STUDY ON THE PERFORMANCE OF POROUS ASPHALT PAVEMENT ON WINTER ROAD SURFACE CONDITOINS

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Abstract

Porous asphalt pavement is widely used on expressways in Japan. This type of pavement offers great performance in driving safety during the rain and the reduction of traffic noise. It is also said, that the porous structure of porous asphalt pavement gives winter road surface characteristics differ from those of conventional dense-asphalt pavement. In order to quantitatively evaluate such characteristics, Japan Highway Public Corporation (hereafter called JH) conducted on-site study. As a result, it was found that there is no significant difference between porous asphalt and dense-asphalt pavement in terms of road surface characteristics, hence no major modification is required to the existing road maintenance method for winter. It was also found that porous asphalt pavement is effective in preventing freezing of road surface. This study focuses on winter road characteristics, i.e. road surface temperature, road surface conditions, effect of anti-icing chemicals and skid resistance: durability by type of pavement structure, clogging of voids in pavement, and cost-effectiveness are not covered by the study.

1. Introduction

Japan has a national plan to build 11,520-km expressway network, of which 6,850 kms were already opened to traffic. JH is a governmental organization responsible for construction and operation of these expressways. Half of these expressways pass through snowy and cold regions with a 10-year average maximum snow depth of 30 cm or over. The expressways in other regions also experience snowfalls several times a year on most of the routes.

Generally in Japan, snow and ice control utilizes special water on road surface for removal of snow. As for JH, about 20 percent of the anti-icing chemical is used in the form of a solution which utilizes water on the road surface. On the other hand, JH plans to widely use porous asphalt pavement in order to improve driving safety during rain and reduce noise level. This poses a problem since porous asphalt pavement drains water from the road surface and this makes it difficult to use conventional snow and ice control methods, for which water on the road surface is essential.

2. Background of the study

2.1 Meteorological characteristics in Japan

There is a lot of snowfall in Japan due to the mountain ranges running through the center of the archipelago and the monsoon during the winter. In addition, since Japan is located at relatively low latitudes, the amount of insolation is large even during the winter, and snow on carrieageways and shoulders tends to repeat the cycle of thaw during daytime and frost at night. In order to cope with this, measures for water that seeps to road surface are regularly taken. Porous asphalt pavement is considered to be effective for water seeping to the surface, since it can prevent pooling on the surface. This feature of porous asphalt pavement, however, can be a disadvantage as well in terms of the maintenance of road during the winter.

2.2 JH's systems for snow and ice control

The typical methods for snow and ice control for expressways in Japan are snow removal with machinery and spreading of anti-icing chemicals. JH has conducted round-the-clock road maintenance with about 1,000 snow-ploughs and 500 anti-icing chemical spreading vehicles. The annual cost for snow and ice control amounts to as much as approximately $200 million, and nearly 150-200 thousand tons of NaCl is used as anti-icing chemical. With the increase of the maintenance length for expressways, the necessity for effective road surface maintenance methods for winter is growing. Winter-time maintenance for road surface using porous asphalt is another difficult technical problem for JH.

2.3 Status of porous asphalt pavement

The status of porous asphalt pavement used for expressways in Japan is as follows:

1) Use of porous asphalt pavement: 33% of the expressways in service (8,500 lane·km)
2) Void ratio of porous asphalt pavement: approximately 20%
3) Permeability requirement: being able to permeate 400 ml of water within 10 seconds
4) Effects on accident prevention: reduction of 80% compared to conventional dense-asphalt pavement during the rain
5) Effects on noise level : reduction of 3 dB compared to conventional dense-asphalt pavement

2.4 Technical problems with respect to porous asphalt pavement

Prior to the nation-wide introduction of porous asphalt pavement, the following technical problems had to be solved:

1) Establishment of methods for snow and ice control
2) Establishment of methods for restoration of permeability
3) Improvement of durability of porous asphalt pavement in regions where tire chains are used
4) Establishment of repair standard and repair methods
5) Densification of lower layers (water proofing of bridge sections)

6) Lowering of costs

Above items 1) to 3) are more specifically described as follows:

a) Isn't the road surface temperature of porous asphalt pavement lower than that of dense-asphalt pavement?

b) Isn't the snow coverage duration for porous asphalt pavement longer than that for dense-asphalt pavement? (Doesn't snow accumulate in a short period of time and remain unthawed?)

c) Cannot anti-icing chemicals effectively work?

