Noise Reduction Effect of Double-Layer Porous Asphalt Pavement

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ABSTRACT: According to our past survey, in the initial period after construction, the double-layer porous asphalt pavement gives an excellent noise reduction effect, compared to that of the single-layer porous asphalt pavement. However, the durability of this noise reduction effect as well as pavement condition thereof are not clear because of the small number of construction sites in Japan. We surveyed noise reduction effects and conditions of pavements over a 5 year period at 7 locations on national highways in Japan. From this survey, it was demonstrated that the yearly change of A-weighted sound power levels (except for 2 locations in snowy regions) is approximately 0.38dB/year for heavy vehicles and approximately 0.85dB/year for light vehicles). Though the conditions of the pavements, such as their permeability, air voids, roughness and rutting has gradually deteriorated, no marked problems have occurred over the course of the 5 year period.

KEY WORDS: Road traffic noise, double-layer porous asphalt pavement, durability of noise reduction effect, sound power level, condition of pavement.

1 INTRODUCTION

In Japan, a porous asphalt pavement, its thickness is 50mm (single-layer), maximum diameter of aggregates is 13mm, designed percentage of air voids is 20%, has been constructed generally. Because of its porous structure, the surface of a porous asphalt pavement is rough compared to that of a dense asphalt pavement. Therefore it is considered that the noise caused by the vibration of tires becomes bigger. The double-layer porous asphalt pavement is constructed using large aggregates (maximum diameter 13mm) for the lower layer (thickness 30-35mm) and by small aggregates (maximum diameter 5-8mm) for the upper layer (thickness 15-20mm) (Figure 1). This structure of double-layer porous asphalt pavement aims to smooth its surface and to keep fluidity resistance. It has been put to practical use as one form of the low noise pavement in Japan since around 1998, because it have been possible to construct both a upper layer and a lower layer at the same time.

In 2000, we measured noise reduction effect at the test track in National Institute for Land and Infrastructure Management (NILIM) in the initial period following construction using test vehicles (Figure 2). Figure 3 shows the noise reduction effect of a single-layer porous asphalt pavement and a double-layer porous asphalt pavement. “Noise reduction effect” is the difference in A-weighted sound power levels when the porous asphalt pavement is compared with a dense asphalt pavement. It was observed that the noise reduction effect of double-layer porous asphalt pavement was 4.5 to 7.9dB (with respect to light vehicles traveling at constant speed between 40 and 80km/h). In the initial period after construction, the double-layer porous asphalt pavement has an excellent noise reduction effect compared to the single-layer porous asphalt pavement.

However, the durability of this noise reduction effect was not clear because of the low number of construction sites in Japan. This report concerns sound power levels and other parameters which demonstrate the condition of pavements surveyed at 7 locations on national highways in Japan over a period of 5 years.

