A study on comparison of noise reduction effect of single-layer drainage asphalt pavement and double-layer drainage asphalt pavement: Part 2 long-term change of sound power level and frequency characteristic

Tomotaka UETA[1]; Kenichi ISHIKAWA[2]; Hisho MORI[3]; Eiji NOGUCHI[4];
Motoomi YOSHIDA[5]; Masami KOKUSHO[6]; Hironori NAGAOKA[7]
[1-7] Oriental Consultants, Japan

ABSTRACT

Using data identical to where described in "Part 1 Sound Power Level and Frequency Characteristics in Initial Construction", The purpose is to study long-term change of sound power level and the frequency characteristic by comparing the single-layer drainage asphalt pavement and double-layer drainage asphalt pavement. It is found that sound power level is calculated, by 6.9log (y+1) [y is equal to years after construction] at light vehicles, 3.0log (y+1) at heavy vehicles. A comparison of initial construction and 70 months after construction for the frequency, A-weighted power spectrum increase uniformly in full range at single-layer drainage asphalt pavement, and increase slightly near the peak frequency at double-layer drainage asphalt pavement. In addition to, equivalent continuous A-weighted sound pressure level of double-layer drainage asphalt pavement is lower than that of single-layer drainage pavement by 2.0-2.5dB.

Keywords: Double-layer drainage asphalt pavement, Frequency characteristic, Power level
I-INCE Classification of Subjects Number(s): 52.3

1. INTRODUCTION

As shown in the paper "Part 1 Sound Power Level and Frequency Characteristics in Initial Construction", double-layer drainage pavement (hereafter referred to as the Double Layer) has gradually proliferated at construction sites, and has entered into practical use. Therefore, study data was collected from experimental construction sites and re-examined to identify the long-term changes in power levels, noise reduction effect, and frequency characteristics. A comparison of this reanalyzed data with the conventional drainage pavement (Single Layer) models summarized in ASJ RTN-Model 2008 are herein described.

2. DATA FOR STUDY

2.1 Study target place

Table 2.1 summarizes particulars of the target sites of the reanalysis. Examination of the noise reduction pavement that sets a high value on durability and has a lower layer of the Double layer that is composed of typical dense asphalt pavement (hereafter referred to as the Thin Layer) has the data label ⑥. While a long-term examination of the power level formulae was conducted for data sets ①–⑥, including a follow-up survey conducted over six years, the Thin Layer examination was based

[1] ueta @oriconsul.com [2] ishikawa-kn@oriconsul.com [3] mori-hs @oriconsul.com
[4] noguchi-ei@oriconsul.com [5] yoshida-mt@oriconsul.com [6] kokusho@oriconsul.com
[7] nagaoka-hr@oriconsul.com

on only one construction site (⑥) on the national road Route 1.