The authors conducted a study to find answers for these questions and obtain necessary information for snow and ice control. The evaluation of porous asphalt pavement in the following description is mainly based on the comparison with dense-asphalt pavement, which used to be the most common pavement for surface coating. The comparison focuses on four factors: road surface temperature, road surface conditions, effect of anti-icing chemical and skid resistance coefficient.

In addition, it is considered that such problems as the quick abrasion of pavement by snow plow blades will be prevalent, with the nation-wide introduction of porous asphalt pavement.

3. Outline of the survey on winter-time road surface condition

3.1 Survey location

In order to obtain information on the winter-time characteristics of road surface using porous asphalt pavement, a nation-wide survey was conducted on expressways in 14 areas in Japan: Sapporo, Towada, Morioka, Furukawa, Fukushima, Kanazawa, Nagaoka, Nasu, Saku, Kofu, Hashima, Hiroshima, Ogori, and Yahata. In each survey location, the winter-time characteristics of porous asphalt and dense-asphalt pavement, each covering 50 ㎝ from the boundary, were compared.

In addition, the survey was conducted with respect to the earthwork sections of expressways.

3.2 Survey items

Survey items included factors which are considered to influence winter-time road surface characteristics, such as outside air temperature; road surface temperature; snowfall; snow depth; snow depth on road surfaces (shoulders, rutted and non-rutted sections); salinity concentration; traffic volume; road surface conditions (shoulders, rutted and non-rutted sections); and conditions of snow and ice control. The duration of the survey was, in principle, from the beginning to the ending of snowfall. Each meteorological value was measured hourly for both dense-asphalt and porous asphalt pavement at the same minutes past the hour. The total measurement duration was 605 hours.

4. Survey results

4.1 Road surface temperature

4.1.1 Changes with time

Figure 1 shows the changes in the road surface temperature with time, which were measured in January in Kofu. In the daytime the road surface temperature of dense-asphalt pavement becomes higher than that of porous asphalt pavement, while at night, the road surface temperature of porous asphalt pavement is higher than that of dense-asphalt pavement. This is probably because of the heat insulation effect of porous asphalt pavement offered by its voids (porous asphalt pavement is hard to heat up and hard to cool down).

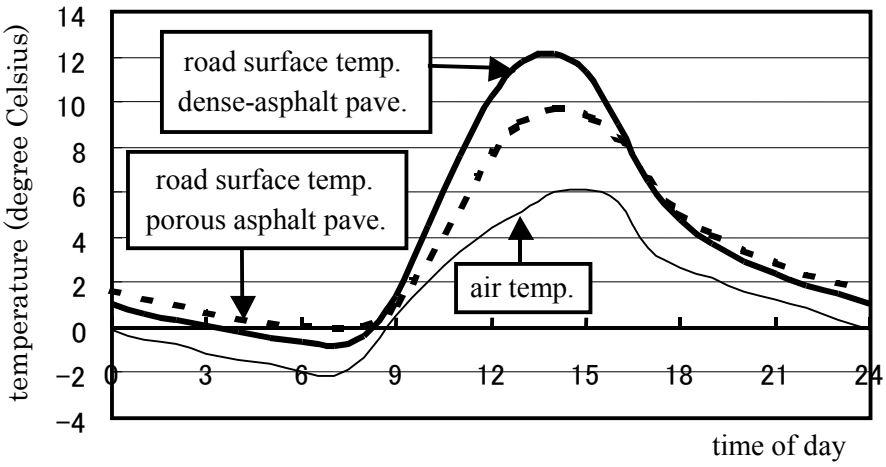

Figure 1 Road Surface Temperature to Time (Kofu:1998.1)

