Effect of road surfaces on road traffic noise on the public roads of Japan

--An investigation based on tyre/road noise measurement--

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ABSTRACT

Tyre/road noise measurements on public roads were conducted in order to investigate the effect of road surface condition on vehicle pass-by noise on public road of Japan. Since applying the CPX method to evaluate public road of Japan must be subject to domestic regulations and is considered to pose some safety risks, a quasi-CPX method was employed after its vehicle noise evaluation validity had been confirmed by road tests on a test track. The tyre/road noise measurements by the method on public roads were performed on 2 routes including 3 types of road surfaces -- dense asphalt (DAC), porous asphalt (PAC), and double layer porous asphalt concrete (DLPAC) surfaces. As a result, it was confirmed that the level of tyre/road noise of each road surface type spreads to the range of 4 to 9dB, and that the spread of DLPAC pavement seems to be wider than other surface types.

Keywords: Tyre/Road Noise, Pavement

1. INTRODUCTION

In order to investigate the efficient reduction of road traffic noise, it is important to know the effects of each noise reducing measures [1]. With regard to vehicle noise as a noise source, power unit noise has apparently been reduced by the noise regulations and consequently the contribution of tyre/road noise has relatively increased [2]. For the further reduction of vehicle noise in Japan, Ministry of the Environment has been proceeding with the review of vehicle noise testing method and of its limit value, considering international harmonization. Although the introduction of tyre-rolling noise regulations is included among the reviewing issues [3], it is also essential to take measures by road surface improvement for efficient tyre/road noise abatement. Although there are various reports on relations between the road surface properties and tyre/road noise [4,5,6], for investigating efficient measures, it is necessary to examine the road surface conditions and tyre/road noise on actual public roads.

The objective of this study is to investigate the effect of road surfaces on tyre/road noise, and to estimate the possible reduction of road traffic noise on public road of Japan. This paper reports the results of tyre/road noise measurement on public road of Japan as the first step.

2. Tyre/road noise measurement method

2.1 Measurement method

As the methods for evaluating the effects of road surface on road traffic noise, statistical pass-by method (SPB, ISO 11819-1) and close proximity method (CPX, ISO DIS 11819-2) have been defined [7,8,9]. CPX method has an advantage in its applicability and is widely used internationally. However, there are some problems concerning domestic regulation and safety to apply this method to public road

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of Japan. In this study, a CPX based method modified for application to public road of Japan was used.

Two types of CPX reference tyres proposed in ISO/TS 11819-3, P1 and H1, were used for the measurements. A general passenger car which could equip with both types of the test tyres at rear axle was selected as a test vehicle.

The microphone positions are illustrated in Figure 1. According to CPX method, microphone positions are stipulated to be outer side of tyre in case of using the self-powered vehicle. However, driving a vehicle equipped with microphones at that position is not allowed on public road of Japan by domestic legislation. Therefore the microphone positions of measurement on public road were changed to opposite side of tyre , that is inner positions of tyre (M1 and M2) shown in Figure 1. As the level of tyre/road noise, energy average of the levels measured at front and rear position was adopted for the measurements in each side of the tyre. Overall levels were calculated by the range from 315 to 5000 Hz in 1/3 octave center frequency.

