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EFFICIENCY OF HIGHWAY NOISE BARRIERS

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1. INTRODUCTION

Noise pollution problem of highways has become serious since 1970's in Japan. As a countermeasure against noise, acoustical barriers have been commonly installed between residential area and highway constructions. These barriers are designed to be tall enough to reduce noise and to satisfy the environmental noise standard. The barrier height is in most cases determined by a design chart such as Maekawa's[1] or other specific design charts. However, the barrier efficiency has not been precisely checked.

This paper presents efficiency of highway noise barriers in several types. As an index, barrier noise reduction is introduced to check the barrier efficiency. Barrier efficiency was determined from the data of noise surveys for single and parallel barriers.

2. BARRIER EFFICIENCY AT HIGHWAYS

2.1 Estimation of Barrier Efficiency at Highways

Efficiency of outdoor barriers is generally described by insertion loss which is determined from the difference of sound pressure levels measured between "Before" and "After" the barrier installation. In the case that a barrier is already erected, it is always difficult to obtain the data of "Before" condition neither by measurement nor by prediction. However, if there is a measured value of sound pressure level at a reference position such as that of 1 m height above barrier top, simple estimation for "Before" condition will be possible by the distance correction to the sound pressure level at this location. By substituting this value for "Before" condition, we can get a kind of insertion loss which is an index of barrier efficiency. The same index is described in Nord Test Nr 496-84[2] and defined as "barrier noise reduction". We will call this index as barrier noise reduction hereafter.

The barrier noise reduction (*BNR*) is defined by the next formula:

$$BNR = L_{EB} - L_{MA} \qquad \text{(dB)} \qquad (1),$$

where L_{MA}: measured sound pressure level at a receiver position behind a barrier, which corresponds to the level in "After" condition (dB),
L_{EB}: estimated sound pressure level at a distance equal to a receiver position behind a barrier, which corresponds to the level in "Before" condition (dB).

The estimated value L_{EB} can be determined by the next formula for a line source (L_{Aeq}) and a point source (L_{Amax}), respectively:

$$L_{EB} = L_{ref} - 10\log_{10}(R/R_{ref}) \quad \text{for line source } (L_{Aeq}) \quad \text{(dB)} \quad (2),$$
$$L_{EB} = L_{ref} - 20\log_{10}(R/R_{ref}) \quad \text{for point source } (L_{Amax}) \quad \text{(dB)} \quad (3),$$

where L_{ref} : sound pressure level measured at a reference microphone (dB),
R : distance between the sound source and a receiver position (m),
R_{ref} : distance between the source and the reference microphone position (m).

Figure 1 shows a cross sectional view of a representative site for noise measurement. Nine microphones were located behind the barrier and a four sets of noise measurements were carried out. Four types of barrier construction were examined as shown in Table 1.

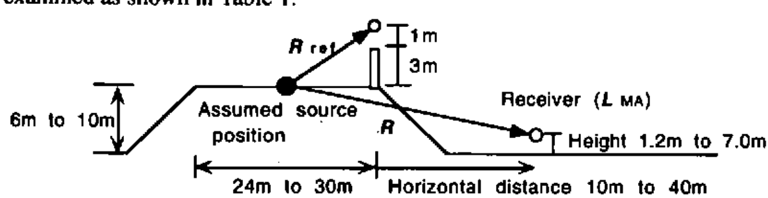

Fig.1 Geometry of the source and the receiver for the estimation of *BNR*

Table 1 Barrier conditions at the site of noise measurement

Case	barrier type		
A	single barrier	reflective (concrete)	
B	single barrier	absorptive (standard panel)	
C	parallel barrier	reflective (concrete)	b, a
D	parallel barrier	reflective/absorptive (concrete/standard panel)	b*, a*

3. BARRIER NOISE REDUCTION

3.1 Single Barriers

The values of *BNR* (barrier noise reduction) were determined from Eq.(1) and Eq.(2). The noise descriptor L_{Aeq},10 min. was used for the calculation.

Figure 2 shows the relationship between path difference and *BNR* for single reflective and absorptive walls. The path difference was calculated on the assumption of a single line source located in the middle of the road at a height of 0 m above the road surface. In this figure, design curves for road traffic noise attenuation due to single barrier are plotted. The dotted curve is used in ASJ/Model-1993[3] which is a recent noise prediction method for L_{Aeq} and was proposed by the technical committee of Acoustical Society of Japan. The design curve is expressed in the following formulae.

$$\Delta Ld=\begin{cases} -20-10\log_{10}(\delta) & \text{for} \quad \delta\geqq 1 \\ -5\pm[-15/\sinh^{-1}(1)]\sinh^{-1}(|\delta|^{0.414}), & \text{for} \quad -0.0537\leqq\delta<1 \\ 0, & \text{else} \end{cases} \qquad (4),$$

where ΔLd ($\leqq 0$; plotted in positive value) is the correction term due to diffraction and δ (m) is the path length difference. Plus and minus signs are used for $\delta>0$ and $\delta<0$, respectively. The solid curve has been used in ASJ/Model-1975[4] for L_{50} (50 % level).