4.1.2 Characteristics during the snowfall

Figure 2 compares the road surface temperature of dense-asphalt pavement and

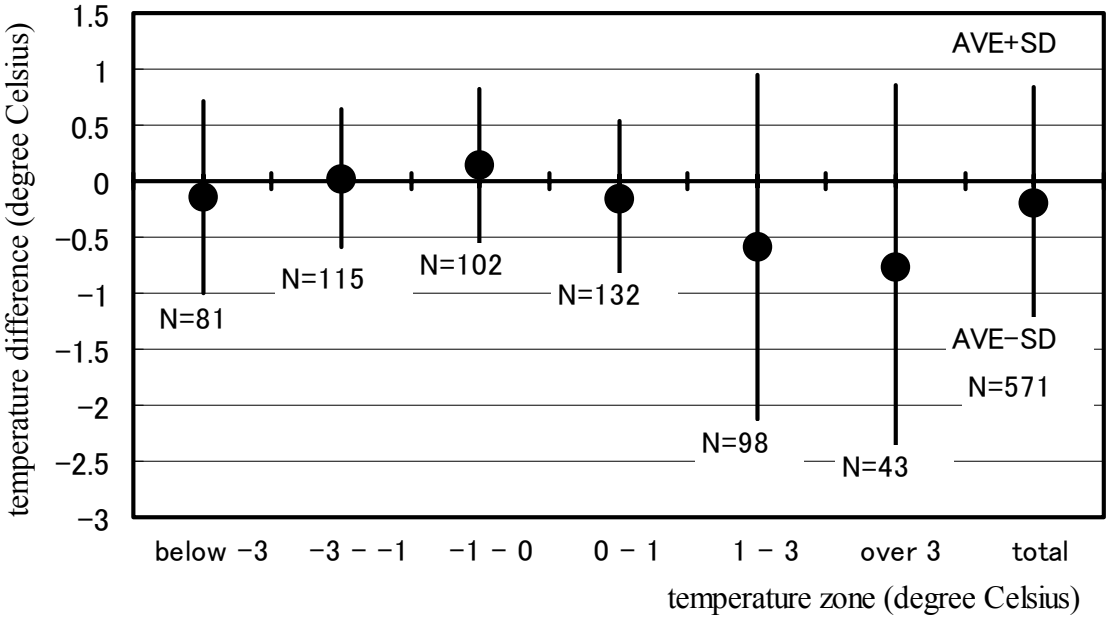

Figure 2 Road Surface Temperature Difference during Snowfall (Porous - Dense asphalt)

porous asphalt pavement during snowfall. The figure shows a difference in road surface temperature of both pavement in every temperature level. It can be seen from this figure that the surface temperature of porous asphalt pavement is lower than that of dense-asphalt pavement by an average of 0.2℃. And the difference becomes prominent where the surface temperature is more than 1℃. In other words, the road surface temperature of porous asphalt pavement is slightly lower than that of dense-asphalt pavement in general, and the difference becomes large particularly when the temperature is positive. In short, it is considered this result may not affect the methods for snow and ice control.

4.2 Road surface conditions

In order to verify the difference between the surface conditions of porous asphalt pavement and those of dense-asphalt pavement, the surfaces of both types of pavement were simultaneously surveyed during the snowfall. Tables 1 and 2 are cross tabulations for the survey results of rutted sections, and non-rutted sections (carriageways), respectively. The figures in the tabulations show the frequency (expressed in hours) of the combination of the road surface conditions given in these tables. The right-upper area of the tabulation corresponds to the case where the road surface conditions of porous asphalt pavement were worse than dense-asphalt pavement (damage to road surface due to snow and ice was worse), and the left-lower area corresponds to the case where the road surface conditions for porous asphalt pavement were better than dense-asphalt pavement. The figures in a cell with the thick border show the frequency of cases where the conditions of porous asphalt pavement and those of dense-asphalt pavement are the

Table 1 Road Surface Conditions during Snowfall (rut)

rutted sections		porous asphalt pavement					
		dry	wet	slush	snow	ice	total
dense-asphalt pavement	dry	33				worse	33
	wet	1	297	23			321
	slush		14	96	2		112
	snow		10	2	88		100
	ice	better	10	3	3	23	39
	total	34	331	124	93	23	605

Table 2 Road Surface Conditions during Snowfall (non-rut)

non-rutted sections		porous asphalt pavement					
		dry	wet	slush	snow	ice	total
dense-asphalt pavement	dry	34				worse	34
	wet	2	247	29	4		282
	slush		13	114	8	3	138
	snow		1	11	109	2	123
	ice	better	4	5	1	18	28
	total	36	265	159	122	23	605

same. "Better" and "worse" in these tables are based on visual judgment and do not take into consideration the actual "skiddiness."