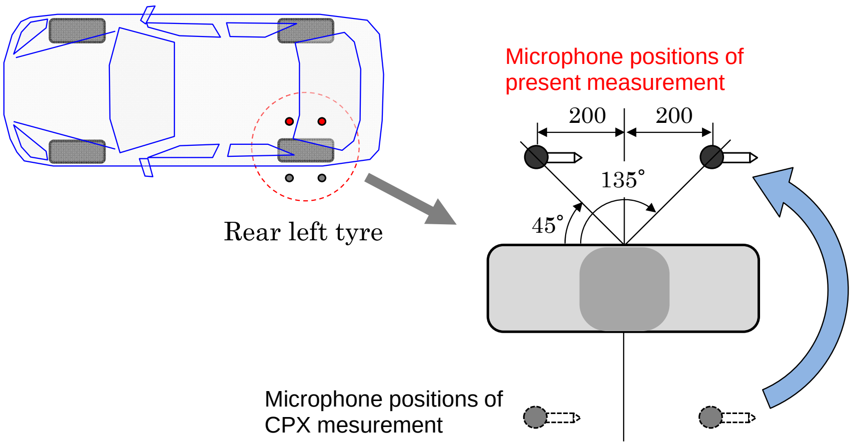


Figure 1 Microphone positions for the measurements

2.2 Validity of the measurement method

In the measurement at inner side of tyre, measured sound pressure levels must be affected by the surroundings. To confirm this point, the level was compared with that measured at outer side. The measurements were conducted on 7 road surfaces on test track shown in Table 1. Surface A is an ISO surface specified in ISO 10844, from B to F are dense asphalt concrete (DAC) pavement or the similar non-absorptive surfaces, and surface G is a porous asphalt concrete (PAC) pavement.

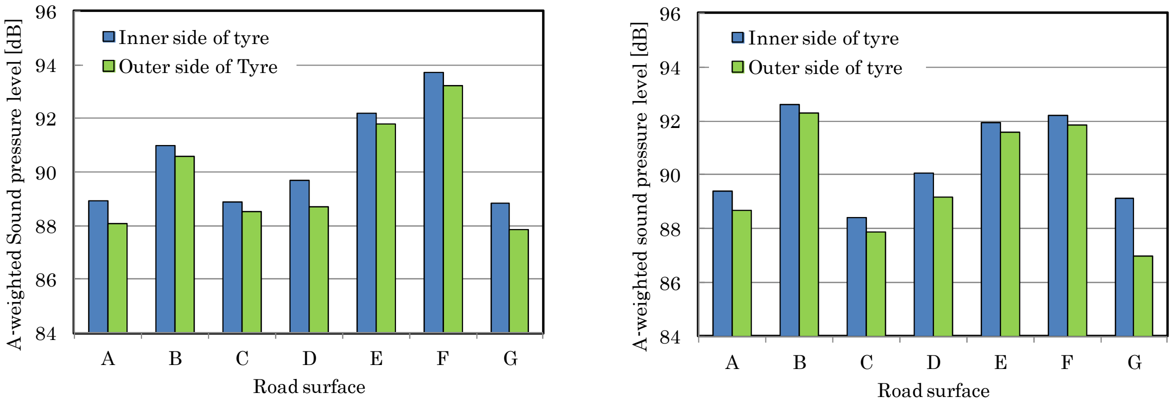
Table 1 Road surfaces on test track

	Road surface type	MPD [mm]
A	ISO surface (ISO 10844)	0.77
B	Flat surface to generate high frequency noise	0.12
C	Open graded asphalt concrete 13	0.93
D	DAC20	0.58
E	DAC20 (Worn, mortal content were removed)	0.81
F	DAC20 (Worn and aggregates are exposed)	1.69
G	PAC13	

*MPD : Mean Profile Depth defined in ISO 13473-1 (1997)

The comparisons between the measured levels at inner side and outer side of the tyre were shown in Figure 2. On the whole, the levels at inner side are higher than that of outer side.

An example of the frequency characteristics of noise on both sides of tyre are shown in Figure 3. The band pressure levels of inner side rises in frequency bands of 1.6kHz, 2kHz, and below 500Hz, and drops in frequency bands of 1k and 1.25kHz. As the similar results for each surfaces, the relative sound pressure level of inner side on an outer side base, is shown in Figure 4. The relative level frequency characteristics are almost similar. These results imply that the noise at inner side of tyre is affected by the acoustic characteristics of the space under the vehicle body. Since it is considered that the effect varies with the structure and dimension of vehicle underbody, it is necessary to take attention to deal with the frequency characteristics of the noise.



