A study of road traffic noise nuisance

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ABSTRACT

In Japan, an increasing number of roadside residential areas meet the noise standards in recent years, which is explained by the ever-improving results of „Achievement rate of environmental quality standard“. There are many cases, however, where the measured noise levels still exceed the standards and thus it is necessary to continue the currnet noise abatement measures.

Despite its success to a certain degree, the current noise abatement measures based on the conventional equivalent A-weighted sound level (L_{Aeq}) evaluation is not the perfect solution for the roadside residents who suffer from the uncomfortable traffic noise, because there are other kinds of noise that cannot be measured by the conventional methods.

In this study, we performed a psychological measurement to quantify the subjects‘ discomfort level from the road traffic noise in L_{Aeq}.

As a result, the measurement found that the average physical discomfort level was increased by about 5dB when the subjects heard the brake sound and the sound of illegal-muffler-equipped vehicle in the test noise. In addition, the noise at low level (test sound at L_{Aeq} 45 dB) tends to increase discomfort level with vibration.

We concluded that the sound of brakes and illegal-muffler-equipped vehicle increased the discomfort levels, since the frequency characteristics are different from the normal road traffic noise.

INTRODUCTION

Road traffic noise has been an ongoing issue specifically in the areas along the major arterial roads with heavy traffic of HDVs (heavy-duty vehicles). For solving the problems, various measures are implemented in Japan, which include road traffic flow control, improvement of automotive structure and road structure (Figure 1). These measures surely helped to improve the achievement rate of the environmental quality standards regarding road traffic noise in recent years; 92.6% of residence was in the range of the reference value in 2012. However, the noise level still exceeds the standards in some areas. So, it is necessary to continue the current noise abatement measures. Despite its success to a certain degree, the current noise abatement measures based on the conventional equivalent A-weighted sound level (L_{Aeq}) evaluation is not the perfect solution for the roadside residents who suffer from the uncomfortable traffic noise, because there are other kinds of noise that cannot be measured by the conventional methods.

In this study, we carried out a psychological measurement to determine the relationship between the discomfort level and the possible factors including

impulsivity and frequency of the noise so that we can identify which factor caused the discomfort level to increase.