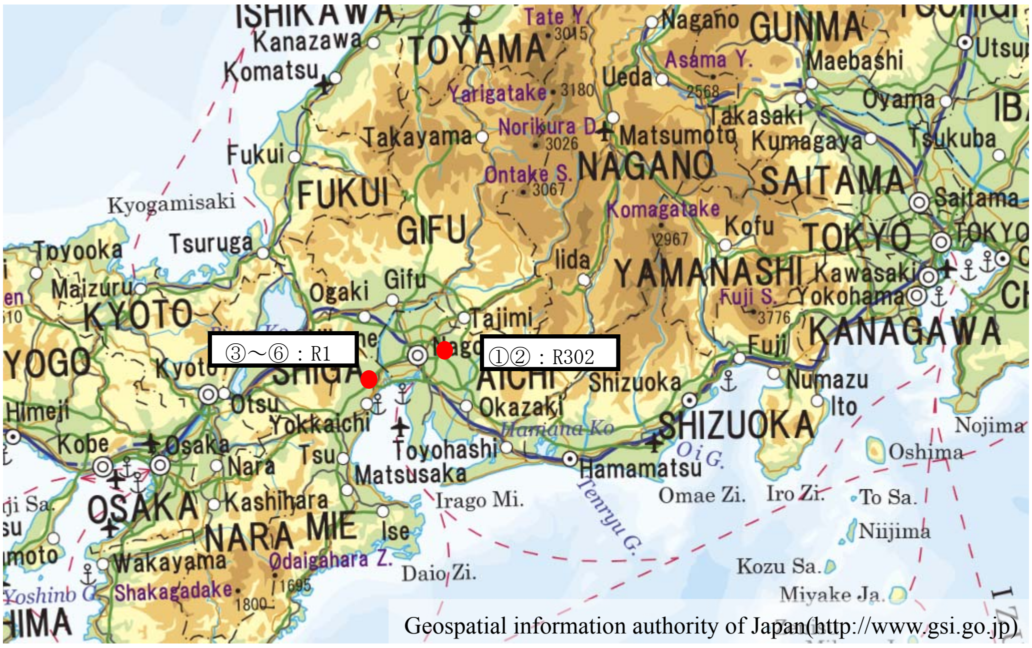

Fig. 1.1 Locations of data collection sites

Table 2.1 Pavement history and structure of data-collected places

Data-collected place		Pavement structure						
Route No.	Constraction date	No.	Thickness of pavement (mm)		Maximum chipping (mm)	Void content (%)	Types of pavement
R302	1999/6/21	①	Top	20	5	23	Double-layer
			Bottom	30	13	25	
		②	—	50	13	20	Single-layer
R1	2000/2/26	③	Top	15	5	23	Double-layer
			Bottom	45	20	23	
		④	Top	15	5	20	Double-layer
			Bottom	35	13	20	
		⑤	—	50	13	20	Single-layer
		⑥	Top	15	5	20	Thin layer
			Bottom	35	20	– (asphalt)	

2.2 Data collection method

The data collection method was identical to that described in "Part 1 Sound Power Level and Frequency Characteristics in Initial Construction"

3. COMPARATIVE PERFORMANCE OF THE DOUBLE-LAYER DRAINAGE PAVEMENT

3.1 Comparison of long-term changes of power levels

At three sites where the Double Layer had been constructed, we conducted a data follow-up survey for a continuous period of 80 months (6 years, 8 months) immediately after construction. Next, we determined the power level velocity dependency of individually driven vehicles, which consisted of two-type classification. Based on the finalized power level velocity dependency, the power levels adjusted to a driving speed of 60 km/h were calculated, and their long-term changes were obtained.

The power level formulae at each point of time were calculated on the basis of the data collected from 50 to 100 units of both types of vehicles.

3.1.1 Long-term changes in light vehicles

Figure 3.2 shows results from our analysis of the long-term changes of light vehicles. Three types of long-term change lines are evident. First is the inclination of the results from actual measurements, second is the inclination of the long-term change in the Single Layer from the ASJ 2008, 7.3 log(y + 1) [y = the number of years passed after construction], and third is the approximation of the survey data to the inclination of the data from the ASJ 2008.

For the light vehicles, the actual measurements resulted in a value of 6.9 log(y + 1), roughly matching the 7.3 log(y + 1) of the light vehicles in the ASJ 2008.

In the figure, the average difference in the light vehicle power levels from the Single Layer formula for the ASJ 2008 is approximately 3 dB with every long-term change inclination being adjusted to match. By extrapolating a regression formula, we observe that it takes approximately 10 years or more for these power levels to exhibit the same level as that of the dense asphalt pavement of the ASJ 2008. This implies that the noise reduction effect of the Double Layer is sustained for a long period of time.

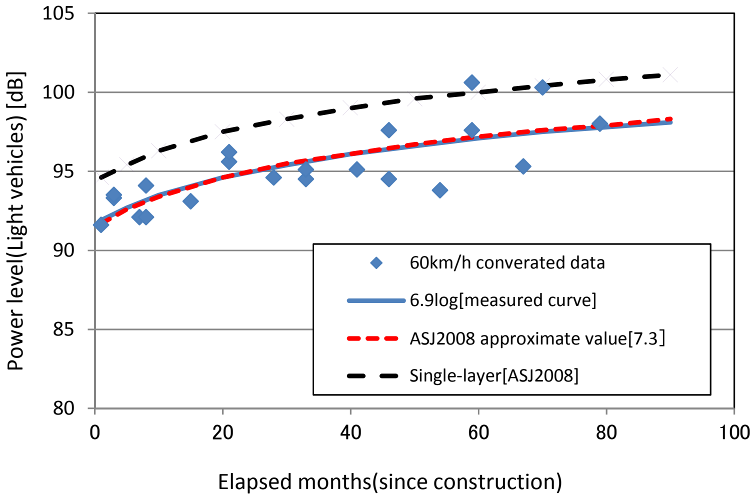

Fig. 3.2 Long-term changes of light vehicle power levels on drainage pavement

3.1.2 Long-term changes in heavy vehicles

Figure 3.3 shows results from the analysis of the long-term changes of heavy vehicles, demonstrating three types of long-term change lines. First is the inclination of the results from the actual measurements, second is the inclination of the long-term change in the Single Layer from the ASJ 2008, 3.6 log(y + 1) [y = the number of years passed after construction], and third is the approximation of the survey data to the inclination found in the ASJ 2008.