(a) Tyre-P1 (b) Tyre-H1

Figure 2 Comparisons of sound pressure levels measured at inner and outer side of the tyre (50km/h)

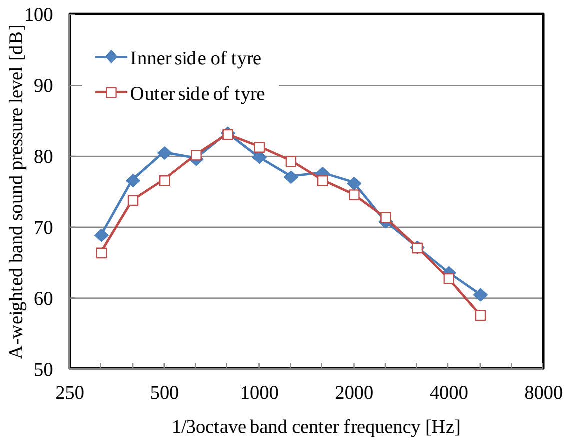


Figure 3 Comparison of frequency characteristics at inner side and outer side (Tyre P1, 50km/h)

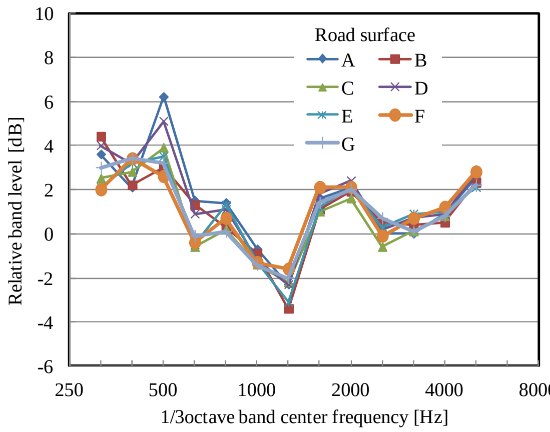


Figure 4 Band sound pressure level at inner side relative to that of outer side (Tyre-P1, 50km/h)

Secondly, the correlation between tyre/road noise at inner side of the tyre and pass-by noise at the point 7.5m left from the center of the lane was investigated when the vehicle running at a constant speed of 50km/h. The vehicle was fitted with tyre-P1 to all four wheels. The measurement was performed on 4 road surfaces on public road in addition to 7 road surfaces on test track shown in Table 1. The results are shown in Figure 5. A strong correlation was observed between the both levels.

It seems to be applicable to evaluate the difference of tyre/road noise caused by difference of road surface conditions if the test vehicle is fixed.

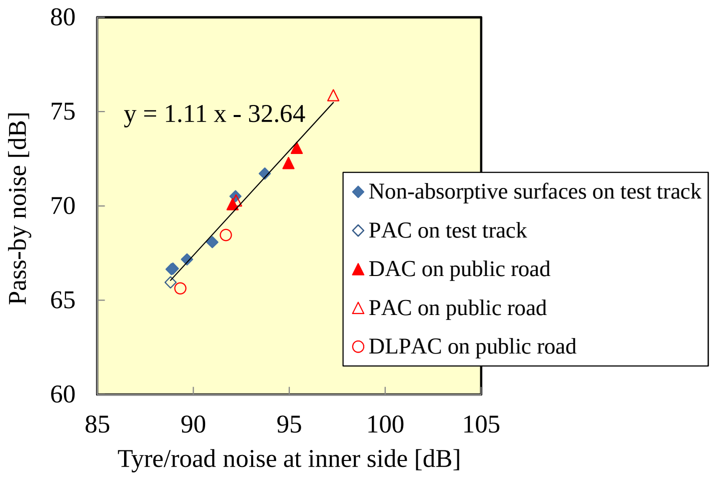


Figure 5 Relation between tyre/road noise at inner side of tyre and pass-by noise (Tyre-P1, 50km/h)
Pass-by noise was measured at 7.5m left from the center of the lane

