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Desirable Road Traffic Noise for Human Hearing

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ABSTRACT

This paper describes the desirable condition of road traffic noise for human hearing in terms of sound quality. In general, the reduction of the envelope fluctuation of the sound and the reduction of high frequency contents of the sound under consideration beyond 1 kHz are effective for realizing the desirable sound perception for machinery noise. This approach is also true for the environmental sound such as road traffic noise according to the result of our laboratory experiment from the view point of sound quality. At present, desirable sound environment is determined by the prescribed Laeq value, i.e., equivalent A-weighted sound pressure level. But from our experience, Even under the same Laeq values, our perception from various road traffic noise differ significantly because of the fact that their sound qualities are different within each other. This fact is examined in detail by laboratory experiment by utilizing the recorded real road traffic noise.

INTRODUCTION

At present, there exists few locations where satisfy the environmental noise criteria in Japan. Accordingly, the rate of percentage of the populations who are suffered from sleep and hearing disturbances near by the main traffic area is very high. At the moment, the environmental noise criterion is determined by the equivalent perceived level, i.e., Laeq. The reason why the environmental noise criterion is determined by Laeq is that this represent well with the loudness of the noise under consideration. But we can understand from our experience that the annoyances of the noises are different even under the case where the Laeqs of the noises are the same when we measured this noise at the different locations, i.e., at the road side and behind the building that faces the main traffic, etc. This difference is due to the difference of sound quality of the traffic noise we are dealing with and could be easily verified by measuring its psycho-acoustical parameters such as sharpness, roughness and per etc. This paper describes the effect of the difference of sound quality of road traffic noise to the perception of annoyance.

ANNOYANCE CAUSED BY ROAD TRAFFIC NOISE

In Figure1, the annoyance caused by road traffic noise was shown separately according to the inhabitant groups, one for the visible and the other for invisible of the main traffic. The data was based on the social survey from the inhabitants who suffered from road traffic noise. The abscissa of this graph is Ldn, which is the weighted equivalent exposure level during the nighttimes with 10 dB increment.

From this figure, the annoyance is significantly different under the same exposure level between the two groups, i.e., one for the visible and the other for invisible of the main traffic. This has been shown to be due to the difference of the sound quality of the road traffic noise and not merely caused by the psychological effect of the visibility and the invisibility of the main traffic [(1)].

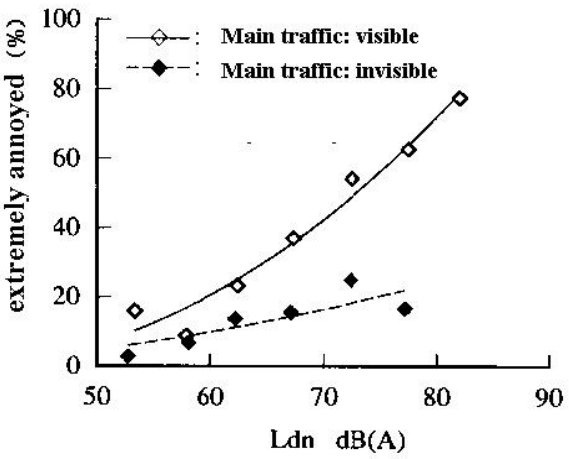


Figure 1. Visibility of Main traffic and annoyance

Difference of sound quality by the measuring point

In order to investigate the difference of sound quality of road traffic noise due to the difference of the measuring point, simultaneously measured two traffic noises at the two different locations in the same area, i.e., the one location near by the main traffic and the other behind the main road where there exists no direct pass to the main traffic, were edited

and used as a sound stimuli for the laboratory experiment for jury evaluation. In the following each figure, the blank rhombus ,i.e.◇ represents the evaluation of the road traffic noise near by the main traffic and the black square,i.e.■ represents the evaluation of road traffic noise behind the main traffic.

Form Figures 2 to 4, the traffic noise near by the main traffic is more unpleasant, more clamorous, and louder than the one behind the building facing the main traffic. Namely, the evaluations obtained by the two locations are discontinuous and have a step.