It is shown that the values of *BNR* are distributed from 15 dB to 22 dB for absorptive barrier (Case B) and 10 dB to 17 dB for reflective barrier (Case A). There seems 5 dB difference in barrier efficiency between reflective and absorptive walls. However, this difference may not always be due to the acoustical property of the barrier surface.

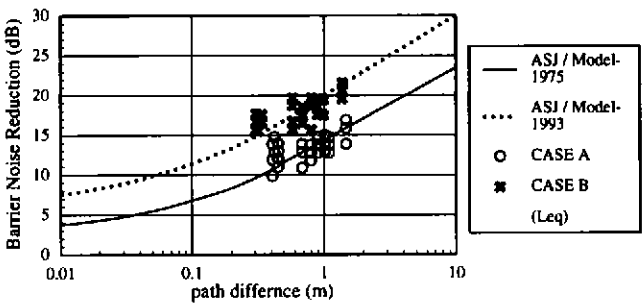

Fig.2 Comparison of barrier noise reduction (based on L_{Aeq}) for reflective (Case A) and absorptive (Case B) single barriers

Table 2 shows the wind velocity and the vector wind during the noise measurements. They were recorded with an anemometer located at a height of 1.5 m above the ground. One can see the noise measurement for single reflective wall (Case A) was carried out in strong down wind condition. The wind velocity was 5.8 m/s in maximum. On the other hand, the wind velocity was 2.3 m/s in average for single absorptive wall and the vector wind was less than +1.0 m/s in average.

Considering these meteorological conditions, the barrier noise reduction of the reflective single wall must be influenced and decreased by the strong down wind. And this influence may be large compared with expected values of barrier efficiency.

Table 2 Wind velocity and vector wind (averaged out of 4 measurements)

Case	wind velocity	vector wind
A	4.4 m/s (3 ~ 5.8 m/s)	+ 2.8 m/s (+1.4 ~ +4.1 m/s)
B	2.3 m/s (1.3 ~ 3.7m/s)	+ 0.6 m/s (-1.4 +1.8 m/s)
C	1.4 m/s (1.0 ~ 2.0 m/s)	± 0.8 m/s (0 ~ ±1.8 m/s), + for b, - for a
D	1.1 m/s (0.9 ~ 1.4 m/s)	± 0.5 m/s (± 1.0 ~ ±0.3 m/s) + for a*, - for b*

a,b: site behind reflective barrier, a* : site behind absorptive barrier, b* : site behind reflective barrier.

3.2 Parallel Barriers

Figure 3 shows the barrier noise reduction for Case C where the barriers are parallel and reflective. The values of barrier noise reduction are in a range from 16 dB to 23 dB and these were obtained under the vector wind of ±0.8 m/s. The barrier noise reductions distribute above the solid curve and rather close to the dotted curve. Expected tendency of decrease in barrier efficiency due to multiple reflection between reflective walls is not clearly seen from the figure.

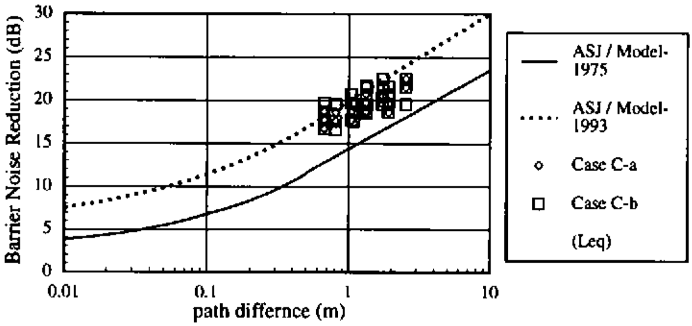

Fig. 3 Barrier noise reduction for reflective parallel barrier (Case C)

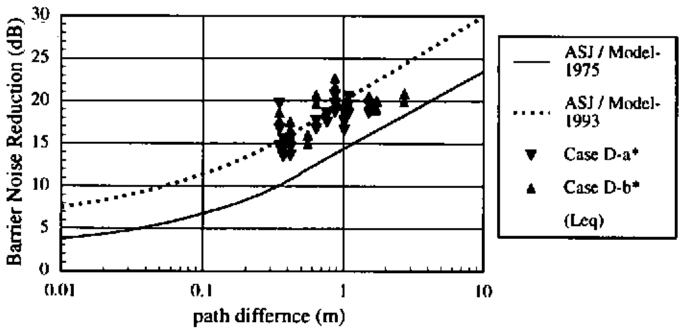

Fig. 4 Barrier noise reduction for absorptive/reflective parallel barrier (Case D)

Figure 4 shows the barrier noise reduction for Case D where the parallel barrier is erected with reflective and absorptive walls. This type of parallel wall was expected to reduce the multiple reflections by the absorption treatment. In this figure a wide scatter in the data is observed too, but a few data with a path difference less than 1 m lie above the dotted curve. This may be due to the effect of absorptive treatment on the surface of the wall.