3. Tyre/road noise measurement on public road

3.1 Measurement method and conditions

In order to investigate the effect of road surface condition on tyre/road noise, tyre/road noise measurements were performed on urban public road of Japan. In the measurements, vehicle position information was obtained simultaneously by GPS to take correspondence of tyre/road noise and the position on the route. 2 routes were selected for the measurements as shown in Table 2, considering wide range of road surface were included. Typical situation of each route is shown in Figure 6. Route-A consists of urban and suburban sections, about 2/3 of the whole are DAC pavement and the rests are PAC. Route-B is one part of a main loop road of Tokyo which has a heavy traffic. PAC and double layer porous asphalt (DLPAC) are paved at plane sections, and DAC is paved at only overpass sections where sound insulation walls are installed.

Table 2 Measurement routes on public roads

	Route A	Route B
Name of road	Urban road in Tsukuba City	Loop 7 of Tokyo
Distance [km]	7.5	12
Lanes in each direction	2 - 3	2
Pavement type	DAC 13 PAC 13	PAC 13 DLPAC 5/13 DAC 13 (Overpass section only)

(a) Route-A (b) Route-B

Figure 6 Typical situations of the routes

The reference speed of the measurement was set to 50 km/h, considering the actual speed of traffic flow. The data at a speed from 40 to 60 km/h were adopted and were corrected to the level of reference speed 50km/h, assuming that the noise is dependent on the speed with 30logV. As a result of the measurement, the averaged data for every 20m segment were adopted.

3.2 Measurement results

The measurement result on route-A using tyre-P1 is shown in Figure 7. Although the route consists of two types of road surfaces, DAC and PAC, the spread of tyre/road noise was up to 5dB. The sound pressure level variation corresponding to the distance from starting point (point-A in Figure 7) is shown in Figure 8. Generally the level of tyre-P1 is higher than that of H1. The level variation range in case of tyre-P1 is wider than that in case of tyre-H1 (about 5dB for tyre-P1, about 4dB for tyre-H1).

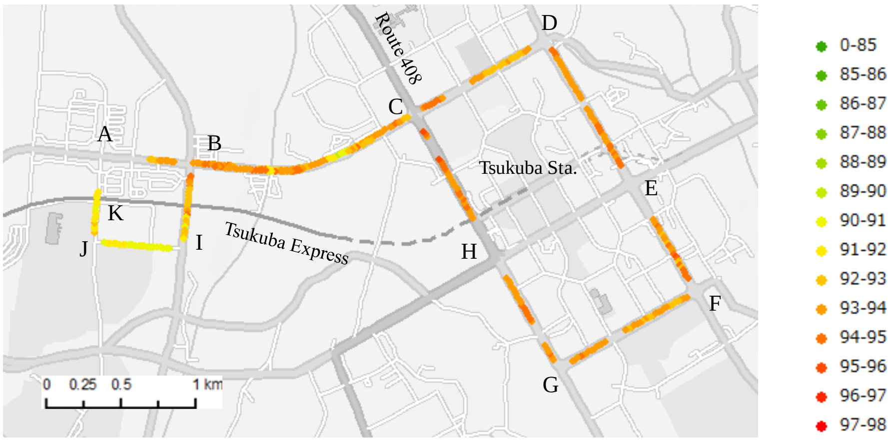
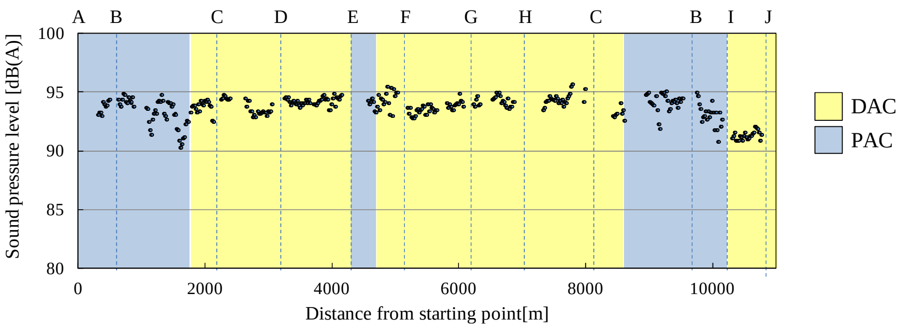
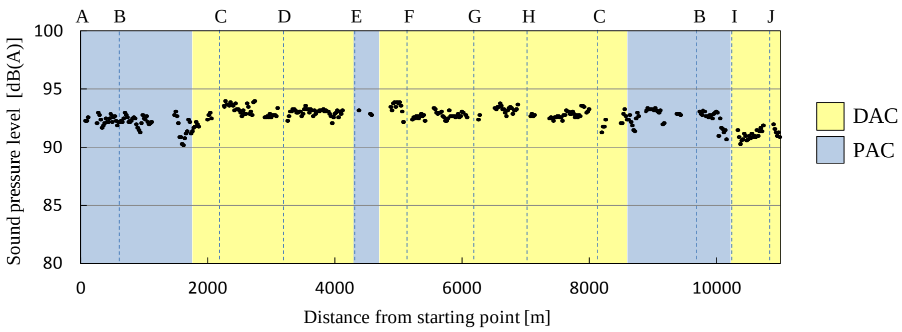


