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NOISE REDUCTION EFFECT OF POROUS ELASTIC ROAD SURFACES

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ABSTRACT
We have been conducting research on the porous elastic road surfaces (PERSs), which are made of rubber granules combined with polyurethane resin. PERSs possess reduction effects on road traffic noise, in particular tire/road noise. The effects are much greater than those of drainage asphalt pavements. We carried out experiments for measuring pass-by noise of vehicles on PERSs and the dense graded asphalt pavement commonly used. Results of the experiments show that one of PERSs has the noise reduction effects of 16-19 dB for a passenger car and 6-10 dB for a heavy truck in the speed range of 40-120 km/h. The frequency analysis of the power-by noise reveals an interesting fact that PERSs have a noise reduction effect even in the frequency range of 600 Hz and below, where the drainage asphalt pavement does not have the effect.

1 - INTRODUCTION
PERSs are pavements made of rubber granules, into which used tires are shredded, and polyurethane resin [1]. There are some sizes and shapes in the granules and those used in this paper are 1-2 mm in width, 10-20 mm in length and fiber in shape. PERS is porous and elastic because it is made of rubber granules. Due to these characteristics, the noise generated by vehicles running on PERS is much smaller than that on the dense graded asphalt pavement commonly used. It is identical with the drainage asphalt pavement that PERS has pores; and however it is different from the drainage pavement that PERS is elastic. This is considered why the noise reduction effect of PERS is much larger than that of the drainage pavement.

2 - EXPERIMENTS FOR ACOUSTICAL CHARACTERISTICS OF PERS

2.1 - Experiments for measurements of power-by noise of vehicles
Some kinds of PERS and a dense asphalt pavement were laid on the test track of the Public Works Research Institute (PWRI), and measurements were carried out for power-by noise of vehicles, which ran on the pavements above. A passenger car and a heavy truck were used. Their engine displacements are 1.98 liter and 10.52 liter respectively. Their cruising speeds were 40-160 km/h and 40-120 km/h respectively at 20 km/h intervals, and their cruising modes are those of power-by and coast-by. The heavy truck carried the maximum load of 12 ton. The vehicles ran three times under each case, and arithmetical mean values of the three noise levels measured are those under each of the cases.
A microphone was set up at a point 5.6 m away from the centerline of vehicle lane and 1.2 m above the ground. Further, two ultra-red sensors were installed at points 10 m away from the microphone in the longitudinal direction of test track.

On the other hand, porous elastic panels of rubber granules were attached onto the base layer of pavement with polyurethane resin. The panels were manufactured at a factory, and their porosity is 40% and thickness is 2-5 cm at 1 cm intervals [2]. Two sizes of rubber granules were used; one was about 1 mm in diameter and about 10 mm in length, and the other was about 1.5 mm in diameter and about 15 mm in length.

2.2 - Measurements of normal incidence absorption coefficients

Two kinds of core samples, of which diameters are 98 mm and 28 mm, were prepared from the various porous elastic panels mentioned in Section 2.1. Normal impedance ratios of the samples were measured with the acoustic tube method using two microphones, and then the normal incidence absorption coefficients were calculated from the impedance ratios.

3 - RESULTS OF THE EXPERIMENTS

3.1 - Relationship between noise reduction effects and specifications of PERS

Using PERSs with porosity of 40 % of which thickness is from 2 cm to 5 cm at 1 cm intervals and of which granule sizes varied, noise measurements were conducted. Figures 1 and 2 show their reduction effects on vehicle noise. In a case of the passenger car the largest effects are 16-19 dB by PERS of 3 cm in thickness and of small granules in the speed range of 40-120 km/h. The second largest effects are 13-17 dB by PERS of 2 cm in thickness and of small granules. The smallest effects are 8-9 dB by PERS of 2 cm in thickness and of large granules. PERSs of small granules show the large effects compared with those of large granules. In respect of the relationship between the noise reduction effects and the vehicle speed, the effect is the largest at a speed of 60 km/h and decreases as the speed goes up in cases of PERSs of small granules. With regard to the thickness of PERS, those of 3 cm and 2 cm show larger effects than those of 4 cm and 5 cm for the PERSs of small granules.