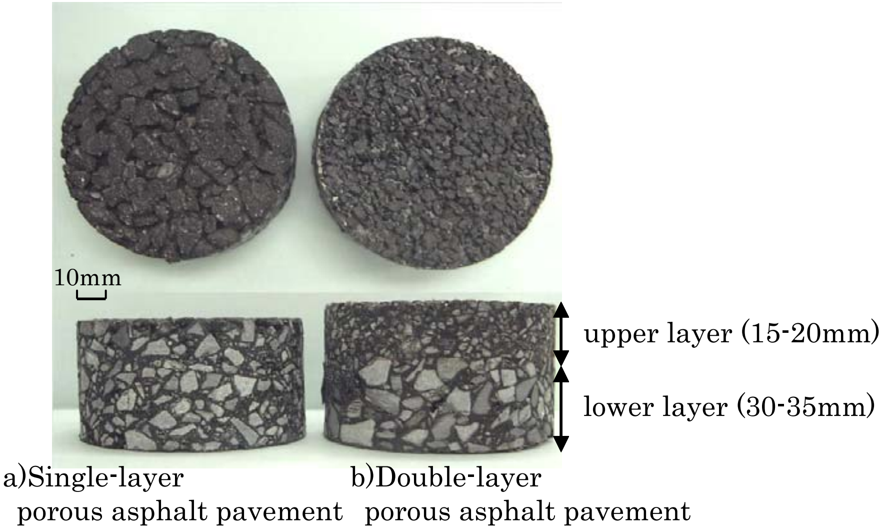


Figure 1: Double-layer porous asphalt pavement

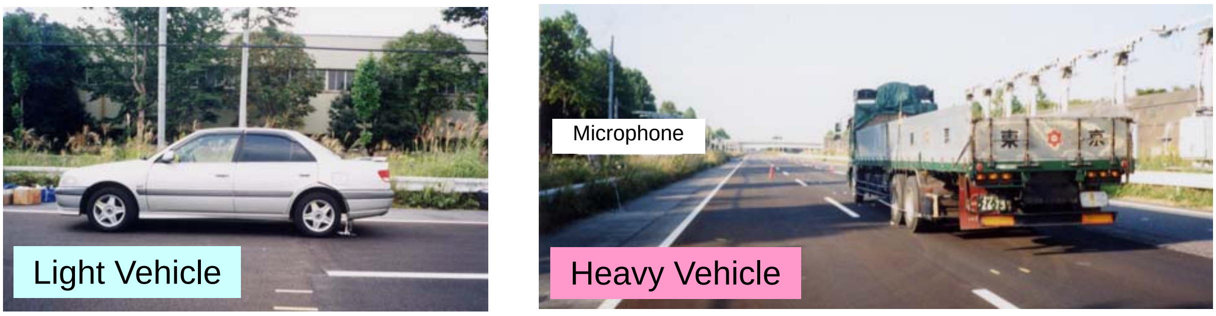


Figure 2: Test vehicles

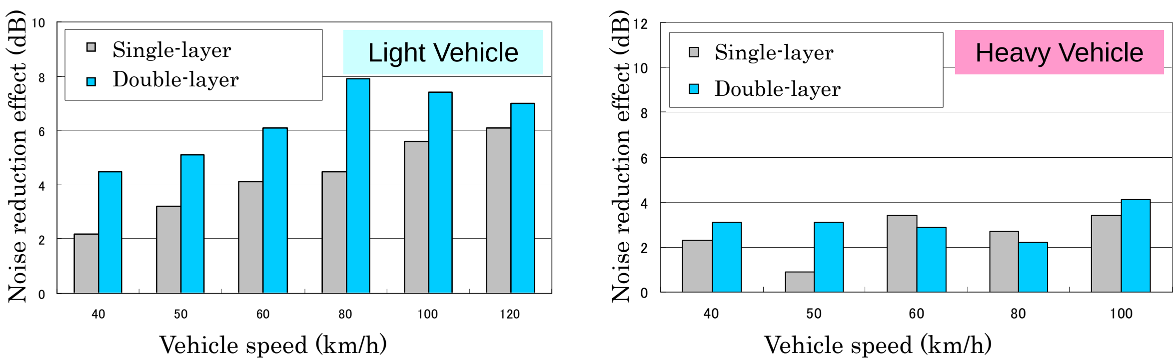


Figure 3: Noise reduction effect of double-layer porous asphalt pavement in the initial period after construction.

2 STATUS OF THE SURVEY LOCATIONS AND CONTENTS OF SURVEY

Figure 4 shows the 7 survey locations. Table 1 gives the statuses of these locations. The double-layer porous asphalt pavements were constructed between 2002 and 2005. Yurihonjo (Route 7) and Jyouetsu (Route 8) are located in snowy regions. The thickness of the upper layer is 15mm or 20mm. The thickness of the lower layer is 30mm or 35mm. The maximum diameter of aggregates in the upper layer is 5mm or 8mm. The maximum diameter of aggregates in the lower layer is 13mm. The designed percentage of air voids is between 20% and 25%.

Table 2 shows the contents of the survey. A “single traveling vehicle” is defined as follows: the car is traveling steadily, the distance from both the vehicle traveling ahead and behind is more than 50m, and there are no other vehicles on the other lane.