Figure 7 Tyre/road noise in dB(A) corrected to the level of 50km/h (Route-A, tyre-P1)



(a) Tyre-P1



(b) Tyre-H1

Figure 8 Tyre/road noise variations corrected to the level of 50km/h (Route-A)

The similar results in case of route-B were shown in Figures 9 and 10. The variation range was obviously wider than that of route-A. This is because this route includes the sections of DLPAC pavement. Moreover, relatively high level was observed in many part of the PAC pavement sections as compared to route-A. The range of the level is about 11dB for tyre-P1, about 8dB for tyre-H1. Similar to the case of route-A, the variation range of P1 is wider than that of H1.

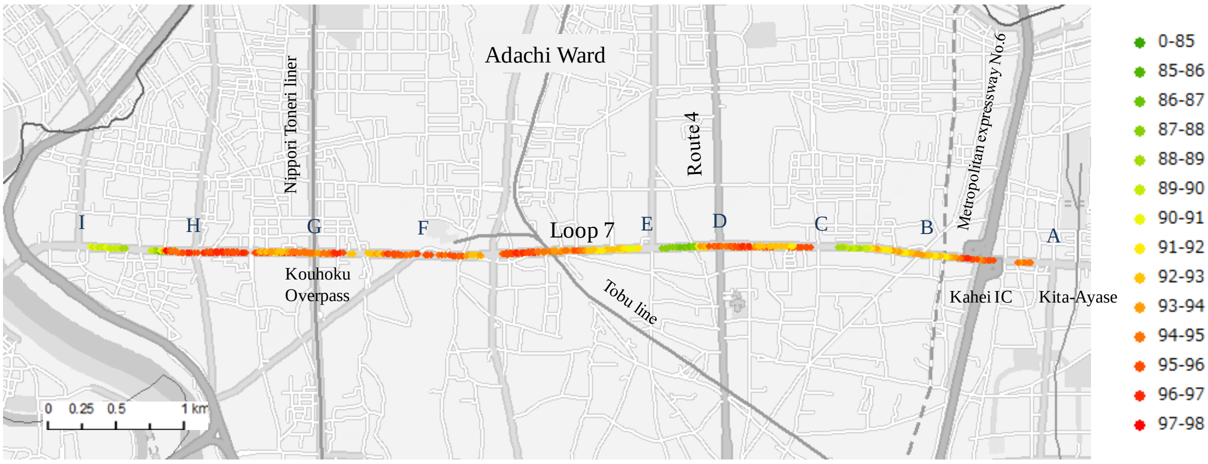


Figure 9 Tyre/road noise in dB(A) corrected to the level of 50km/h (Route-B, tyre-P1)