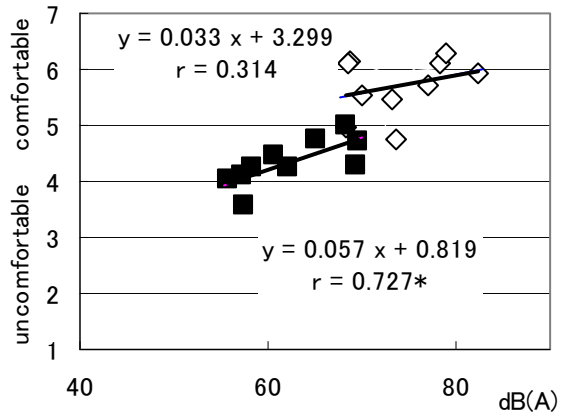


Figure 2. Comfortability of road traffic noise and dBA

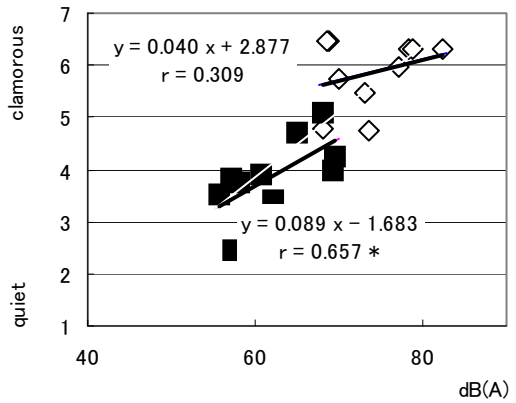


Figure 3. Clamor of road traffic noise and dBA

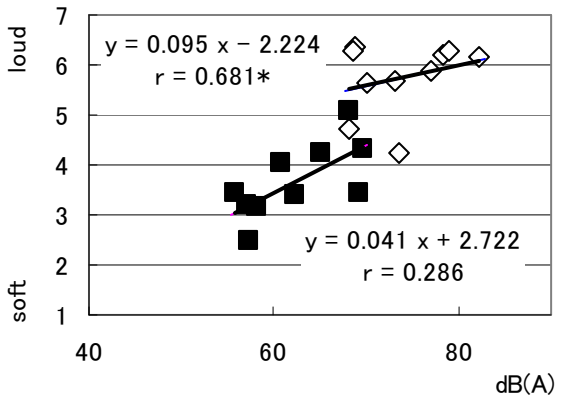


Figure 4. Loudness of road traffic noise and dBA

In Figure 5 was shown the metallic evaluation of traffic noise, and from this figure, the traffic noise by the road side is sharper than the traffic noise behind the building provided that the Laeqs dBA are remained the same. The reason why the traffic noise behind the building is less sharp is that the high frequency content of the noise is absorbed and isolated during the sound path.

