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A CONTRIBUTION OF SOUND QUALITY ON ANNOYANCE CAUSED BY ROAD TRAFFIC NOISE

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ABSTRACT
This paper describes a laboratory study for investigating the contribution of sound quality on annoyance caused by road traffic noise. To measure the annoyance, two kinds of subjective evaluation test were carried out, i.e., one for annoyance and the other for listening interference. Our findings were: (1) contribution of high frequency contents of road traffic noise on annoyance was significant, (2) the contribution of high frequency contents of road traffic were equivalent to 3 dB(A) even when the levels of the noise were fixed to 70 dB(A), and (3) multiple regression models for annoyance in terms of LAeq, roughness and sharpness were constructed and the trade off relationships between the sound quality parameters and LAeq were calculated. The trade off of one standard deviation in roughness and sharpness for annoyance were equivalent to 4.3 dB(A) and 0.8 dB(A) respectively provided that one standard deviation in LAeq in the model was 6.0 dB(A).

1 - INTRODUCTION

LAeq is generally thought to correspond well with annoyance, but it has been reported [1] that factors other than LAeq such as envelop fluctuation of sound signal in time and high frequency contents of noise also contribute annoyance. This paper describes the contribution of sound qualities of road traffic noise on annoyance quantitatively. In order to measure the annoyance caused by road traffic noise, two kinds of subjective evaluation test were carried out.

2 - SUBJECTIVE EVALUATION TESTS OF ANNOYANCE

2.1 - Subjective evaluation tests using road traffic noise recorded in urban area: test 1

Stimuli: 48 kinds of road traffic noise recorded simultaneously at the edge of the road, at the location where direct sound propagation from the main traffic was confirmed and at the location behind the building without direct sound propagation were used as the stimuli for Test 1. These test noise ranged from 54-74 dB(A) in LAeq.

Fig. 1 shows the differences on the frequency spectra between the direct propagated noise and the indirect propagated noise. Among the frequency spectra of these noise, the differences of the SPL on high frequency components higher than 2.5 kHz were significant.

Subjects: 9 female and 24 male subjects with normal hearing ability participated in Test 1.

Test procedure: This test was carried out in a sound proof room. Test noise was presented in randomized order for 40 seconds through a pair of loud speakers. Subjects were asked to evaluate their impression on annoyance in five categorical scales from not annoying at all to extremely annoying.

Test result: Fig. 2 shows the relationship between the annoyance evaluated by subjects and LAeq of test road traffic noise in each group. From Fig. 2, it was found that the annoyances were different between the three groups due to the differences of high frequency contents of noise while LAeqs of the noise were the same.

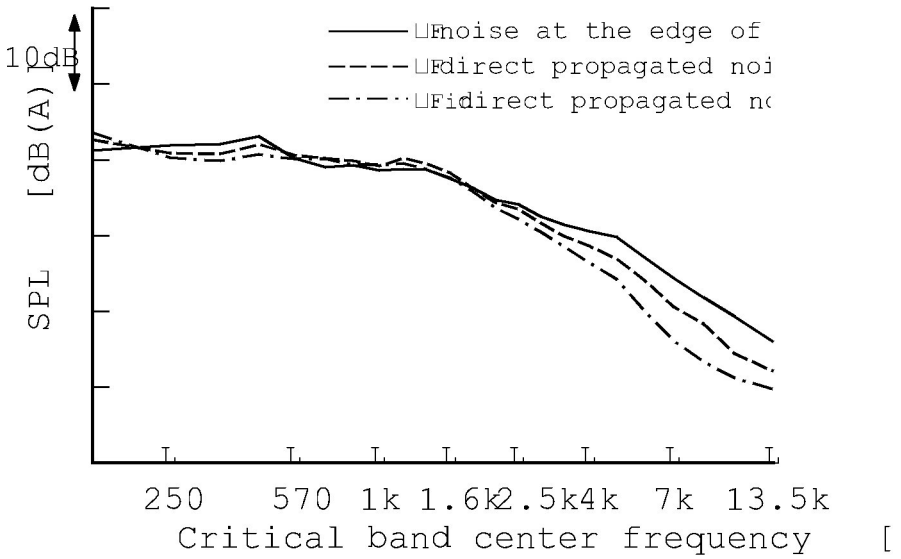

Figure 1: Difference on frequency spectra between direct propagated noise and indirect propagated noise.

2.2 - Subjective evaluation tests using artificially modified road traffic noise: test 2-1, test 2-2

Stimuli: This modification method consisted of modifying the high frequency components (above 1 kHz) of the original road traffic noise as in the following six types. 1: original sound + 1 dB(A)/oct., 2: unmodified original sound, 3: original sound − 1 dB(A)/oct., 4: original sound − 2 dB(A)/oct., 5: original sound − 3 dB(A)/oct., and 6: original sound − 4 dB(A)/oct. One example of the set of modified road traffic noise was shown in Fig. 3. Four sets of six noises with the similar frequency spectra as shown in Fig. 3 were prepared and the total of 24 noises were used for Test 2-1 and Test 2-2. These test noise ranged from 53-73 dB(A) in LAeq.