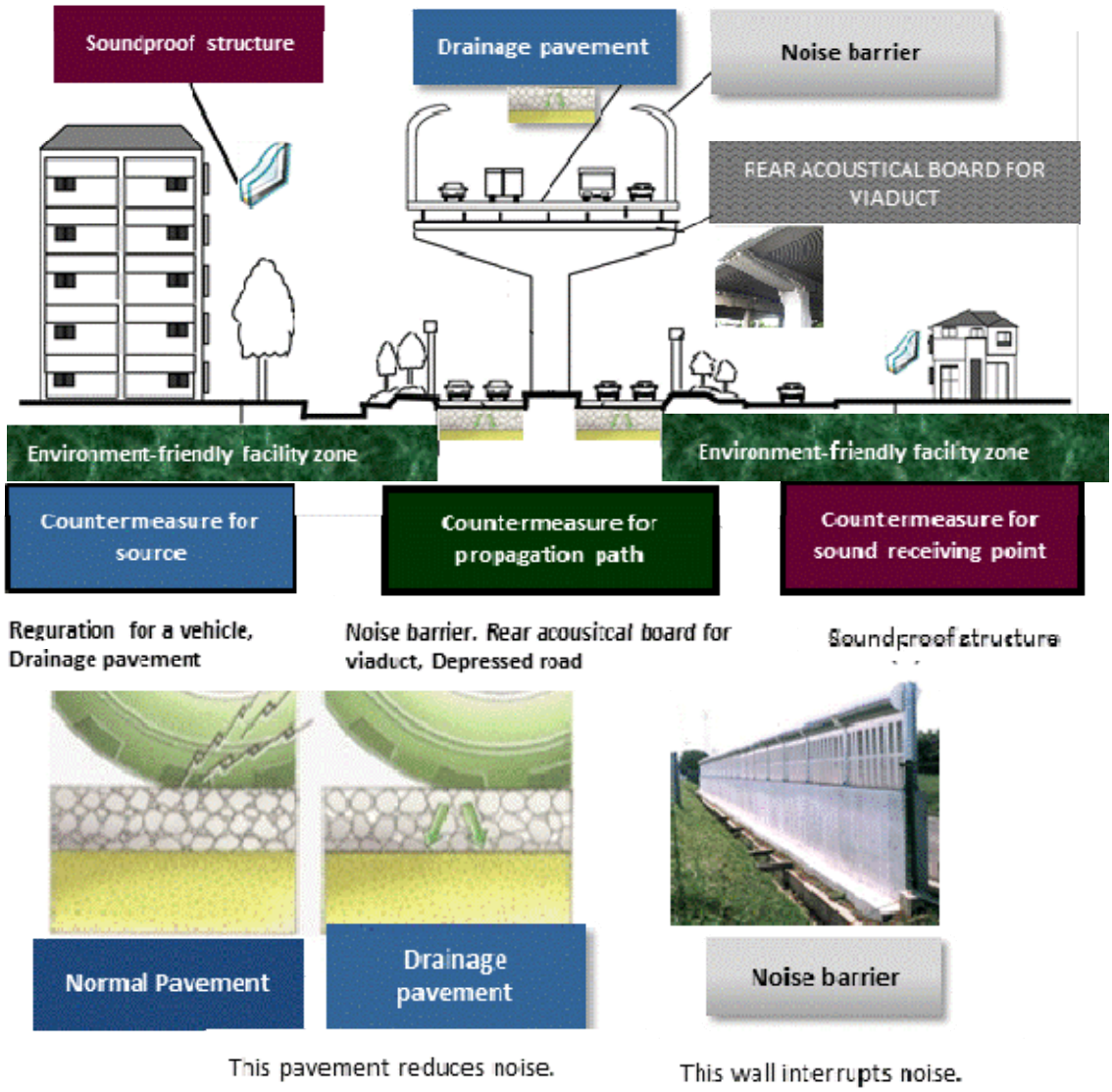

Figure 1: Various measures against road traffic noise

EXPERIMENT-1

Procedure

In order to find the relationship of discomfort levels with i) sound characteristic and with ii) attributions, we carried out the psychological measurement, in which 42 subjects in their 20s to 50s with normal hearing abilities participated. The subjects were grouped into 5 according to questionnaire results (Table 1).

The measurement was taken in a stationary van. The background noise level was 35 dB.

The subjects were asked to imagine that they were relaxing in a living room of a condominium that faces the major arterial road.

The evaluation was carried out by the ME (magnitude estimation) method. The subjects listened to the test sound through headphones, and evaluated the test sound with respect to the reference sound as "loudness" and "discomfort" in a quantitative manner. The reference sound's frequency characteristics are the same as road traffic noise in the steady sound of 40 dB.

We transformed the ME values in logarithmic scale, the quantified evaluation of the test sound by the subjects, then performed a regression analysis to determine the PSE (point of subjective equality) based on the regression equation. Finally, we analysed the PSE.

Table 1: Classification of the subjects

Groups	Attribute to noise	Findings from the questionnaire
1	Accustomed to the road traffic noise	Currently living (or have lived in the past) in the area along a road with four or more lanes (the first row or the second row facing the road).
2	Accustomed to noisy environment	Workplace is at noisy location such as a construction site.
3	Prefer a quiet environment	Favorite music genre is classical music.
4	Have a bad impression against road traffic noise	Feeling uncomfortable with the road traffic noise.
5	none of the above	none of the above

Test sounds

The test sounds were synthesized according to the test conditions using the recorded sound on the public and private boundary of the road.

We assumed that the condominium was reinforced concrete structure with highly-popularized double sliding windows (w: 1.8 m, h: 1.8 m). In consideration of the transmission loss, we tuned to the test sound to the indoor sound.

Length of the test sound was 15 seconds. Details of the test sounds used in this study are described in Table 2.

Results-1

We calculated the average value of the PSE using the evaluation values of all subjects for all test sound.

Figure 2 shows the relationship between PSE and L_{Aeq}. PSE of loudness correlate well with the L_{Aeq}. PSE of loudness is not affected by the frequency characteristics and time variability of sound. On the other hand, PSE of discomfort showed a low correlation with L_{Aeq}. Figure 3 shows the PSE of discomfort to the test sound L_{Aeq} 40 dB. As a result, it was found that the PSE of discomfort was increased from 4 dB to 5 dB when subjects heard sound 6, sound 7 (illegal-muffler-equipped vehicle) or sound 8 (brake) compared to the sound 2 (3 passenger cars steady running condition). We concluded discomfort level increased because the sound frequency characteristics were different from the steady sound of road traffic noise. Figure 4 shows frequency characteristic.