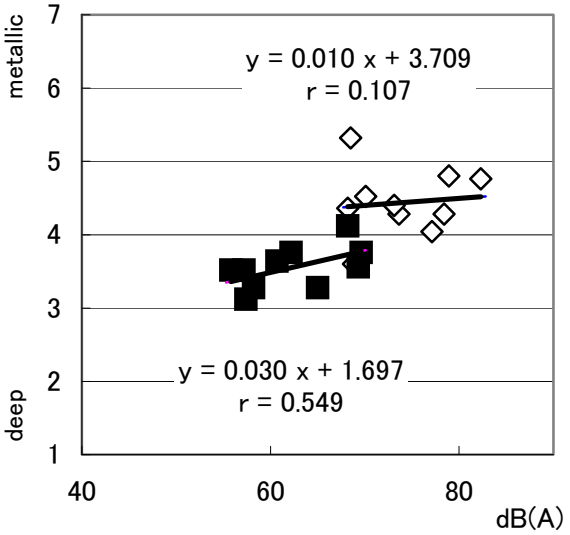


Figure 5. Metallic evaluation and dBA

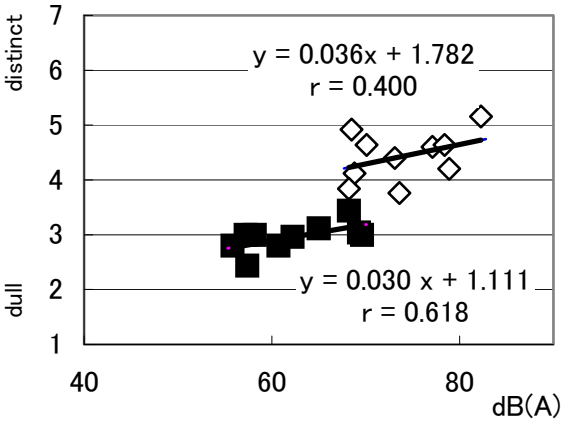


Figure 6. Clarity of traffic noise and dBA

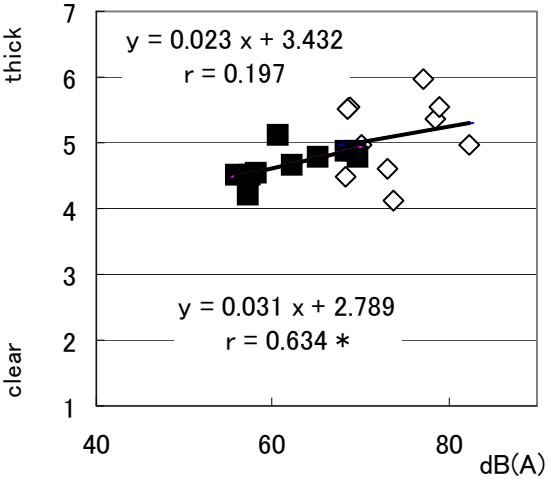


Figure 7. Thickness of traffic noise and dBA

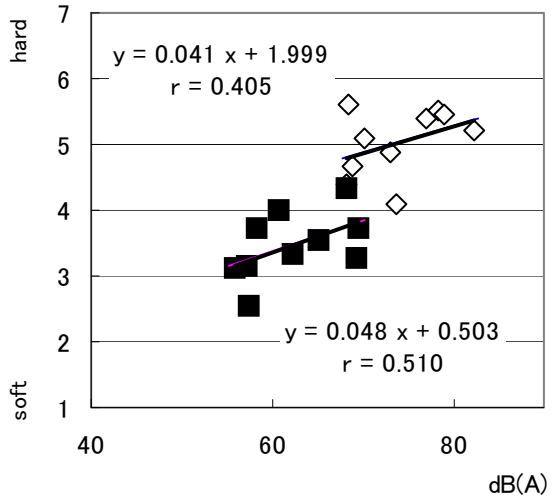


Figure 8. Hardness of traffic noise and dBA

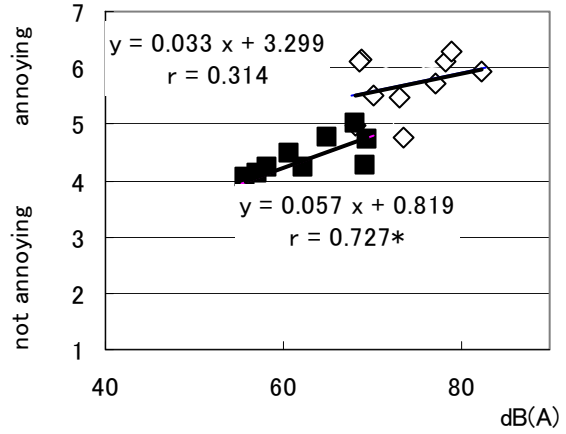


Figure 9. Annoyance of road traffic noise and dBA

Figure 6 represents the evaluation on “distinct – dull”. From this figure, the impression of the traffic noise by the main roadside is more distinct and, on the contrary, that of the back street is dull.

Figure 7 is the evaluation of “thick – clear”. The clearness of the road traffic noise is continuously changed and doesn’t show a discontinuous step between the main road and the back street.

Figure 8 represents the evaluation on “hard – soft” of the traffic noise. This result shows the discontinuous step between the main road and the back street. This is also judged to be due to the differences of the power in the high frequency contents of the noise.

These differences in sound quality of the road traffic noise are synthesized psychologically to conclude that the overall impression of the road traffic noise is more annoying at the roadside and the result is shown in Figure 9.

Annoyance and the roughness [2]

The relation between the annoyance of the road traffic noise and the roughness of the sound is investigated and this relation is shown in Figure10. Roughness is higher by the roadside compared with the back street and this means that the envelope fluctuation is higher by the main roadside. This higher value of roughness could be one cause of the higher annoyance by the main roadside.

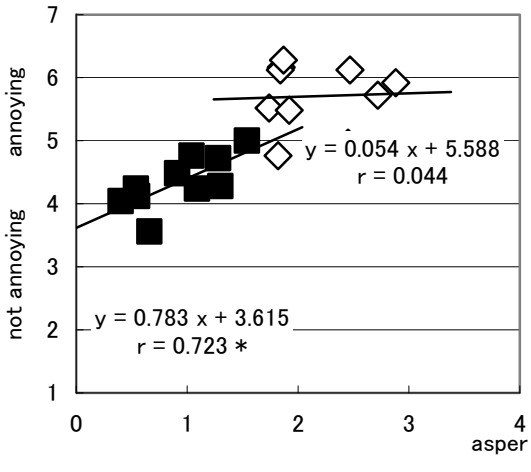


Figure 10. Annoyance of road traffic noise and roughness

Metallic-ness, hardness of road traffic noise and sharpness [2]

Figure 11 represents the relation between metallic-ness of road traffic noise and the sharpness. Sharpness is clearly higher by the main road side. This higher value of sharpness is also thought be the one of the cause of the higher annoyance by the roadside.

