slush did not drain, which caused the skid-resistance coefficient to be less than 0.3. This demonstrates the superiority of the porous asphalt pavement.

Figure 7 shows the skid-resistance coefficients under Case 3. The air temperature was -1.0ºC, the road surface temperature was -10.0ºC, and the road surface condition was black ice on part of the conventional dense-graded pavement but dry on most of the porous asphalt pavements. The skid-resistance coefficients on porous asphalt pavements were higher than on conventional pavement. On conventional dense-graded pavement, snow that melted during the day did not drain and remained to form black ice. On porous asphalt pavements, it was thought that the porosity afforded drainage that kept the meltwater from refreezing on the surface.

Figure 8 shows the skid-resistance coefficients under Case 4. The air temperature was -0.6ºC and the road surface temperature was -2.0ºC.The road surface was ice sheet on the conventional dense-graded pavement, 17%-void porous asphalt pavement, and 23%-void porous asphalt pavement. The road surface was black ice on the 20%-void porous asphalt pavement. When a road is covered with ice sheet, the surface roughness is not retained. For the three pavements with ice sheet, the skid-resistance coefficients were about 0.2. For the pavement with black ice (20%-void porous asphalt pavement), the road surface texture was retained, and the skid-resistance coefficient was about 0.4.

Figure 9 shows the skid-resistance coefficients under Case 5 measured at three years after installation. The air temperature was -3.0ºC and the road surface temperature was -6.2ºC.The road surface was granular snow on the conventional dense-graded pavement, 17%-void porous asphalt pavement, 20%-void porous asphalt pavement and 23%-void porous asphalt pavement. The skid-resistance coefficients of porous asphalt pavements were greater than those of the conventional dense-graded pavement. This shows that porous asphalt pavement’s ability to mitigate reductions in skid resistance remains for several years.

Figure 10 and Figure 11 shows the skid-resistance coefficients under Case 6 and Case 7 measured at Site B. It is shown that skid resistance of the porous asphalt pavement is greater than that of the conventional dense-graded pavement. This is the same result as measured at Site A, as mentioned before.



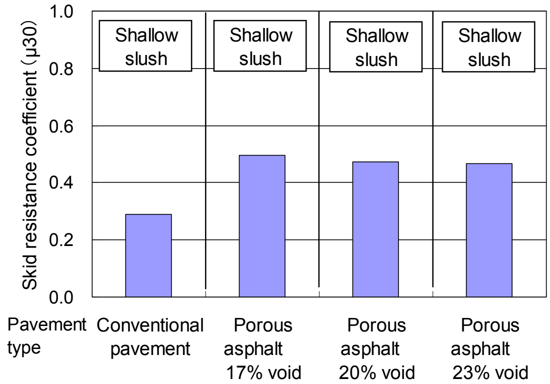
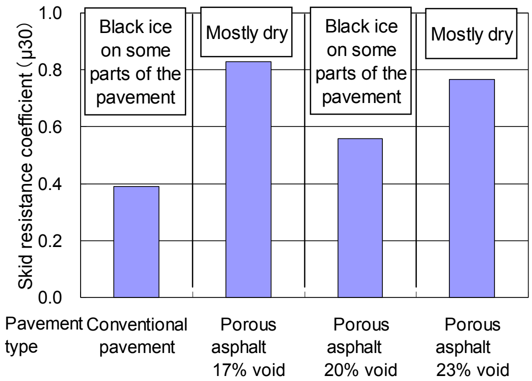




Figure 5 – Skid-resistance coefficient (Case 1, Left)
Figure 6 – Skid-resistance coefficient (Case 2, Right)



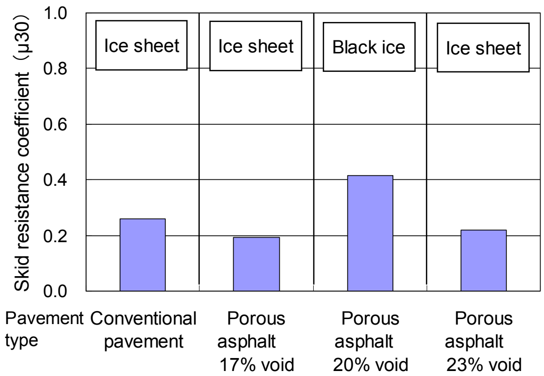




Figure 7 – Skid-resistance coefficient (Case 3, Left)
Figure 8 – Skid-resistance coefficient (Case 4, Right)

