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ACOUSTIC PROPERTIES OF POROUS PAVEMENT WITH DOUBLE LAYERS AND ITS REDUCTION EFFECTS FOR ROAD TRAFFIC NOISE

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ABSTRACT
Author studied the reduction effect on road traffic noise by porous pavement including double-layered new type. From some experiments, it was found that new type pavement had high sound absorption in wide frequency range of 800-3kHz, while that the ordinary single layer type had only in narrow frequency range below about 1 kHz. Then, calculations were made about noise propagation from a point source along pavement with assumption of locally reactive surface condition. This study made clear that excess attenuation by both type porous pavement was larger than 5dB by A-weighted level in the area over 10m distance referring to case of an ideal hard pavement. Additional reduction effect by the new type porous pavement compared to that of ordinary type is remarkable as 2-4 dB over 20m distance.

1 - INTRODUCTION
Noise reduction effect of porous pavement had attracted a great deal of attention, and recently, new type one with double layers has more attracted. [1] Author made experiments about acoustical properties of ordinary type porous pavement and new type one, which has fine porous layer over based porous asphalt. Then, author made some calculations about noise propagation along some kinds of pavement and along a new type ideal model. From the calculations, it was found that excess attenuation was larger in the far distance area on both type porous pavements. In this paper, additional noise reduction effect of the new type porous pavement is considered as due to acoustic absorptive characteristics.

2 - ACOUSTIC PROPERTIES OF POROUS PAVEMENT
At first, basic acoustical properties were measured for each pavement of ordinal porous pavement with single layer and imaginary new type double-layered porous pavement as by thin small glass balls, with diameter of 5mm over, ordinary porous pavement. Basic acoustical properties of material were propagation constant and characteristic impedance, and both were measured by author's original tube method which were available not only to fibrous material such as glass wool but also to powder material such as sand, small ballast and glass ball. [2]
From measured results, acoustical surface impedance for any thickness and for any combined materials can be obtained as Z_s by following equation,

$$Z_s = Z\frac{Z_0\cosh p_r l + Z\sinh p_r l}{Z_0\sinh p_r l + Z\cosh p_r l}$$

where, Z is characteristic impedance, p_r is propagation constant, and l is thickness of a surface material, and Z_0 is acoustic surface impedance of an under-layered material.
For examples, Fig. 1 shows propagation constant of porous asphalt with maximum grave size 13 mm referring with glass wool 32 k, and it shows propagation speed in some kinds of medium including powder materials.
Fig. 2 shows measured sound absorption coefficient of porous pavement with typical thickness of 40 mm, and it also shows calculated result of very thick pavement as 300 mm, and that of over-layered by fine

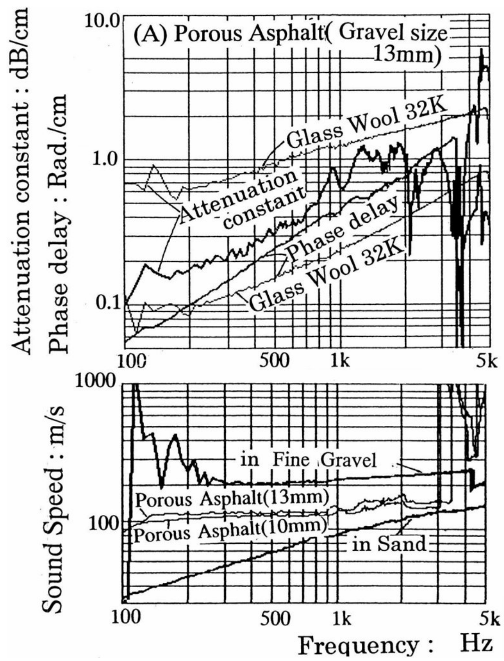

Figure 1: Examples of measured basic acoustical properties.

sand. In this figure, typical porous pavement has high absorption peak below about 1 kHz, and very thick pavement has weak and flat frequency characteristics of sound absorption.

3 - NOISE REDUCTION EFFECTS BY POROUS PAVEMENT

By using acoustic impedance or specific acoustic admittance, reduction effects on road traffic noise were theoretically calculated under assumption of locally reacting condition.
Used formulae are the same in the precise type road traffic noise prediction method proposed by the Acoustical Society of Japan in 1998. [3]

3.1 - Effects due to sound absorption in very near filed

At first, reduction effects on radiation of tire noise were considered as only influence of sound absorption, excluding the direct effects such as suppressing pumping noise.
Geometry for calculation is shown in Fig. 3.
Fig. 4 shows comparisons relative A-weighted sound pressure from a point source on each road surface with typical spectra of running road vehicles. [3] This figure shows that porous pavement is quiet as about 2 dB referring to an ideal dens asphalt pavement (left end in this figure), and typical thickness is most suitable to reduce the noise; i.e. thin and very thick pavement can not make quite. It also shows that absorptive over-layer as glass wool, only in imaginary conditions, is very effective, sand is not effective, and layer of small glass balls (right end) bring additional reduction of 1-2 dB. In this paper, PA, GW, SA are abbreviations for materials as porous asphalt, glass wool and sand.