For heavy vehicles, the actual measurements resulted in the value 3.0 log(y + 1), roughly matching the 3.6 log(y + 1) of the light vehicles in the ASJ 2008.

In the figure, the average difference of the light vehicle power levels from the Single Layer formula in the ASJ 2008 is approximately 1 dB with every inclination of long-term changes being adjusted to match. By extrapolating a regression formula, we can see that it takes approximately 10 years or more for these power levels to exhibit the same level as the dense asphalt pavement in the ASJ 2008. This implies that the noise reduction effect of the Double Layer is sustained for a long period of time.

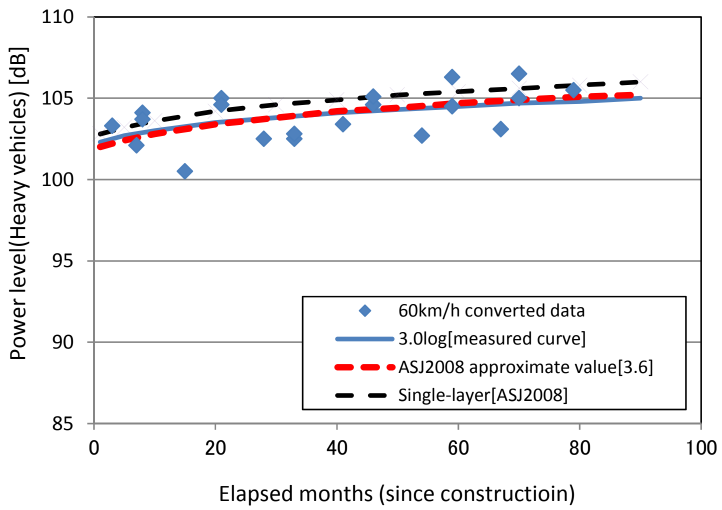

Fig. 3.3 Long-term changes of heavy vehicle power levels on drainage pavement

3.2 Comparison of power levels in initial construction

To determine differences in frequency characteristics among pavement types, we compared the power levels of a test passenger car (See Fig. 3.4) being driven at a speed of 50 km/h on each of the pavement types, including the ASJ 2003 dense asphalt pavement. The study was conducted on national road Route 1, which comprises all of the pavement types.

Figure 3.4 The test passenger car used for the frequency characteristics test

While the Thin and Single Layers show almost the same frequency characteristics approximately six years (70 months) after construction (Fig. 3.6), the Double Layer continues to demonstrate noise level reductions in the frequency zone of 1000 Hz or more, although its noise level increases to a level similar to that of dense asphalt pavement in frequency levels lower than 1000 Hz.

Compared to the data eight months after construction (Fig. 3.5), the noise level increases by approximately 10 dB in the frequency zones of 400 Hz or lower and 1000 Hz or higher. At approximately 500 Hz, where the Double Layer shows a peak, the increase in the noise level stops at approximately 5 dB, showing that the frequency noise reduction effect around this peak continues for a relatively long time.

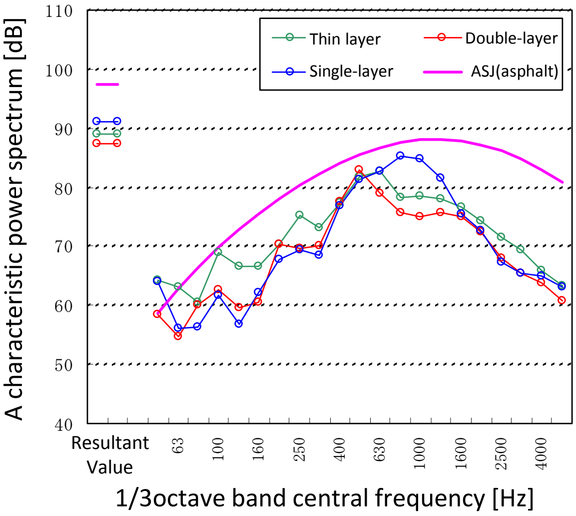

Fig. 3.5 Frequency characteristics of the test passenger car on drainage pavements (8 months after construction)