In a case of the heavy truck, the largest noise reduction effects are 6-10 dB by PERS of 3 cm in thickness and of small granules in the speed range of 40-120 km/h. The second largest effects are 5-8 dB by PERS of 2 cm and of small granules. The smallest effects are 2-4 dB by PERS of 2 cm and of large granules. In respect of the relationship between the effects and the vehicle speeds, the effect increases as the vehicle speed goes up from 40 km/h to 80 km/h, and it decreases as the speed goes up further to 120 km/h for any specifications of PERS. PERS does not show characteristics in noise reduction effect that the effect increases as the vehicle speed increases like the drainage asphalt pavement. They are also true to the cases of heavy trucks that PERSs of smaller granules possess larger effects and that PERSs of 3 cm and 2 cm in thickness show larger effects than those of 4 cm and of 5 cm.

3.2 - Frequency analysis of power-by noise

With regard to the frequency characteristics of the reduction effects of PERS on the power-by noise of the heavy truck, it has been observed that the effects are 20-22 dB in 100 Hz, 10-12 dB in 500 Hz, 5-11 dB in 1 kHz and 5-7 dB in 2 kHz. They are almost same in the speed range of 40-100 km/h except the frequency range of 800-1,500 Hz (see Figure 3). In the frequency range of 800-1,500 Hz, the noise reduction effects are 4-7 dB at a speed of 40 km/h, 6-10 dB at 60 km/h, 11-13 dB at 80 km/h and 9-11 dB at 100 km/h. This is why the overall noise reduction effects are different by speed as mentioned in Section 3.1. We can account for why the noise reduction effect of PERS is larger than that of the drainage asphalt pavement based on the frequency characteristics of the noise reduction effects of both the pavements as below. While the drainage asphalt pavement has the noise reduction effect in the frequency range of 800 Hz and over, 3 dB in 800 Hz and 6-7 dB in 1 kHz [3], PERS possesses the effect even in the range of 1 kHz and below, in particular 10-22 dB in 600 Hz and below where the drainage asphalt pavement does not has the effect. The reduction effects on power-by noise of the passenger car are 18-27 dB in 100 Hz, 12-19 dB in 500 Hz, 17-21 dB in 1 kHz and 15-20 dB in 2 kHz (see Figure 4). Since the effect is very large, 15-21 dB, in the frequency range of 800-2,000 Hz where the power-by noise of the passenger car is dominant, the overall noise reduction effect is very large, 16-19 dB, as stated in Section 3.1.

3.3 - Normal incidence absorption coefficients

Three sets of samples were prepared for each of the dense graded asphalt pavement and seven kinds of PERSs. Acoustic impedance ratios were measured with the tube method using two microphones, and normal incidence absorption coefficients were calculated from the impedance ratios. Absorption characteristics of the three sets of samples are relatively similar to one another, and their averages are considered as their absorption characteristics.

The normal incidence absorption coefficients of the dense asphalt pavement are nearly nil in all frequency ranges except the range of 1,600 Hz, where it is about 0.2 (see Figure 5). On the other hand, peak values