Table 2: The test sounds

Test sound #	Description
1	A passenger car at a steady speed
2	3 passenger cars at a steady speed
3	Sound 2 + a heavy vehicle at a steady speed
4	3 passenger cars and a heavy vehicle in depressed road with overpass
5	Acceleration of a passenger car and a heavy vehicle near signalized intersection
6	Sound 2 + illegal-muffler-equipped vehicle (high tone)
7	Sound 2 + illegal-muffler-equipped vehicle (low tone)
8	a heavy vehicle brake near signalized intersection
9	Idling noise of a heavy vehicle

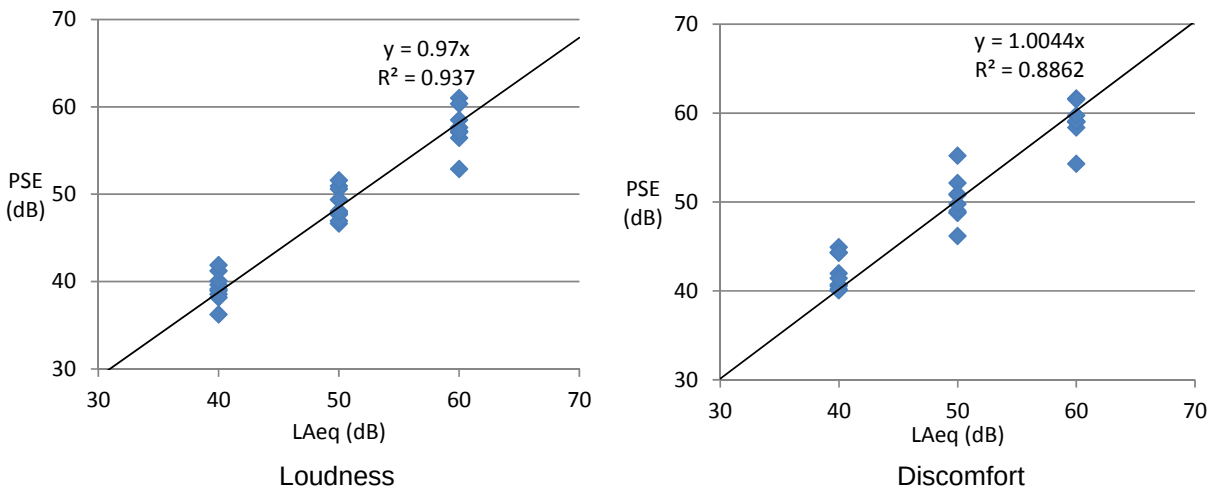

Figure 2: The average value of the PSE using the evaluation values of all subjects for all test sound

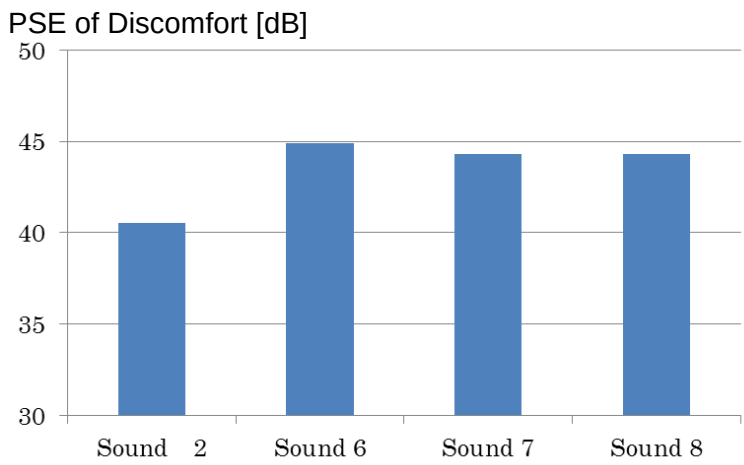

Figure 3: PSE of discomfort (40 dB)