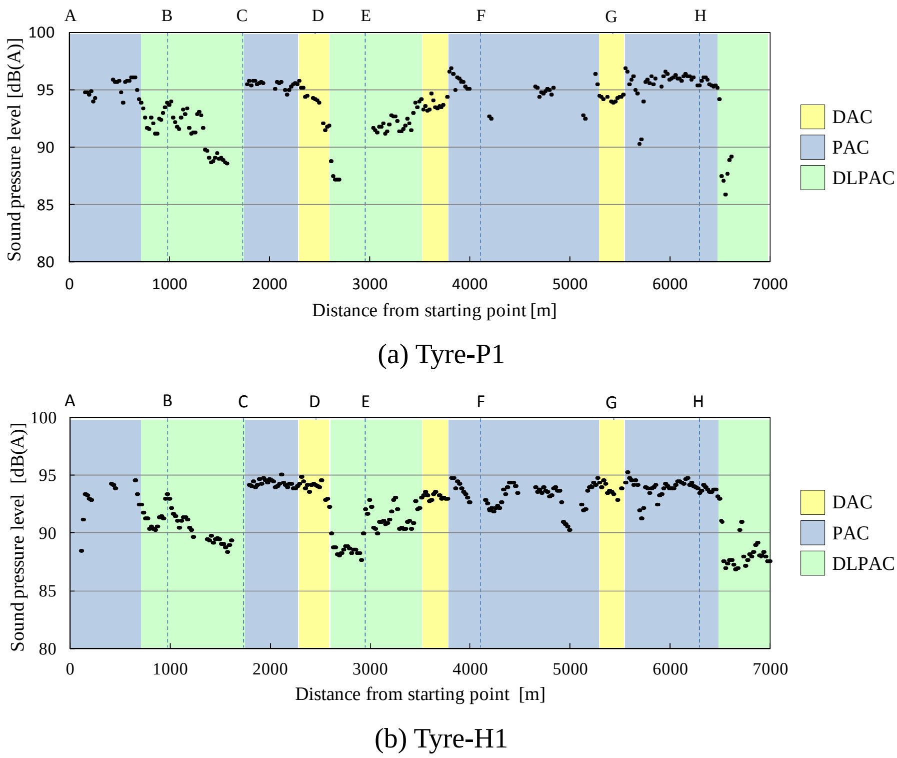


Figure 10 Tyre/road noise variations corrected to the level of 50km/h (Route-B)

The frequency distributions of tyre/road noise based on the results of 2 routes are shown in Figure 11. The average level on DLPAC pavement section is 2.9dB lower than that of PAC in case of tyre-P1, and is 1.6dB lower in case of tyre-H1. In case of tyre-P1, the distribution range of the noise is 7dB on DAC, 5dB on PAC, and 9dB on DLPAC. Similarly, in case of tyre-H1, the distribution range of noise is 5dB on DAC, 4dB on PAC, and 6dB on DLPAC. From these results, although the advantage of DLPAC in noise reduction is apparent, the spread of noise distribution is wider than those of other surface types. The appearance of 2 points on DLPAC where obviously different levels were observed are displayed in Figure 12. The road surface of low noise looks highly smooth. On the contrary the serious aggregate removal and the increase of roughness are observed on the road surface of high noise level. This result implies the importance of suitable maintenance of surface condition for DLPAC in order to exhibit its noise reduction performance.