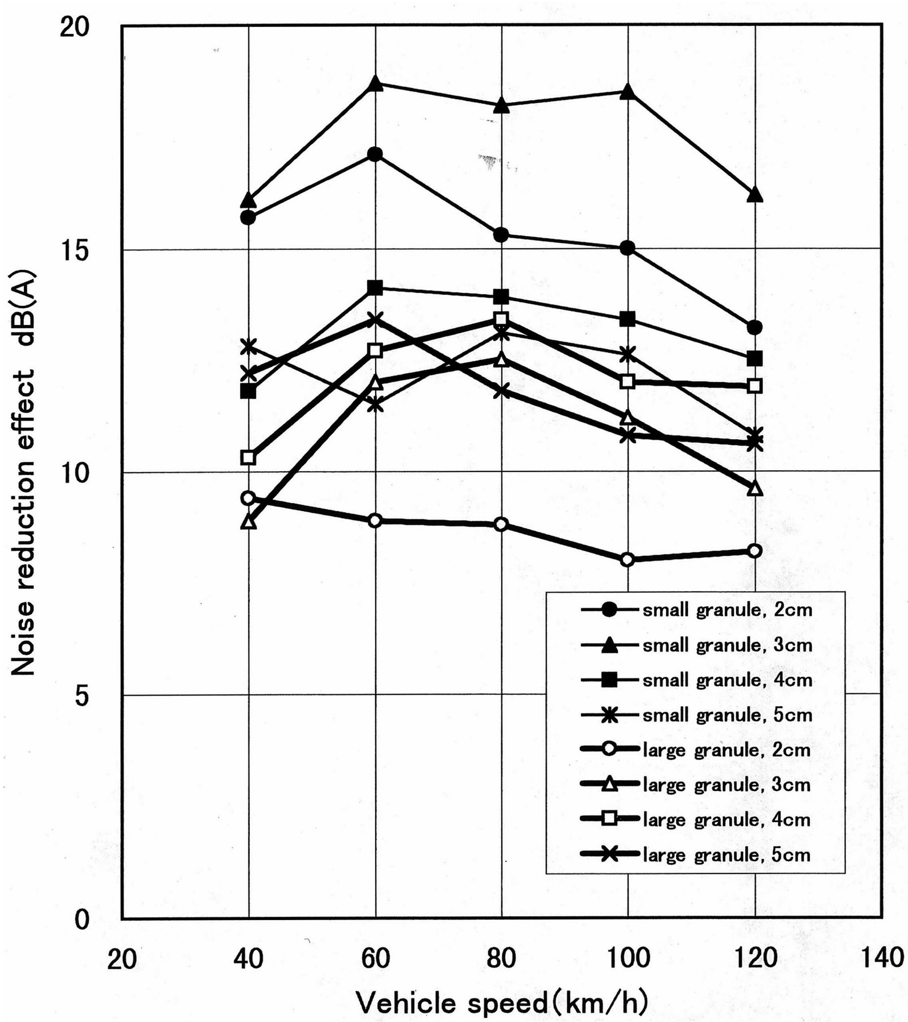

Figure 1: Noise reduction effects of PERS by thickness of PERS and by size of rubber granule in case of power-by noise of passenger car.

of normal incidence absorption coefficients of PERSs are approximately 0.9 from 800 Hz to 2,000 Hz, where their peak values are in different frequency ranges depending on thickness of PERSs. Furthermore, the second peak values are seen in the frequency ranges of four times the ranges of the first peaks. The frequencies of the first peaks are 1,800 Hz for the PERS of 2 cm in thickness, 1,500 Hz for that of 3 cm (see Figure 6), 1,000 Hz for 4 cm, and 850 Hz for 5 cm. The thicker the pavement becomes, the lower the frequency range of peak absorption coefficient becomes. In view of the characteristics mentioned above, the absorption mechanism of PERS is considered to be of resonance type.

4 - CONCLUSIONS

We have derived the following acoustical characteristics of PERS from the results of the various experiments and measurements.

- PERS of 40% in porosity, 3 cm in thickness and of small granules, shows the large noise reduction effect of 16-19 dB for the passenger car and 6-10 dB for the heavy truck in the speed range of 40-120 km/h.
- PERS does not show such a relationship between the noise reduction effect and the vehicle speed as that of the drainage asphalt pavement, that is the effect becomes larger as the speed increases.
- PERS possesses the noise reduction effect even in the frequency range of 600 Hz and below, where the drainage asphalt pavement does not have the effect. This is one of reasons why PERS has a very large noise reduction effect compared with the drainage pavement.