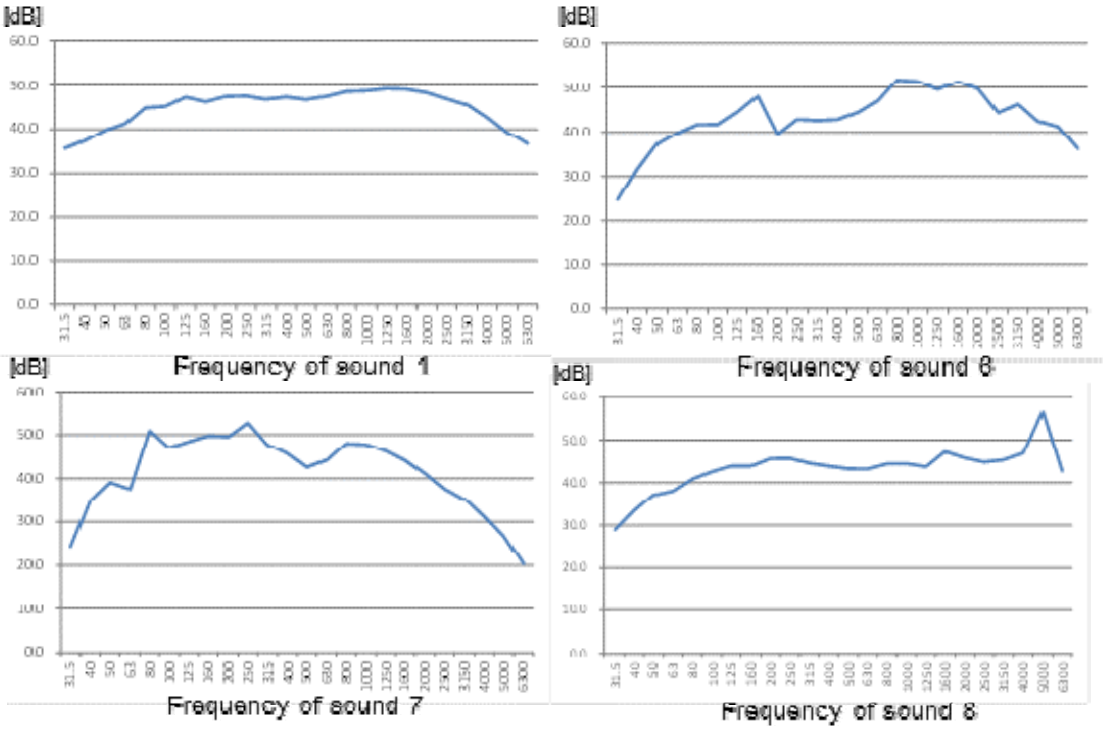

Figure 4: Frequency characteristic

Results-2

We examined the difference in PSE by attribute of the subjects. Group 2 marked greater values than the other groups, and there was no noticeable difference in PSE among other 5 groups. However, when the subjects heard the sound 6 and the sound 7 (illegal-muffler-equipped vehicle) noticeable difference between groups was observed (Figure 5).

For further analysis, we defined the difference between PSE of discomfort and PSE of loudness as D-PSE. D-PSE of group 1 was 0.3 dB, while D-PSE of group 4 was 1.5 dB (Figure 6) with the Standard deviation of 5 dB. In this result, subjects who have a bad impression against road traffic noise appeared to feel greater discomfort.

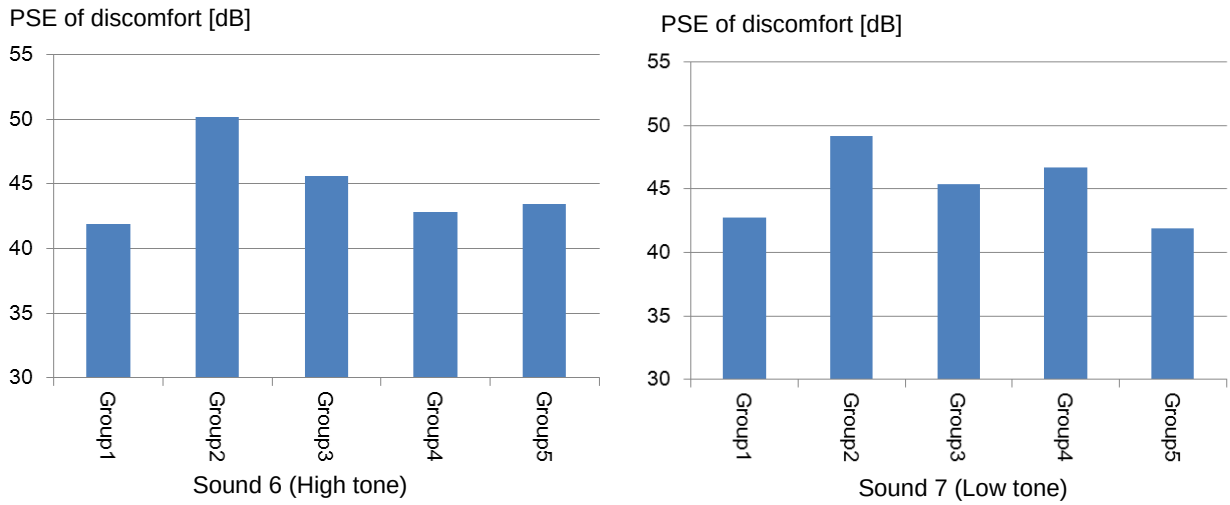

Figure 5: The relationship between PSE and attributes to noise (L_{Aeq} 40 dB)