Although, in most cases (80 to 90 %), the road surface conditions for both types of pavement are the same as shown in these tables, some distinctive cases are also observed: a brief explanation on the typical combinations is as follows:

(1) Case where dense-asphalt pavement is wet and porous asphalt pavement is covered with slush

This combination is observed both in rutted and non-rutted sections. Porous asphalt pavement covered with slush in the non-rutted section could deteriorate to snow condition. This is related to the existence of water on the road surface. While snow on dense-asphalt pavement is melted by water on the road surface, snow on porous asphalt pavement remains unthawed and continues to pile up since water to melt snow does not exist on the surface and porous asphalt pavement is less affected by tires.

This combination is not necessarily predominant, since it accounted for only 3.8 percent (= 23 hours/605 hours) for rutted sections and 5.5 percent (= (29+4)/605) for non-rutted sections. However, the appearance of this combination is sometimes taken as a serious problem because of the following features:

1) Larger white non-rutted area gives a strong impression.

2) Being covered with "slush," the porous asphalt pavement section looks whiter than the dense-asphalt pavement section.

This indicates that this problem is influenced by appearance rather than physical characteristics.

(2) Case where dense-asphalt pavement is covered with ice film, and porous asphalt pavement is wet.

This combination also has a close relationship with water on the road surface. Basically, freezing of road surface is difficult to occur on porous asphalt pavement since water does not stay on the road surface. On the other hand, for dense-asphalt pavement, road surface water could freeze if the conditions for temperature and salinity concentration content are met. These facts indicate that porous asphalt pavement ensures "removal of water from road surface," which is the basic requirement for the prevention of road surface freezing during the winter.

4.3 Effects of anti-icing chemicals

It has been pointed out that porous asphalt pavement drains anti-icing chemicals through voids, thus the effects of the chemicals are reduced when compared with dense-asphalt pavement. In some cases, the application dose of the chemicals was increased to cope with this problem.

Figure 3 shows the changes in salinity concentration after spreading of anti-icing chemicals by spreading method. As shown in this figure, the decrease rate of salinity concentration for porous asphalt pavement is smaller than that for dense-asphalt pavement regardless of spreading method. The probable reason for this is that porous asphalt pavement offers better bond with chloride than dense-asphalt pavement, so the amount of chloride spattering from the road surface is small. The small decrease in the chloride content offered by porous asphalt pavement allows the amount of anti-icing

chemicals used for freezing prevention to be reduced.

Where anti-icing chemical solution is spread, porous asphalt pavement always maintains higher salinity concentration than dense-asphalt pavement. On the other hand, where the solid of anti-icing chemical or wet salt is spread, the salinity concentration for dense-asphalt pavement immediately after spreading tends to be higher than that for porous asphalt pavement. The probable reason for this is that since the amount of road surface water is smaller for porous asphalt pavement, it takes a certain period of time before the chemicals are dissolved in the water, and thus the chloride content immediately after spreading is smaller. However, such difference in salinity concentration for solid formulation and wet salt, becomes minimal after 20 minutes. From the viewpoint of snow and ice control, high salinity concentration immediately after spreading is not so important (it is more important to maintain the salinity concentration at a proper level). Therefore, it can be concluded that the effects of anti-icing chemicals are not so influenced by the type of pavement.