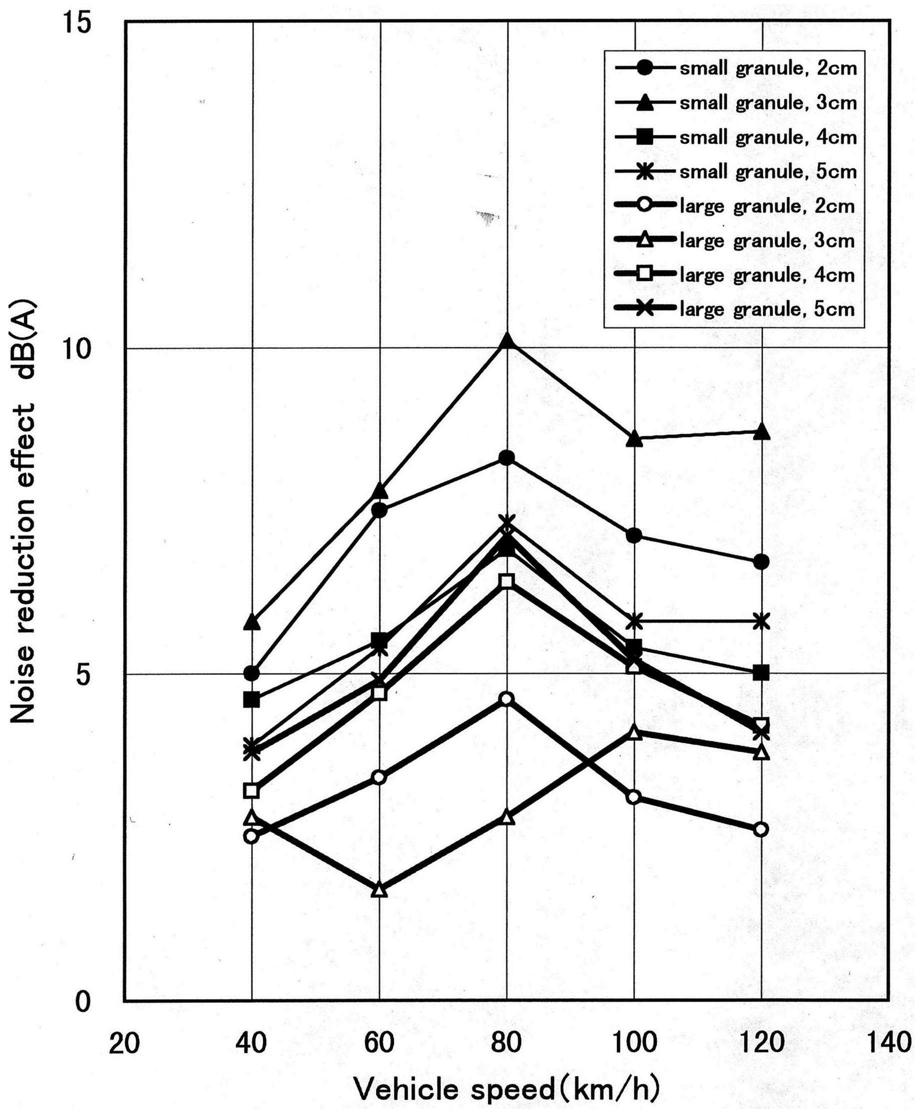

Figure 2: Noise reduction effects of PERS by thickness of PERS and by size of rubber granule in case of power-by noise of heavy truck.

- The peak values of normal incidence absorption coefficients of PERSs are around 0.9 in the frequency range of 800-2,000 Hz, where the frequencies of peak values differ from each other depending on thickness of PERSs.