3.2 - Excess attenuation due to sound absorptive boundary

At next step, excess attenuation along each pavement was calculated by the same way mentioned in (1). As shown in Fig. 5, distributed sound sources model was used for taking account of plural tires, engine and multiple sound reflection between road surface and vehicle's bottom.
Fig. 6 shows noise attenuation with propagation distance, and 0 dB means level at 1 m distance in a free field. In this figure, excess attenuation due to porous pavement is clearly shown over 10 m area. Thickness of porous pavement is effective in noise reduction, although very thick are not effective as over 50 mm.
Fig. 7 shows level differences by changing surface comparing to case of typical porous pavement with thickness 40 mm. It is found that absorptive layer over porous pavement; i.e. double layered pavement, is effective in noise reduction in far distance.

4 - NOISE REDUCTION EFFECTS BY DOUBLE LAYERED POROUS PAVEMENT

Acoustic properties of a new type porous pavement were tested by the same way introduced in 2-. Sound absorption coefficient is shown in Fig. 8. Test ideal pavement had 20 mm thick layer by glass ball with

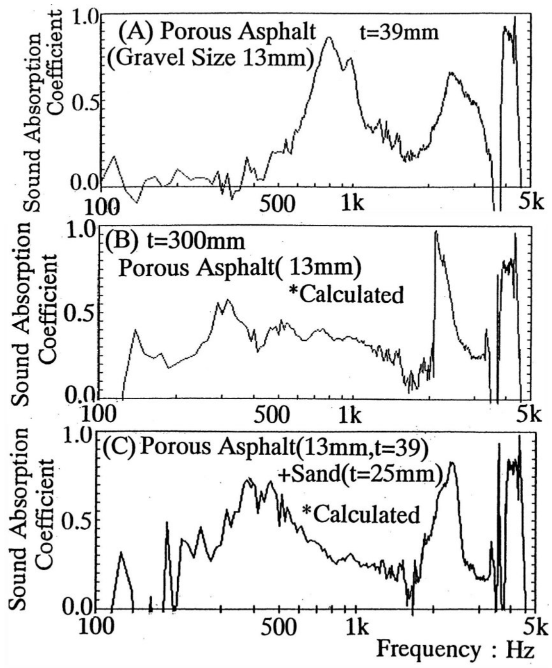

Figure 2: Sound absorption coefficient on each porous pavement surface.

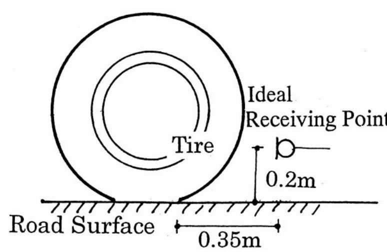

Figure 3: Geometry of near sound filed around tire.

5 mm diameter over porous pavement with thickness of 30 mm, and total thickness was matched to be 50 mm. In this case, high sound absorption is appeared in wide frequency range of 800-3 kHz instead of only 600 Hz and 2.5 kHz.

Estimated noise propagation is shown Fig. 9. The left side is in using typical noise spectra of running vehicles; the right side is in using that on typical porous pavement, which have certain level decreasing in frequency range of 800-4 kHz. [3]

More attenuation by double layered porous pavement comparing to typical porous pavement is appeared in distance over 10m or 20m. Additional reducing effect comes up to 2 dB in the latter case and to 4dB in the former case.

5 - CONCLUSIONS

- For noise reduction, most effective thickness of porous pavement is about 40 mm.
- Double layered porous pavement has high absorption in wide frequency range of 800-3 kHz, and it additional noise reduction effects seems to be 1-2 dB in near filed, and 3-4 dB in far filed comparing to ordinal porous pavement.
- In addition to these reduction effects, smoother surface of double layered pavement may effectively suppress striking tire noise that caused by roughness of road surface.

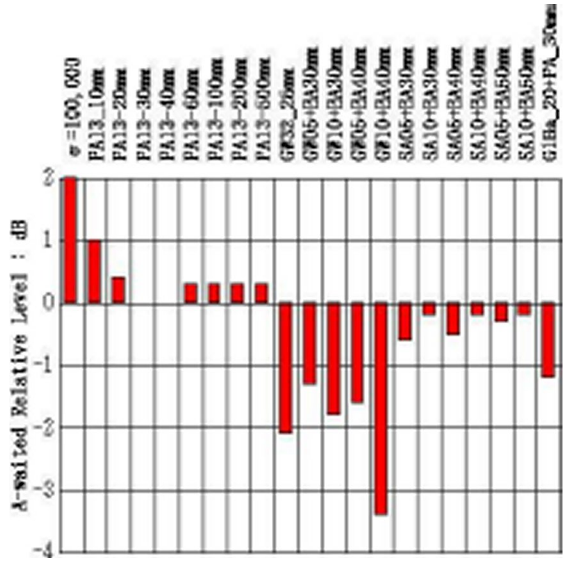

Figure 4: Comparisons of radiated sound pressure on each pavement surface.