3.3 Relationship between Barrier Noise Reduction and Vector Wind

The relationship between barrier noise reduction and vector wind was examined. Since the sound attenuation by barriers depends upon the geometry of the source and the receiver, the comparison was made to a normalized value. This value was determined from the level difference between barrier noise reduction and the value from the dotted curve, i.e. the chart in ASJ/Model-1993. The difference is plotted in Fig.5 in terms of vector wind. There is also a wide scatter in the data within the vector wind range of ± 2.0 m/s and there seems no dependency on vector wind. However, the values of Case A show 1 dB to 8 dB and they seem to increase as vector wind increases.

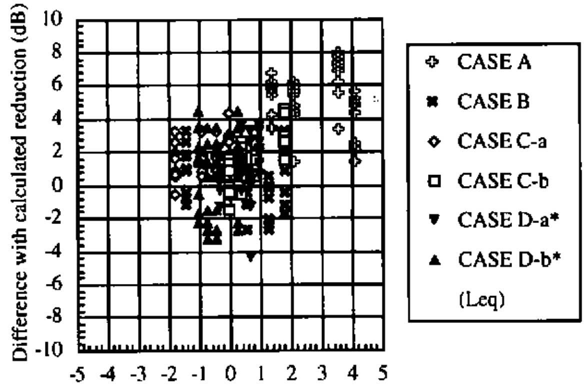

Fig. 5 Normalized barrier noise reduction vs. vector wind (Normalized with the chart value in ASJ/Model 1993)

3.4 Mean Barrier Noise Reduction

Figure 6 shows a comparison of the barrier noise reduction averaged out of 4 measurements with the path difference. The data of Case A is excluded from this figure. It may be said that the barrier noise reduction of all types lies close to the design chart of noise attenuation by single barrier. And the values tend to apart downward from the curve when they exceed 20 dB.

The average difference between the measured values and the values in the dotted curve was examined. The results are shown in table 3. The mean value for Case C was calculated regardless of receiver sites (Case C_a and Case C_b). It is shown that the mean difference is 0.1 dB for the absorptive single barrier and 1.6 dB for the reflective parallel barrier. For the absorptive/reflective parallel barrier, the difference of 1.0 dB is obtained behind the absorptive wall and 0.2 dB behind the reflective one.

Table 3 Mean difference between *BNR* and the chart value in ASJ/Model-1993

	Case A	Case B	Case C	CaseD_a*	Case_b*
Mean difference	5.1 dB**	0.1 dB	1.6 dB	1.0 dB	0.2 dB

** : measured under strong down wind condition.

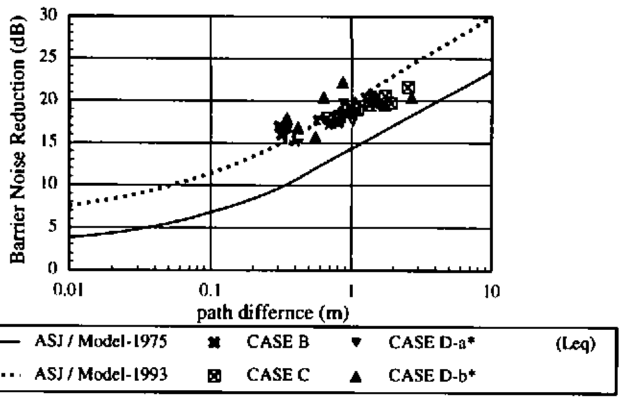

Fig. 6 Comparison of mean barrier noise reduction for Case B, Case C and Case D

4. CONCLUDING REMARKS

Efficiencies of highway barriers have been examined by the use of an index called barrier noise reduction which is described in Nord Test. This index is not exactly an insertion loss nor a sound attenuation relative to free field, but it has been shown this is one of the indices applicable to the barrier efficiency. The data showed that the barrier noise reduction was 15 dB to 23 dB for highway barriers of 3 m height and they showed close values to the design chart of noise attenuation due to barrier. It has been noted that strong down wind over 5 m/s affects the barrier efficiency and reduces barrier noise reduction It has been concluded that the difference in barrier efficiency between single and parallel barriers was less than 1.5 dB for actual barriers at highways of 24 m to 30 m in width.

[REFERENCE]

1)Z.Maekawa,"Noise reduction by screens,"Applied Acoustics,1,157-173(1968).
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