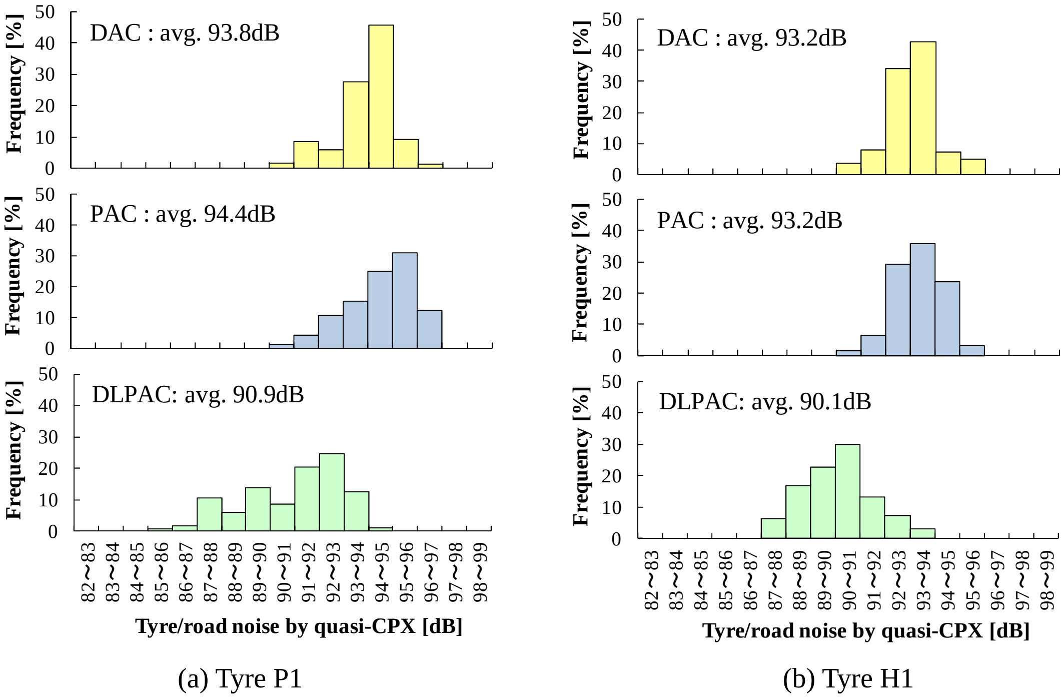
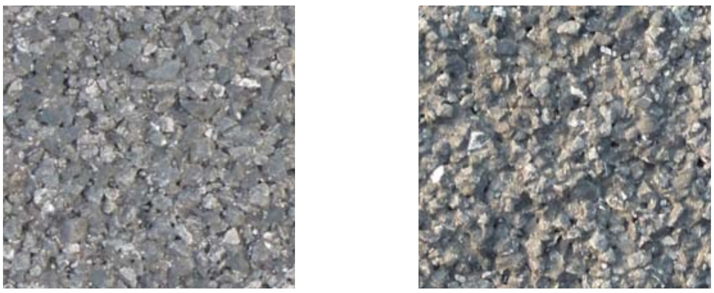


Figure 11 Frequency distributions of tyre/road noise (corrected to the level of 50km/h)



Sound pressure level: 87-88dB Sound pressure level: 92-93dB

Figure 12 Appearance of road surfaces indicating different levels of tyre/road noise (Tyre-P1, 50km/h) in case of DLPAC pavement

4. CONCLUSIONS

Tyre/road noise measurements were conducted using a method applicable to public road of Japan (quasi-CPX method), and the effect of road surface types and conditions on the noise was examined. The conclusions are as follows.

- The effect of road surface on tyre/road noise can be evaluated relatively by the tyre/road noise measured at inner side of the tyre.

- The variation of tyre/road noise on the route was measured, and the frequency distribution on 3 road surfaces, DAC, PAC and DLPAC, was produced. The result shows that the generated noise on each road surface has a range of 4 to 9dB. This result implies the importance of appropriate maintenance of the pavement.
- Although the noise reduction effect of DLPAC is apparent, the spread of noise distribution caused by road surface condition seems to be wider than those of other surface types.

It is necessary to investigate the problems as follows in the future:

- to estimate possible reduction of road traffic noise by road surface improvement
- to investigate efficient measures by comparing the possible reduction by various measures

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