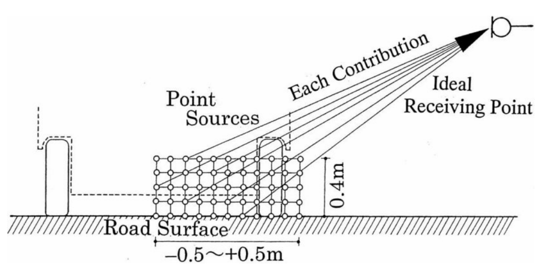

Figure 5: Distributed sound sources model for calculation of excess attenuation.

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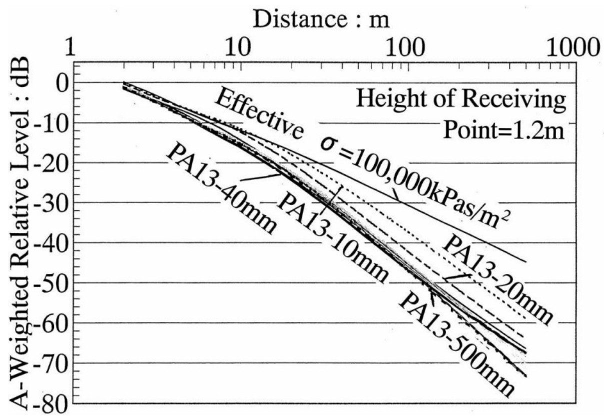

Figure 6: Relation between noise attenuation and propagation distance along each porous pavement.

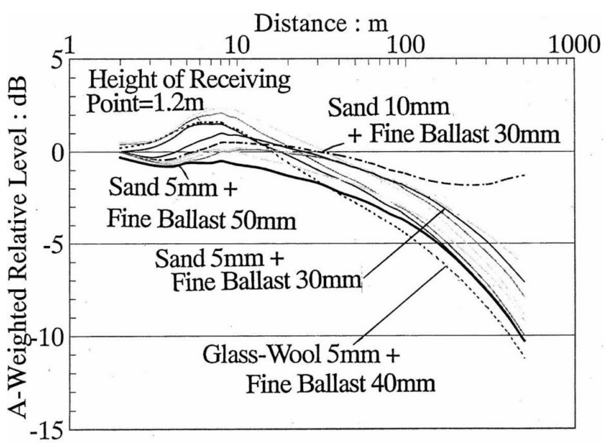

Figure 7: Noise reduction effect by double layered porous pavement, referred to ordinal porous pavement.

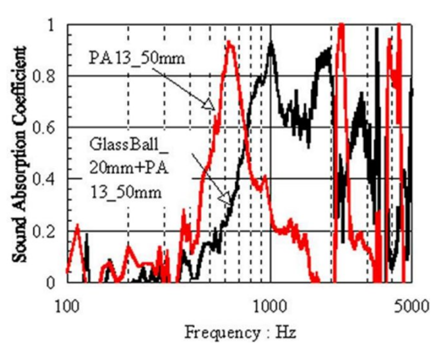

Figure 8: Sound absorption characteristics of both single and double layered porous pavement.

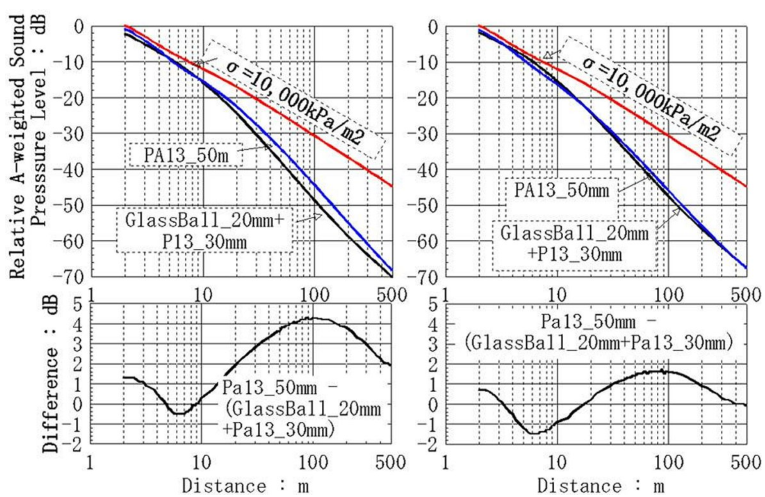

Figure 9: Noise attenuation with distance and additional reduction effect by double layered porous pavement.