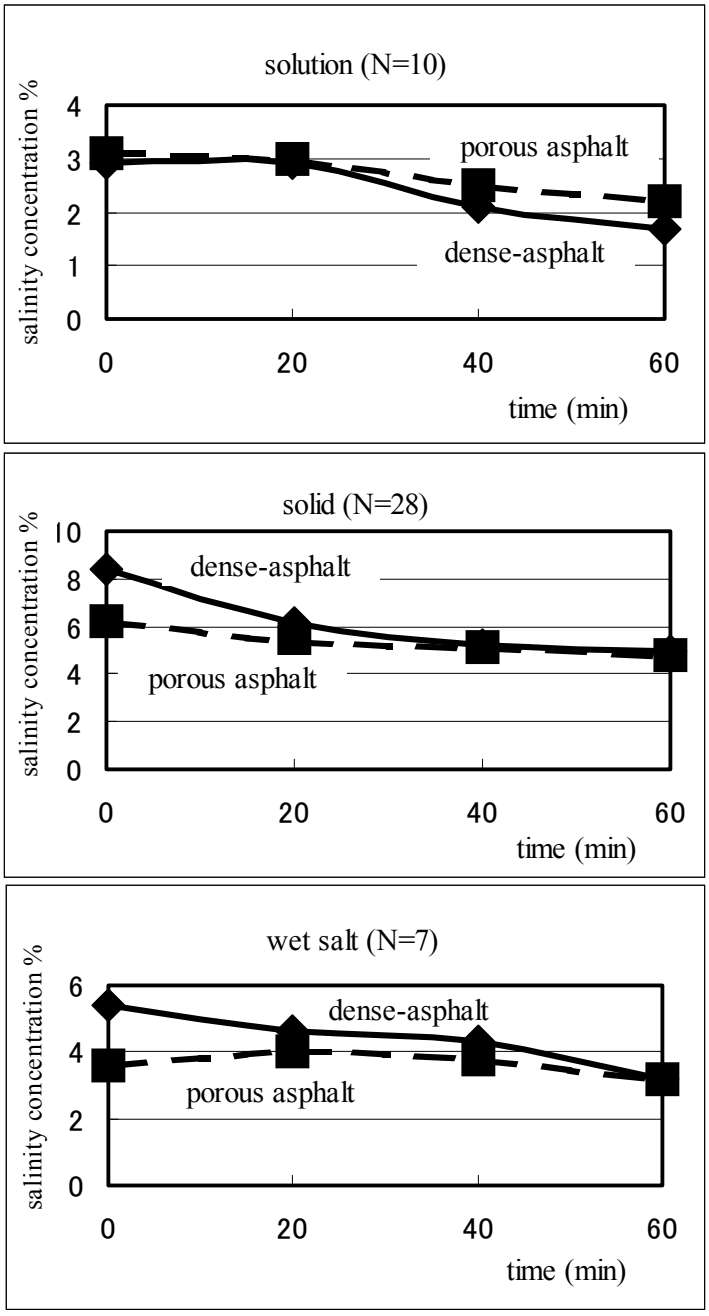

Figure 3 Salinity Concentration

4.4 Skid resistance coefficient

Figure 4 shows the skid resistance coefficient by type of pavement, which was obtained from tests using JH's large friction testing vehicle. The measurement was based on the lock wheel of the friction testing vehicle equipped with winter tires (studless tires) specially designed for the tests and traveling at 50 km/h.

Except for road surfaces covered with compacted snow, the skid resistance coefficient of porous asphalt pavement is larger than that of dense-asphalt pavement.

The skid resistance coefficient of road surfaces covered with compacted snow is not affected by the type of pavement, since the coefficient for such surface is determined only by the friction between snow and tires. For wet road surface and road surface covered with ice film, the irregularity of porous asphalt pavement effectively works and offers higher skid resistance. The high skid resistance coefficient for road covered with ice film is significant for traffic safety and could prevent multiple collisions on icy roads.

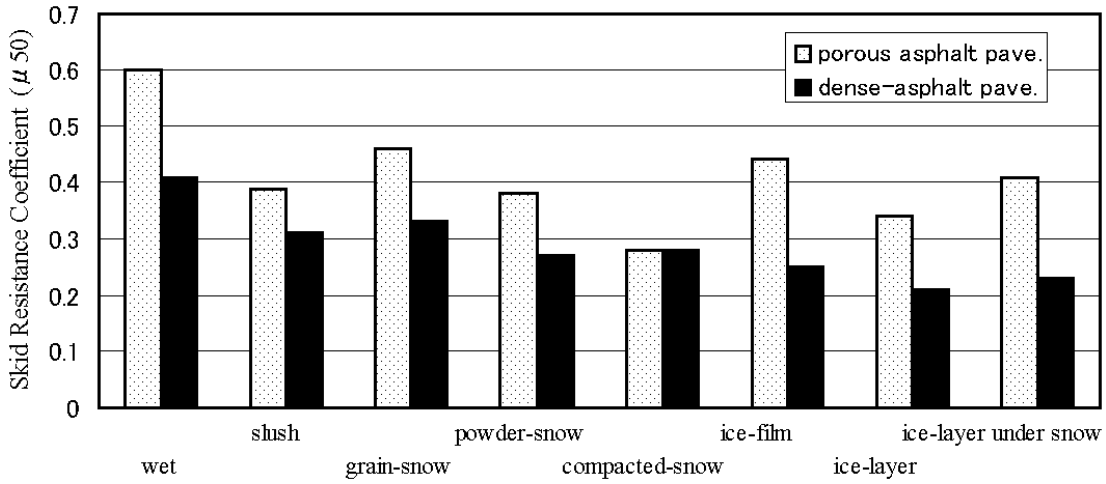

Figure 4 Skid Resistance Coefficient

5. Decrease in traffic accidents

Figure 5 shows that the number of traffic accidents in dense-asphalt pavement road sections compared with that in the same road sections with an improved porous asphalt pavement. In the comparison, the number of traffic accidents in a year before the pavement improvement (dense-asphalt pavement) and that in a year following the pavement improvement (porous