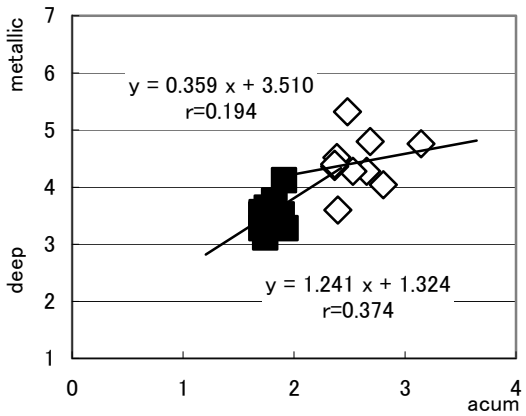


Figure 11. Metallic-ness of traffic noise and sharpness

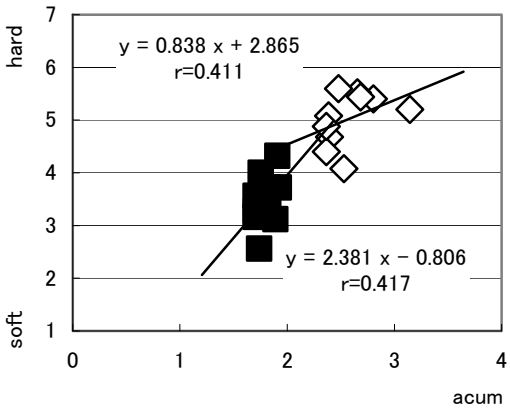


Figure 12. Hardness of traffic noise and sharpness

Figure12 represents the hardness of road traffic noise and the sharpness. The reason why the traffic noise by the roadside is harder is thought to be due to the higher value of sharpness.

COMPARISON OF THE SPECTRA OF ROAD TRAFFIC NOISE

Road traffic noise near by the main road has been shown to be more rough and sharper than the one at the back street. Then the three spectra of the road traffic noise measured simultaneously at the three locations were compared, i.e., near by the main traffic, at the side road where the direct path from the main road is secured and behind the building faced to the main road where there exist no direct path from the main traffic and the result is shown in Figure 13.

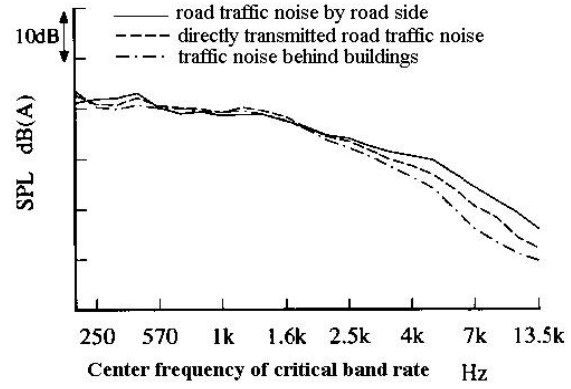


Figure 13. Difference of spectra due to different locations

The three road traffic noises were adjusted their noise level to have the same Laeqs. It has been shown apparently from this figure that the spectra beyond the 1.6 kHz were significantly different among the three spectra. Especially, this portion of the spectrum is significantly higher in the case of road traffic noise recorded near by the main traffic.

This significant difference in the high frequency region beyond 1.6 kHz is the cause of the differences of roughness and sharpness of the traffic noise.

As like this measurement, the recordings of road traffic noise of the three simultaneous measurements at the several places where we could find heavy main traffic were conducted for the subsequent laboratory experiment on annoyance. Figure 14 represents the result of this experiment with respect to Laeq.