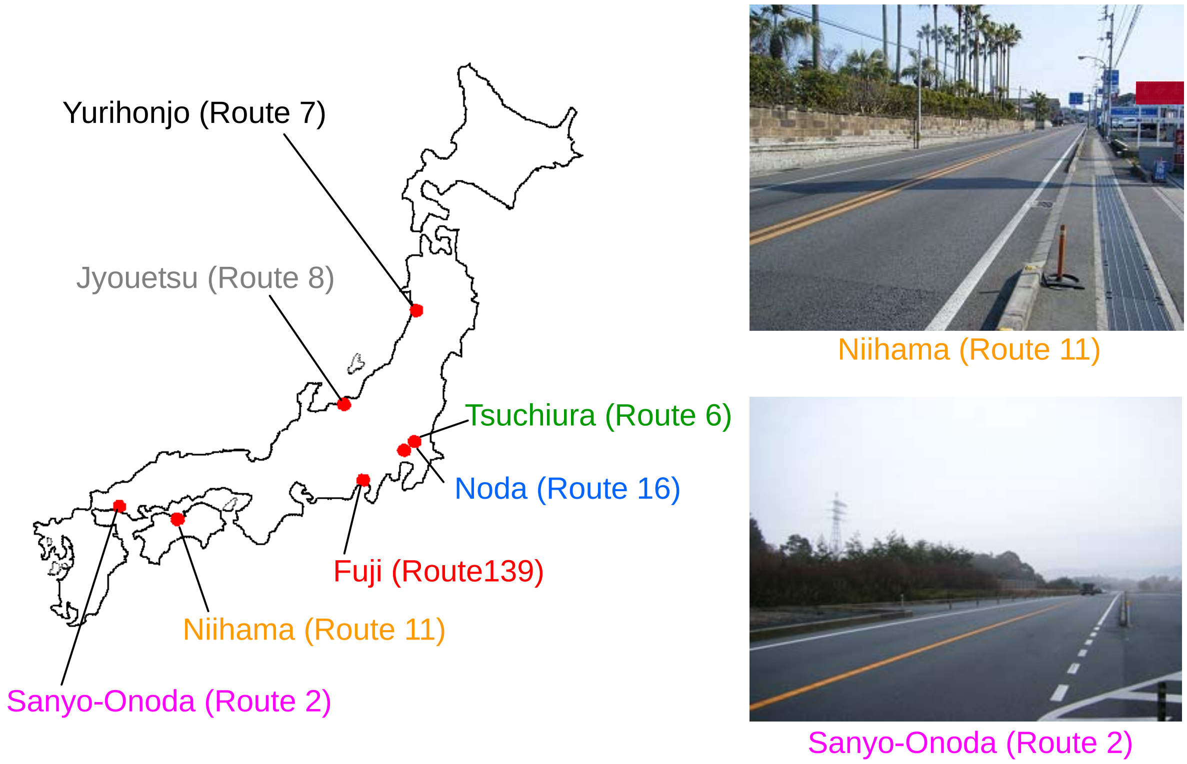


Figure 4: Survey locations

Table 1: Status of survey locations

Survey location			Thickness of pavement (mm)		Maximum diameter of aggregate (mm)	Designed percentage of air voids (%)	Traffic volume of heavey vehicles (vehicles/day /lane)	Ratio of heavey vehicle (%)	Date of survey (month/year) (Months since construction)					
City	Route No.	Construction (month/year)												
Yurihonjo	Route 7	11/02	upper	20	5	23	2,000	18.5	12/02 (1)	03/04 (16)	11/04 (24)	10/05 (35)	10/06 (47)	10/07 (59)
			lower	30	13	23								
Noda	Route 16	11/02	upper	15	5	25	4,700	41.3	12/02 (1)	02/04 (15)	11/04 (24)	11/05 (36)	11/06 (48)	01/08 (62)
			lower	35	13	25								
Tsuchiura	Route 6	09/04	upper	20	8	23	3,000	22.3	–	–	11/04 (2)	11/05 (14)	11/06 (26)	01/08 (40)
			lower	30	13	20								
Jyouetsu	Route 8	10/02	upper	20	8	21	2,500	23.0	12/02 (2)	11/03 (13)	11/04 (25)	11/05 (37)	10/06 (48)	11/07 (61)
			lower	30	13	21								
Fuji	Route 139	03/03	upper	20	5	23	2,300	16.0	03/03 (1)	01/04 (11)	01/05 (23)	01/06 (35)	02/07 (48)	01/08 (59)
			lower	30	13	20								
Sanyo-Onoda	Route 2	03/04	upper	20	5	24	1,000	29.9	–	–	07/04 (4)	08/05 (17)	11/06 (32)	11/07 (44)
			lower	30	13	20								
Niihama	Route 11	05/02	upper	20	8	23	2,500	22.1	–	12/03 (19)	10/04 (29)	10/05 (41)	11/06 (54)	11/07 (66)
			lower	30	13	20								