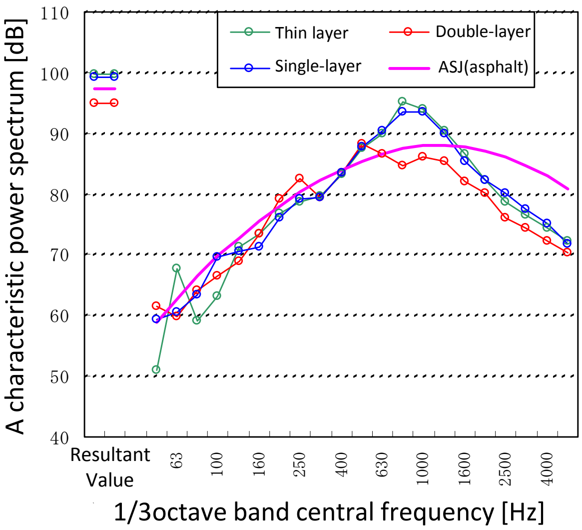

Fig. 3.6 Frequency characteristics of test passenger car on drainage pavements (70 months after construction)

4. COMPARISON OF ACTUAL MEASUREMENT VALUES AND ESTIMATED VALUES OF THE EQUIVALENT NOISE LEVELS

For the study target sites where power levels were examined, a comparison was made between the noise levels obtained by an estimation formula on the basis of corrected measured noise levels, as described in the previous section for power levels and long-term changes, and noise levels that were calculated by a formula based on the measured noise levels applied with corrections for the drainage pavement road surfaces in the ASJ 2008

Table 4.1 shows the relevant corrections to the drainage pavement road surfaces that were used in the estimated calculation. Equivalent noise levels were estimated on the basis of the corrections of the power levels of the Double Layer collected in the previous year, as shown in the table. The results show that the measured values and the calculated values roughly match, although there is approximately a 1.5-dB difference (standard deviation) between them (Fig. 4.1).

Next, the measured values were compared with the noise levels calculated using the power level formula in ASJ 2008 and applied with a correction for the drainage pavement road surface. The results, as shown in Fig. 4.2, show that the dispersion of the calculated values is similar to that in Fig. 4.1, but there is a noticeable difference of 2 to 2.5 dB. This difference seemingly indicates the Double Layer's superiority to the Single Layer in its noise reduction effect for equivalent noise levels in the ASJ 2008.

Table 4.1 Corrections relevant to drainage pavement road surfaces

Type	Vehicle type	
Estimation formula (Double Layer)	Light vehicles	Correction = −8.6 + 6.9 log(y + 1)
	Heavy vehicles	Correction = −4.1 + 3.0 log(y + 1)
ASJ 2008 (Single Layer)	Light vehicles	Correction = −5.7 + 7.3 log(y + 1)
	Heavy vehicles	Correction = −3.9 + 3.6 log(y + 1)

y:the number of years after construction

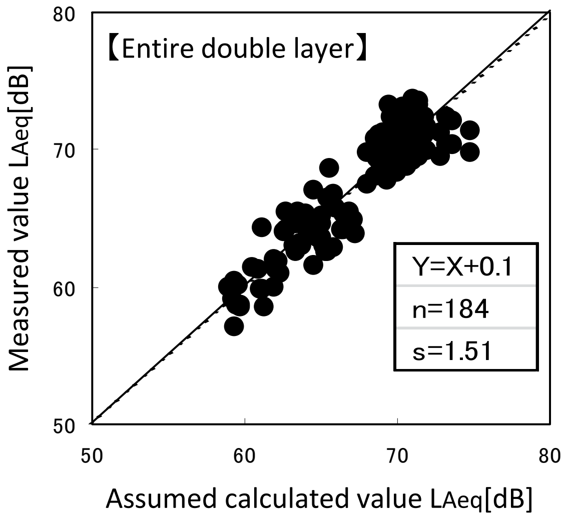

Fig. 4.1 Comparison of measured values with values estimated in the previous section