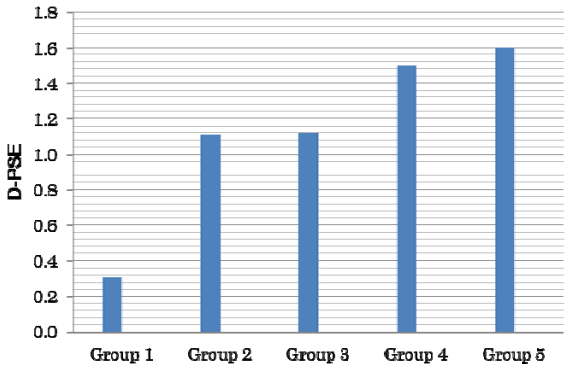

Figure 6: The relationship between D-PSE and attributes to noise

EXPERIMENT-2

Procedure

In order to determine the contribution of vibration to discomfort when the subjects heard the road traffic noise, we carried out the psychological measurement, in which 12 subjects (9 males and 3 females) in their 20s to 50s with normal hearing abilities participated. We experimented in custom-made sound proof room which placed on shaking table used for vibration testing of industrial products (Figure 7). Vibration levels were set 70 dB and 75 dB (percentile vibration level L10). The background noise level was 37 dB, and data was processed by the same method as the experiment-1.

Figure 7: Experimental system

Test sounds and vibration

The test sound we used in this measurement was the sound of steadily running 3 passenger cars and a heavy vehicle added impulsive noise at rut or joint of bridge. Length of the test sound was 15 seconds (L_{Aeq} 45 dB, 55 dB, 65 dB). The same transmission loss as Experiment-1 was taken into consideration. We used the test vibration with the waveforms that were measured on the foundation of the reinforced concrete structure of the houses in the roadside area of the national highway.

Results

Figure 8 shows the average value of the PSE using the evaluation values of all subjects for all test sound. PSE of loudness correlate well with the L_{Aeq}. On the other hand, PSE of discomfort showed a low correlation with L_{Aeq}. When the subjects heard the test sound L_{Aeq} 45 dB, it was found that the discomfort level increased with the increase of vibration. Discomfort level from the test sound with vibration increased by

about 8 dB compared to the discomfort level from the test sound without vibration. When the subjects heard L_{Aeq} 65 dB, there was no difference in the PSE with and without vibration. We considered that discomfort levels would not be greatly increased by vibration when the noise level is already significant. Therefore, it is concluded that discomfort tends to increase with vibration when road traffic noise is low.

CONCLUSIONS

In this study, we experimented to determine the relationship of psychological discomfort and characteristic of sound. It was found that discomfort level increased by from 4 dB to 5 dB when the subject heard the brake sound and the sound of illegal-muffler-equipped vehicle in the test noise. Then noise at low level (test sound at L_{Aeq} 45 dB) tends to increase discomfort level with vibration.

We have heard the opinion that roadside residents get used to road traffic noise, just as we become unaware of the sound of the air conditioning once we get used to it. However, there is other noise that we do not get used to it. For example, a sudden noise, a noise with only a certain frequency and a noise with vibration tend to cause discomfort. For further analysis, it is necessary to verify the relationship between physical discomfort and the attributes of the subjects.

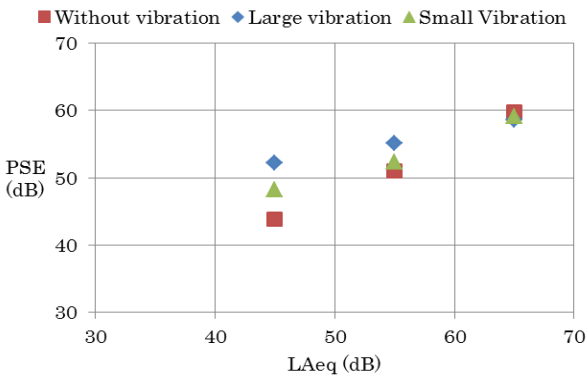

Figure 8: The relation between L_{Aeq} and PSE

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