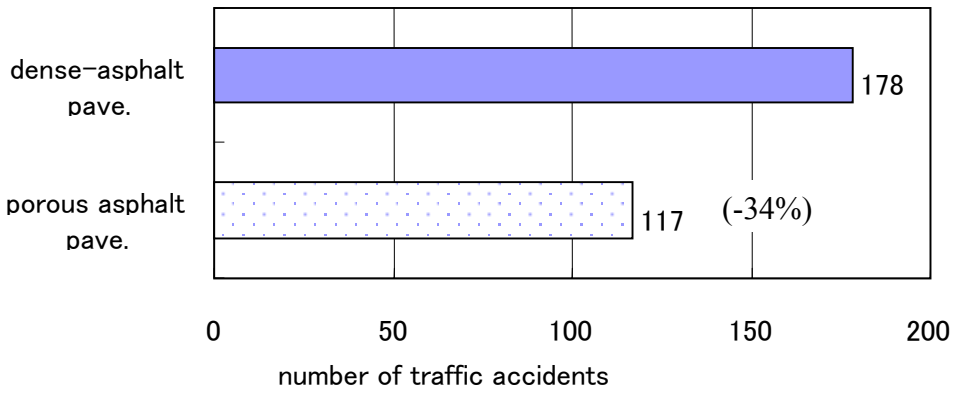

Figure 5 Accidents on the Winter Surface

asphalt pavement) were compared directly. The traffic accident statistics were collected by JH, and weather conditions before and after the pavement improvement were not taken into account.

The comparison revealed that the number of traffic accidents on icy or snow-covered surfaces in the road sections (1,043 km) which were improved with a porous asphalt pavement in 1997 or 1998 decreased from 178 to 117, 34% decrease.

It was thus confirmed that the porous asphalt pavement helps reduce the number of traffic accidents on icy or snow-covered roads as well as under the wet weather. The porous asphalt pavement, which effectively drains the road surface, greatly contributes to road safety in winter.

6. Conclusion

The differences between the winter-time characteristics of conventional pavement (e.g. dense-asphalt pavement) and those of porous asphalt pavement are summarized as follows:

1) The road surface temperature of porous asphalt pavement during the snowfall is lower than conventional pavement by an average of approximately 0.2℃. However, since the temperature difference between conventional and porous pavement becomes prominent only where the surface temperature is positive, the lower surface temperature of porous asphalt pavement is not a problem in terms of snow and ice control.

2) There is no significant difference between conventional and porous asphalt pavement in terms of road surface conditions during the snowfall.

3) There is no significant difference between conventional and porous asphalt pavement in terms of the salinity concentration of anti-icing chemicals.

4) The surface roughness of porous asphalt pavement offers higher skid resistance coefficient than dense-asphalt pavement, even if the surface is slightly frost.

5) The number of traffic accidents have decreased in sections where dense-asphalt pavement has been replaced by porous asphalt pavement when the surface conditions are snow and ice.

Given these findings, it is considered that no major modification is necessary for the existing snow and ice control method. Particularly for snowy and cold areas, where snow tends to pile up on the road surface, the existing maintenance method is still effective. On the other hand, in relatively warm areas, surface paved with porous asphalt may look whiter during the snowfall particularly on non-rutted sections. This, however, does not pose a problem, because the skid resistance of porous asphalt pavement is higher than that of dense-asphalt pavement.

7. Postface

This report summarized the winter-time road surface characteristics of porous asphalt pavement based on the results of surveys which were conducted on expressways in Japan. Some of the previous reports pointed out problems related to snow and ice control of roads using porous asphalt pavement. In some cases, the area, to which porous

asphalt pavement is applied, is limited, and the amount of anti-icing chemicals is increased, in order to cope with such problems. The evaluation on porous asphalt pavement varies depending on the area and road administrator because of the differences in meteorological and maintenance conditions. JH will continue detailed surveys to verify the characteristics of porous asphalt pavement.