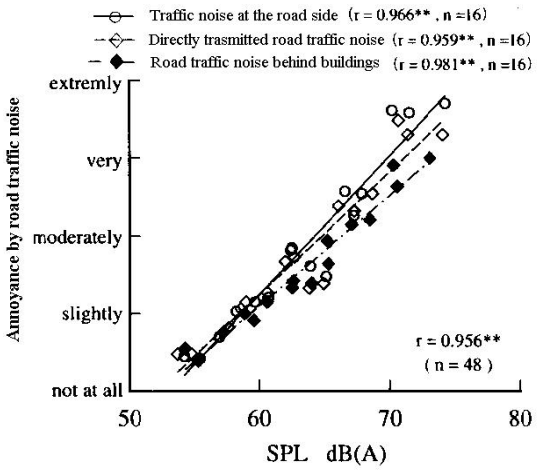


Figure 14. Annoyance of traffic noise and dBA

From Figure14, the annoyance caused by the road traffic noise near by the main traffic has been shown to be more annoying compared with the rest of the two road traffic noises under the same Laeqs.

MULTIPLE REGRESSION ANALYSIS

A laboratory experiment was conducted for evaluating annoyance caused by road traffic noise by using the real road traffic noise and its artificial variations beyond the 1kHz components varied +1dB/oct, -1dB/oct, -2dB/oct, -3dB/oct, -4dB/oct respectively and the total of 24 sounds were used as the experimental stimuli. The evaluation was conducted using five categorical scales from unbearably annoyed to not annoyed at all and the subjects were the mixture of 29 males and females with normal hearing aged between 22 to 54 years. The average scores obtained by this experiment were analyzed through multiple regression and Laeq, roughness and sharpness were used as the candidate of the explanatory variables. As a result, the following model was developed for the normalized variables.

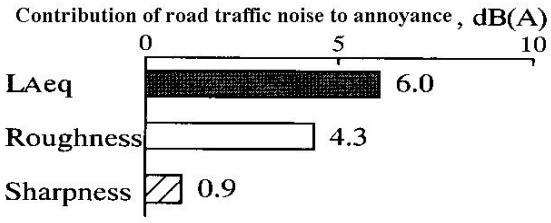
$$(\text{annoyance}) = 0.56\text{Laeq} + 0.40\text{roughness} + 0.08\text{sharpness} \quad (1)$$

As the standard deviations of Laeq, roughness, sharpness are 6dBA, 0.56asper, 0.31acum respectively, the deviation of annoyance due to the one standard deviations of the each explanatory variables are 0.56 for Laeq, 0.40 for roughness and 0.08 for sharpness. The equivalent Laeq values for the deviations of one standard deviation for roughness and sharpness are obtained by the following formula for the conversion. For roughness,

$6.0 \times 0.40/0.56 = 4.3\text{dBA}$

and for sharpness,

$6.0 \times 0.08/0.56 = 0.9\text{dBA}$



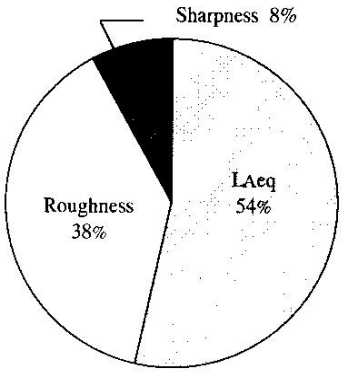


Figure 15. Contributions of each variable on annoyance under the exposure of road traffic noise

This conversion to equivalent Laeqs was shown in Figure 15.The circle graph shown in Figure 15 was the percentage of Laeq, roughness, and sharpness to the contribution on annoyance to road traffic noise. From this figure, it is clarified that roughness and sharpness as well as Laeq significantly affect the annoyance. Especially the contribution of roughness to the annoyance was large and this could lead to the conclusion that annoyance to road traffic noise is smaller with the traffic noise having smaller envelope fluctuation provided that the Laeqs are the same. As well as the roughness, though the contribution is less, to reduce high frequency content of the road traffic noise leads to the reduction of sharpness and these results in the reduction of annoyance.

CONCLUSIONS

1. To think of the way to reduce envelope fluctuation of the road traffic noise. According to this method, roughness of the noise decreased and this leads to the expectation to the reduction of annoyance comparable to the effect due to the noise level reduction.

2. To think of the way to reduce the spectrum component beyond 1 kHz for reducing sharpness of the road traffic noise that leads to the reduction of annoyance.

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1. T. Ishiyama, T. Hashimoto: “Effect of sound quality to the perception of annoyance to road traffic noise”, Trans. JSAE, Vol.29, No.4, October 1998.
2. E.Zwicker, H.Fastl: Psychoacoustics, Facts & Models, Springer-Verlag, 1990.