Table 2: Contents of survey

Contents of survey	Survey method
A-weighted sound power levels of singly running vehicle	Setting of microphone; 7.5m from the center of the lane at a height of 1.2m Vehicle speeds were also observed
Cores of double-layer low noise pavement	Cores were cut and the percentage of air voids measured
Roughness (longitudinal profile)	Measured by a longitudinal profile meter
Rutting (transverse profile)	Measured by a transverse profile meter
Permeability	Measured by in-situ permeability test

3 SURVEY RESULTS

3.1 A-weighted Sound Power Level

Table 3 gives data showing measured numbers of single traveling vehicles by location and year. Figure 5 shows A-weighted sound power levels of single traveling vehicles by the location and month since construction. Each plot is a logarithmic representation of the average A-weighted sound power level. Because the traveling speed of each vehicle was different, these A-weighted sound power levels have been converted to correspond to 50km/h using the following equation.

$$a_i = L_{WA,i} - 30\log_{10}\frac{V_i}{50} \qquad (1)$$

a_i : A-weighted sound power level at 50km/h
$L_{WA,i}$: measured A-weighted sound power level (dB)
V_i : vehicle traveling speed (km/h)

This figure demonstrates the same trend for both heavy and light vehicles. A-weighted sound power levels are invariable or increase by month. In the snowy regions, Yurihonjo (Route 7) and Jyouetsu (Route 8), it is considered that the effects produced by tire chains result in a quicker decrease in the noise reduction effect.

Table 3: Data for numbers of measured single traveling vehicles

	Heavy vehicles						Light vehicles					
	2002	2003	2004	2005	2006	2007	2002	2003	2004	2005	2006	2007
Yurihonjo (Route 7)	54	88	131	143	139	128	36	108	167	174	159	148
Noda (Route 16)	26	56	28	61	58	61	55	100	133	162	131	116
Tsuchiura (Route6)	―	―	67	81	81	95	―	―	163	164	145	133
Jyouetu (Route 8)	41	76	61	86	108	100	56	98	146	153	146	158
Fuji (Route139)	22	75	99	119	109	139	74	134	145	153	157	169
Sanyo-onoda (Route 2)	―	―	54	92	102	86	―	―	82	146	143	163
Niihama (Route 11)	―	75	106	95	115	73	―	122	153	152	164	155