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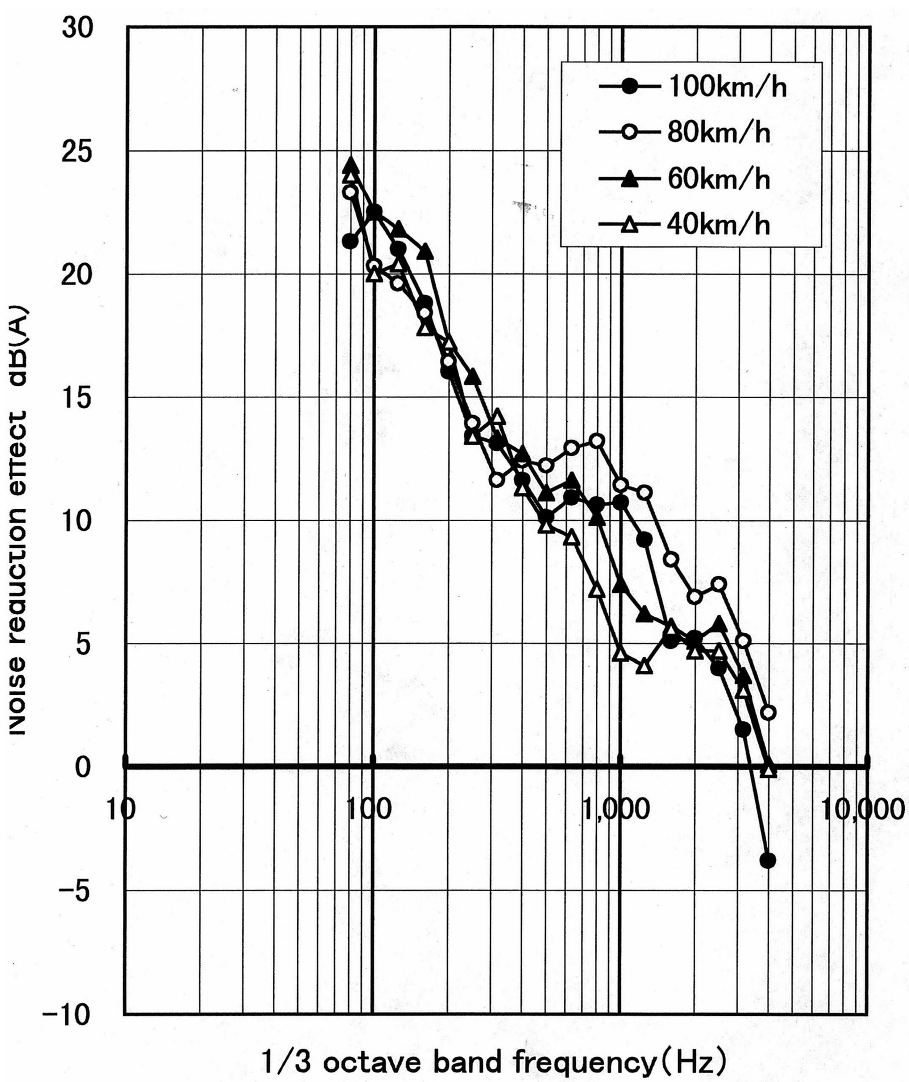

Figure 3: Frequency characteristics of noise reduction effects of PERS (3 cm thick, small granule) in case of power-by noise of heavy truck.