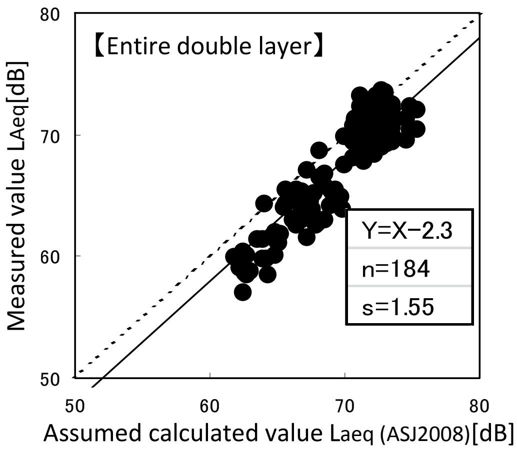

Fig. 4.2 Comparison of measured values with values in the ASJ 2008

5. CONCLUSION

In this study, we presented results from follow-up studies on double-layer drainage pavements experimentally constructed between 1999 and 2003. The data were re-sorted and the points mentioned below were examined after correcting for drainage pavement road surfaces in the ASJ RTN-Model

2008 and for the frequency spectrum with respect to the drainage pavements. The results are as follows.

5.1 Long-term changes of power levels in the Double Layer

Based on the study of data in the 80 months after construction, the long-term change values of the Double Layer was 6.9 log(y + 1) for light vehicles and 3.0 log(y + 1) for heavy vehicles [y = the number of years after construction]. These values roughly match, although are slightly smaller than, the 7.3 log(y + 1) value for light vehicles and 3.6 log(y + 1) for heavy vehicles of the conventional drainage pavement (Single Layer) in the ASJ 2008.

5.2 Frequency characteristics of power levels of Double Layer

The frequency characteristics determined from using a test passenger car in initial construction, and again approximately six years after construction, showed a peak in the frequency at approximately 500 Hz in the Double Layer. The Single Layer, however, showed a relatively uniform increase in power levels throughout the entire zone with respect to long-term changes. The increase in the Double Layer was slightly smaller near the peak.

5.3 Equivalent noise level reduction effect of the Double Layer

The results from the study of the equivalent noise levels at the power level study sites were applied with corrections to the power levels and long-term changes on double-layer pavement road surfaces. Equivalent noise levels were estimated and compared with the measured values. The results showed that the estimated equivalent noise levels matched the measured values well. However, equivalent noise levels calculated by applying the ASJ 2008 correction for the conventional drainage pavement road surface (Single Layer), showed a 2 to 2.5 dB difference from those of the Double Layer. This difference seems to be attributable to the use of the Double Layer.

6. FUTURE RESEARCH

To build on our understanding of long-term changes, it will be necessary to continue to collect and analyze data beyond this study's six-year time frame to at least 10 years after construction, since this is the typical design period for common pavement. In addition, since new products are continuously being developed, and noise reduction effects and durability are improving, it is also necessary to study new construction sites for conducting further continuous studies.

REFERENCES

1. Ueta, Ishiwata, Ishikawa, Kaneki, Matsuoka. Noise Reduction Effect of Double-Layer Drainage Pavement (Fourth Report). The Acoustical Society of Japan, Lecture papers. 2003.9; p. 811-812.
2. Ishikawa, Hosokawa, Ueta, Kaneki, Matsuoka. Sustainability of Noise Reduction Effect of Double-Layer Drainage Pavement on Ordinary Roads. The Acoustical Society of Japan, Lecture papers. 2003.9; p. 813-814.
3. Ueta, Ishikawa, Ohtani, Ohya, Kaneki, Matsuoka. Sustainability of Noise Reduction Effect of Double-Layer Drainage Pavement on Ordinary Roads (Second Report). The Acoustical Society of Japan, Lecture papers. 2004.9; p.929-930.
4. Ishikawa, Ishiwata, Ueta, Kodama, Ohya, Kaneki, Fukui. Sustainability of Noise Reduction Effect of Double-Layer Drainage Pavement on Ordinary Roads (Third Report). The Acoustical Society of Japan, Lecture papers. 2005.9; p. 895-896.
5. Daimoto, Ishikawa, Ueta, Kaneki, Fukui. Sustainability of Noise Reduction Effect of Double-Layer Drainage Pavement on Ordinary Roads (Fourth Report). The Acoustical Society of Japan, Lecture papers. 2006.9; p. 11.
6. Road Traffic Noise Research Committee. The Acoustical Society of Japan "Road Traffic Noise Prediction Model" ASJ RTN-Model 2008. The Acoustical Society of Japan Journal. 2009.4. 65; pp 179-232.
7. Ministry of the Environment. Published data, "Automobile Traffic Noise Status in 2011." 2013. pp