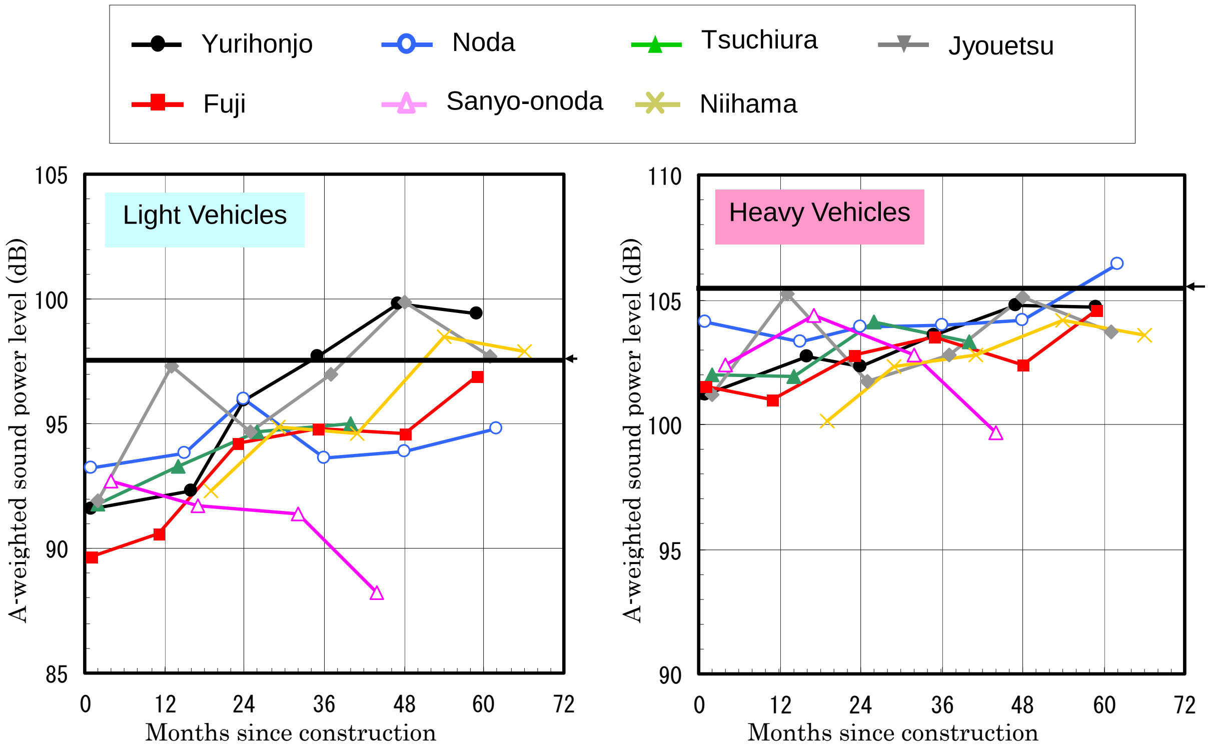


Figure 5: A-weighted sound power levels for single traveling vehicle by location (50km/h)

As shown in Figure 6, the slope of the regression line, representing the yearly change of A-weighted sound power levels, is 0.85dB/year (0.071dB/month) for light vehicles and 0.38dB/year (0.032dB/month) for heavy vehicles. These calculations do not include the data for the snowy regions (black line). These trends are the same as those for the single-layer porous asphalt pavement demonstrated by correction for drainage asphalt pavement of “ASJ-RTN Model 2003”(red straight line) and “ASJ-RTN Model 2008”(blue curved line), suggested by the Acoustical Society of Japan. The double-layer porous asphalt pavement has an excellent noise reduction effect in the initial period after construction, so it is expected that the noise reduction effect will remain longer than that of single-layer porous asphalt pavement.

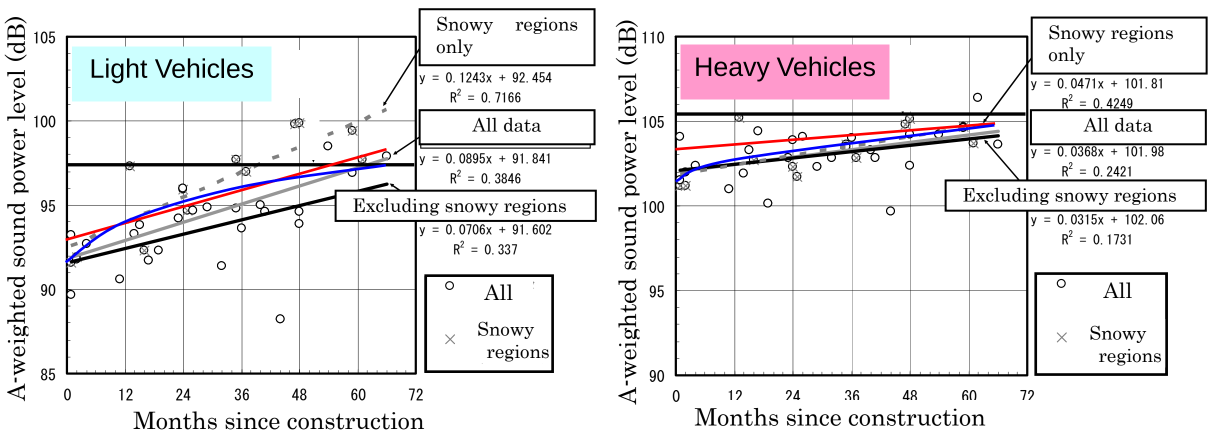
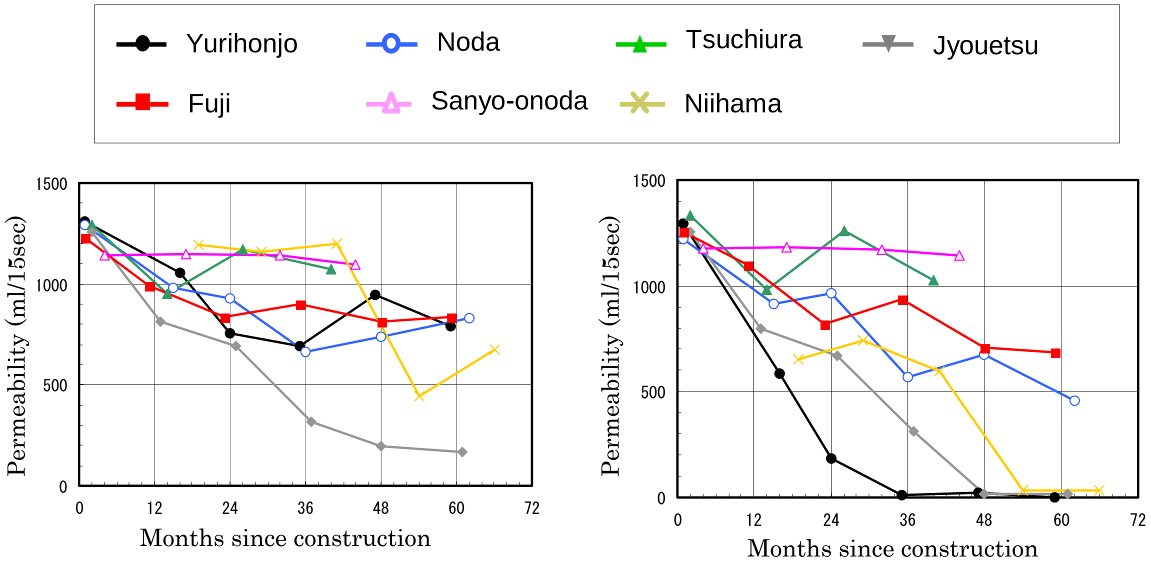