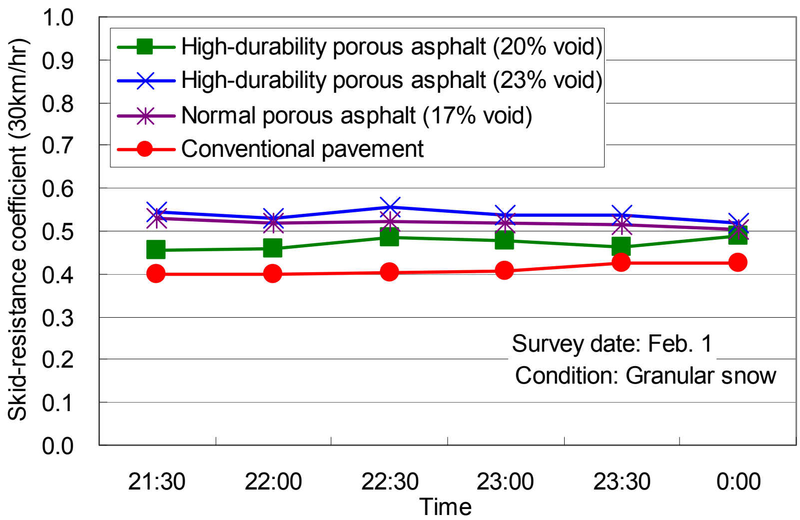



Figure 9 – Skid-resistance coefficient on porous asphalt (Case 5)

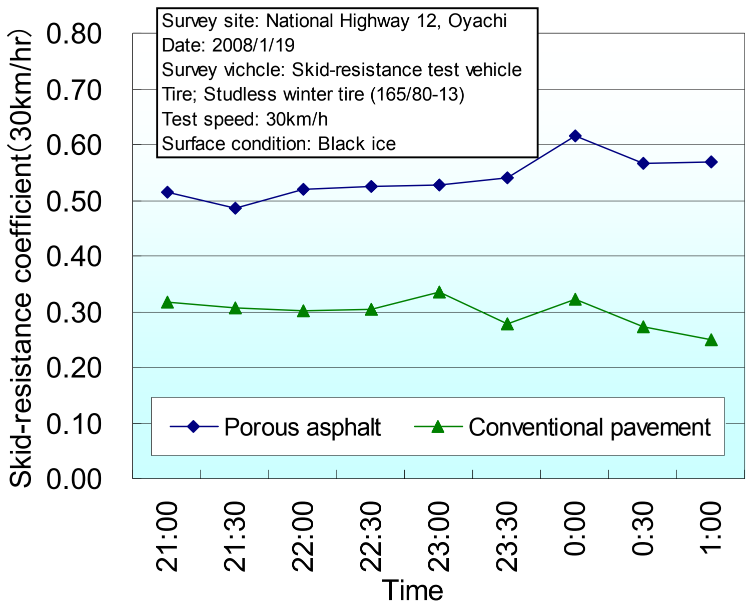



Figure 10 – Skid-resistance coefficient on porous asphalt (Case 6)

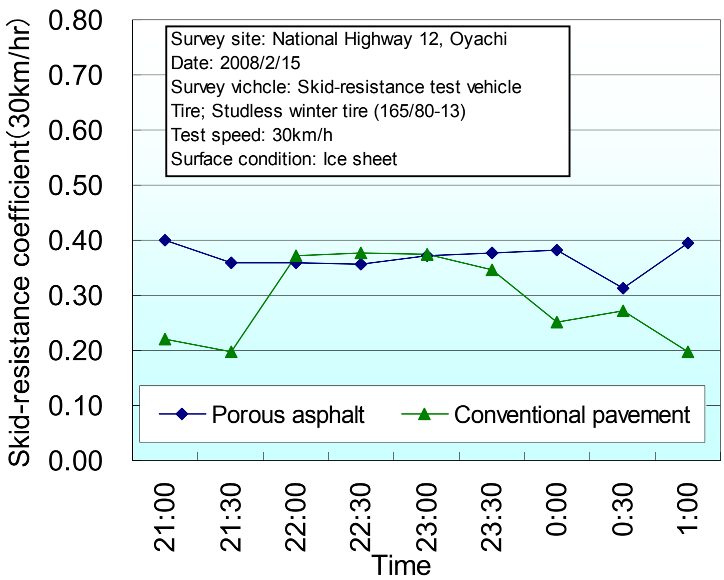



Figure 11 – Skid-resistance coefficient on porous asphalt (Case 7)

## 5. CONCLUSIONS

The following were confirmed:
1) On porous asphalt pavement, the skid resistance decreases with increases in the ice film thickness. This is because the pavement surface is covered with ice and its rough surface texture is not maintained.
2) For the compacted snow surface and the ice sheet surface, snow or ice fills the textured surface of the porous asphalt pavement, lowering the skid resistance to that of the dense-graded pavement.
3) For the slush surface, water from the slush drains through the porous asphalt pavement, leaving the surface texture exposed. This makes the skid resistance of such pavement greater than that of the dense-graded asphalt pavement.

4) For the black ice surface, the surface texture of the porous asphalt pavement remains exposed, and the skid resistance of such pavement is greater than that of the dense-graded asphalt pavement.
5) For the black ice surface on porous asphalt pavement that has been in service for three years, the skid resistance is greater than that of the dense-graded asphalt pavement. This shows that porous asphalt pavement's ability to mitigate reductions in skid resistance remains for several years.

Porous asphalt pavements are expected to show improved skid resistance in the following circumstances: 1) under the road conditions of early and late winter, 2) for roads with a high winter maintenance service level, and 3) in regions with little snowfall.

## REFERENCES

[1] Japan Road Association: "Manual for testing of pavements," 1988
[2] Ichihara, K., Onoda, M.: "Skidding on road surfaces and preventive measures," Gijyutsu Shoin, pp.10-11, 1999