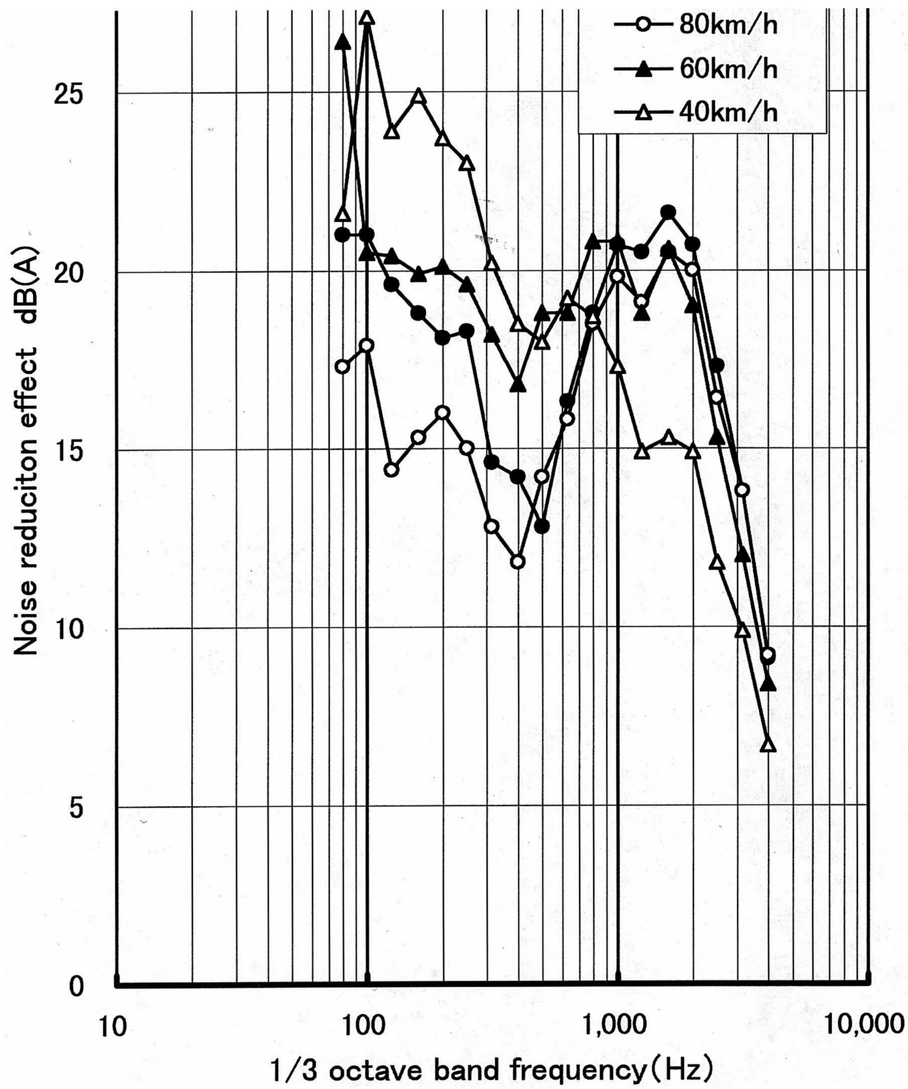

Figure 4: Frequency characteristics of noise reduction effects of PERS (3 cm thick, small granule) in case of power-by noise of passenger car.

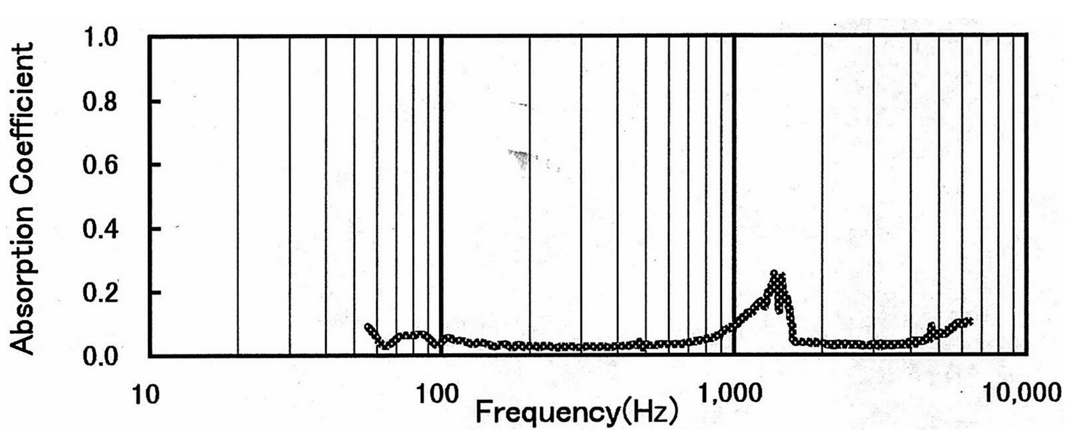

Figure 5: Frequency characteristics of normal incidence absorption coefficient of dense graded asphalt pavement.

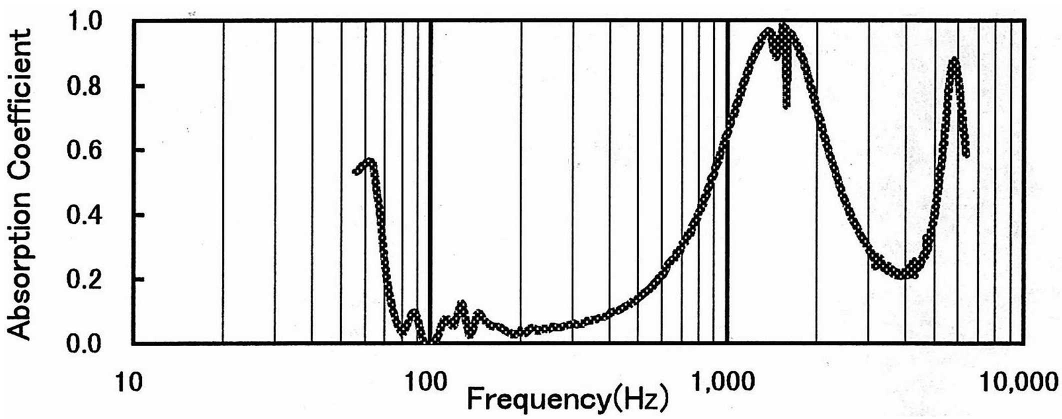

Figure 6: Frequency characteristics of normal incidence absorption coefficient of PERS (3 cm thick, small granule).