Figure 6: Slope of regression lines

3.2 Permeability

Figure 7 shows the results of the in-situ permeability tests by month since the constructions. The permeability is invariable or decreases by month. Except at a few locations, a certain level of permeability is still generally present at 60 months since construction. In addition, there are high correlation coefficients between permeability and A-weighted sound power levels.

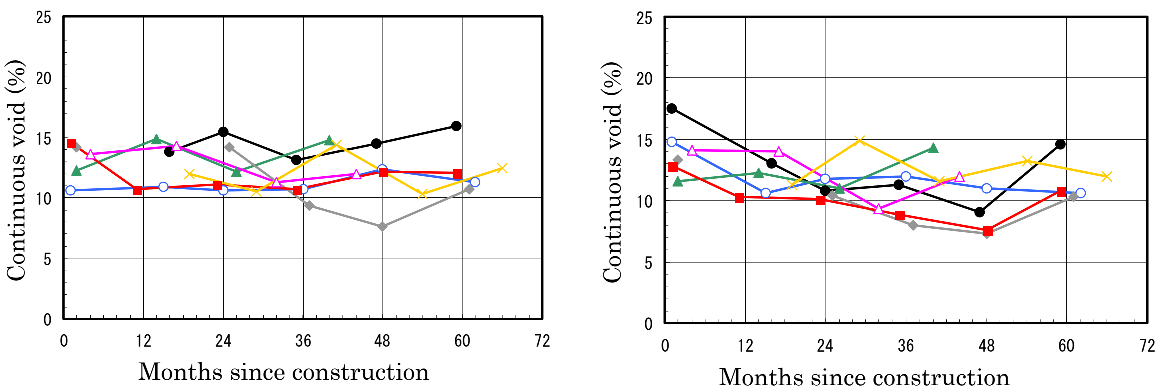


a) OWP b) BWP

Figure 7: Results of permeability tests

3.3 Air voids

Figure 8 shows the percentage of air voids measured from the cores of double-layer porous asphalt pavements. Air voids gradually decrease with months since construction.



a) OWP b) BWP

Figure 8: Percentage of air voids

3.4 Roughness and Rutting

Figure 9 shows the roughness (longitudinal profile) around the survey location by number of heavy vehicles passing since construction. Figure 10 shows the rutting (transverse profile) around the survey location by number of heavy vehicles passing since construction. There is no marked deterioration in values, except at a few locations. Amongst the 7 locations, Yurihonjo (Route 7) is the snowiest region. It is considered that tire chains and the clearing of snow may affect the surface of the pavement.

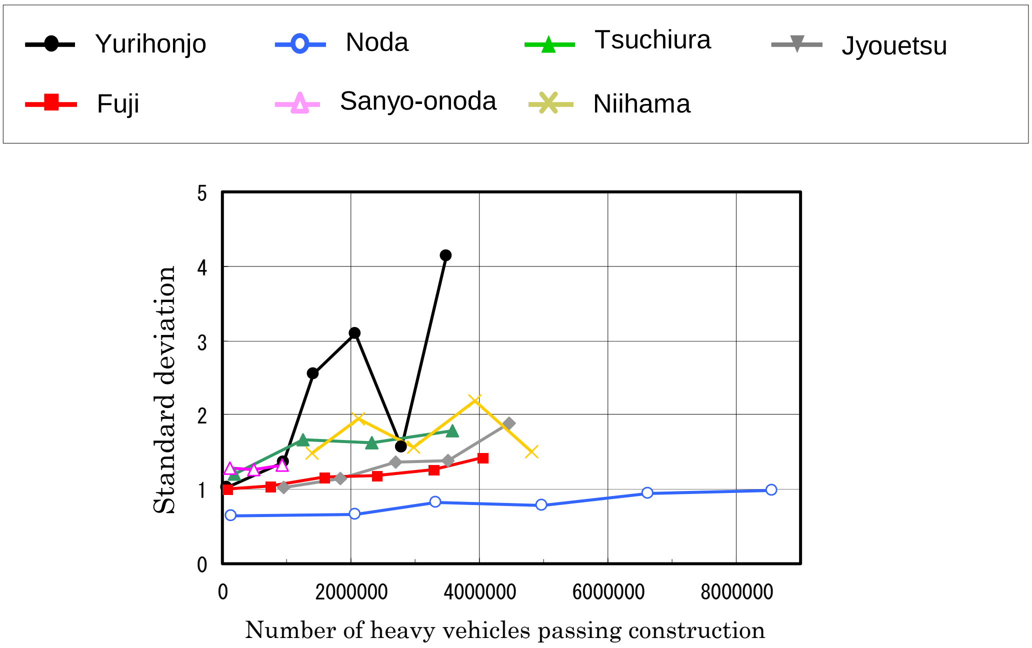


Figure 9: Roughness (longitudinal profile) around survey locations

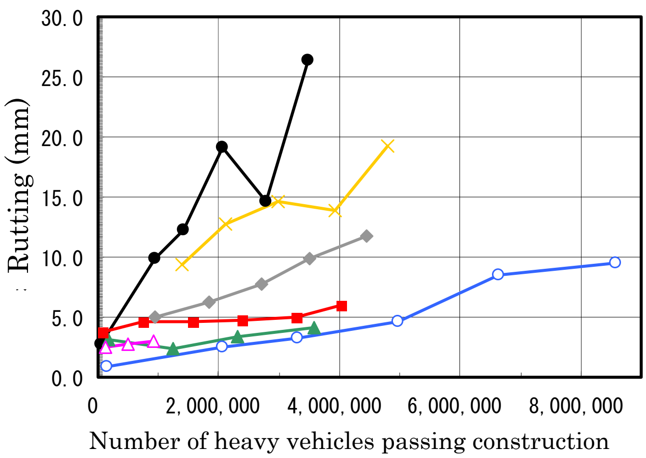


Figure 10: Rutting (transverse profile) around survey locations

4 CONCLUSION

In our past survey of a test-track in the initial period after construction, it was observed that the noise reduction effect for double-layer porous pavements was 4.5 to 7.9dB (with respect to passenger cars traveling at a constant speed between 40 and 80km/h).

From the 5-year survey at 7 points on national highways in Japan, it was observed that the durability of the noise reduction effect in double-layer porous asphalt pavements (except for 2 locations in snowy regions) was approximately 0.38dB/year for heavy vehicles and approximately 0.85dB/year for light vehicles. There is no marked deterioration, and these trends seem to same as those for the single-layer porous asphalt pavement. Because the double-layer porous asphalt pavement has an excellent noise reduction effect in the initial period after construction, it is expected that the noise reduction effect will remain longer than that of single-layer porous asphalt pavement.

Although the condition of the pavements, such as their permeability, air voids, roughness and rutting, has gradually deteriorated, no marked problems have occurred over the course of the 5 year period.

It is considered that the double-layer porous asphalt pavement is one of the most excellent low noise pavement which we can now practical use. As the next step, we correct more data and work out the requirement of application.

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