Subjects: 6 female and 23 male subjects with normal hearing ability participated in Test 2.

Test 2-1: Test for annoyance using five categorical scales.

Test 2-2: Listening interference test. The difference in subject's preferred listening levels of music with road traffic noise and in quiet was defined as listening interference level and this was used as a scale for annoyance caused by road traffic noise.

Test result: Figs 4 and 5 show the annoyance and listening interference level versus LAeq for six types of artificially modified road traffic noise including original. The annoyances were higher with the type 1 noise than with the types 5 and 6 noise both in Figs 4 and 5. The annoyance increased as the high frequency contents of noise increased even with the fixed LAeq level. The differences in level for the variation of high frequency contents are equivalent to 1, 2 and 3 dB(A)s when LAeqs of the test noise were equal to 60, 65 and 70 dB(A) respectively. It means that the reduction of annoyance due to the reduction of high frequency contents beyond 1kHz is equivalent to the reduction of 3 dB(A) in its noise level when the noise level is 70 dB(A).

3 - INFLUENCE OF ROUGHNESS AND SHARPNESS ON ANNOYANCE

The differences in annoyance with the same LAeqs in Figs 4 and 5 are thought to be due to the contribution of the difference in sound quality of the noise other than LAeq. For obtaining this answer quantitatively, the multiple regression models for annoyance were constructed with using sound quality parameters such as roughness [2], sharpness [2] as well as LAeq were used as the explanatory variables.

$$\text{Model 1} \ : \ \text{Annoyance} \ = \ \text{f}\,(\text{LAeq}, \text{roughness}, \text{sharpness}) \tag{1}$$

The model 1 can be expressed as in the following multiple regression model (1') using its standard regression coefficients.

$$[\text{Annoyance}] = 0.563 \times [\text{LAeq}] + 0.400 \times [\text{Roughness}] + 0.076 \times [\text{Sharpness}] \tag{1'}$$

According to the model (1') the trade off values of one standard deviations in roughness and sharpness with LAeq are equivalent to 4.3 and 0.8 dB(A)s provided that one standard deviations in LAeq is 6.0

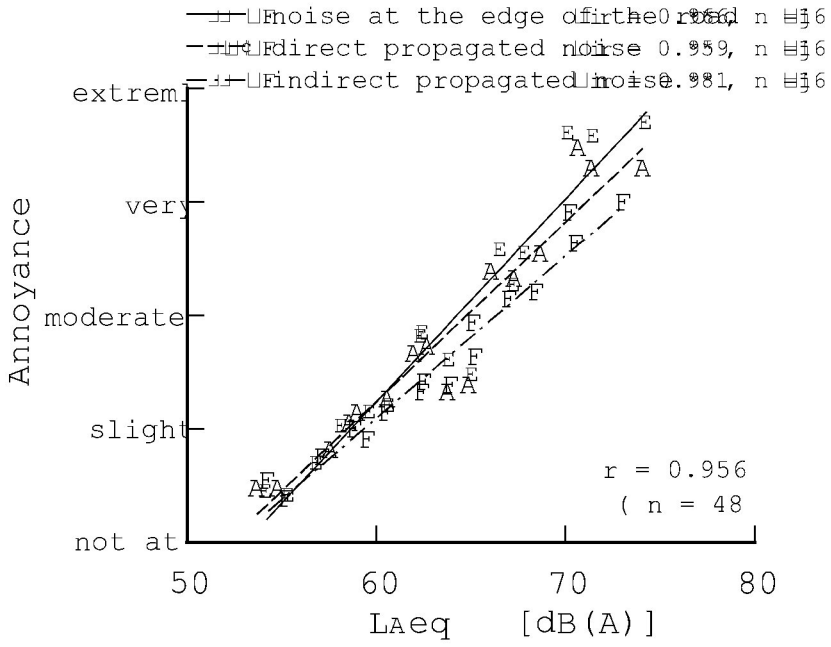

Figure 2: Relationship between the annoyance and LAeq (Test 1, **: significant ($P < 0.01$)).

dB(A). One standard deviations in roughness and sharpness are 0.56 asper and 0.31 acum in this case. Fig. 6 shows this trade off relationship for presenting the contribution of sound quality on annoyance in a case where the variation in LAeq is 6.0 dB(A).

4 - CONCLUSIONS

(1) The contribution of sound quality on annoyance as well as on listening interference level increased as the high frequency contents of road traffic noise increased even under the fixed LAeq level.
(2) The reduction in annoyance by reducing the high frequency contents of road traffic noise beyond 1 kHz is equivalent to reduce its noise level in 3dB(A) even when the noise level itself is remained constant at 70 dB(A).
(3) The contributions of sound quality parameters such as roughness and sharpness on annoyance were quantitatively considered by constructing multiple regression models of annoyance in terms of roughness, sharpness as well as LAeq as its explanatory variables.

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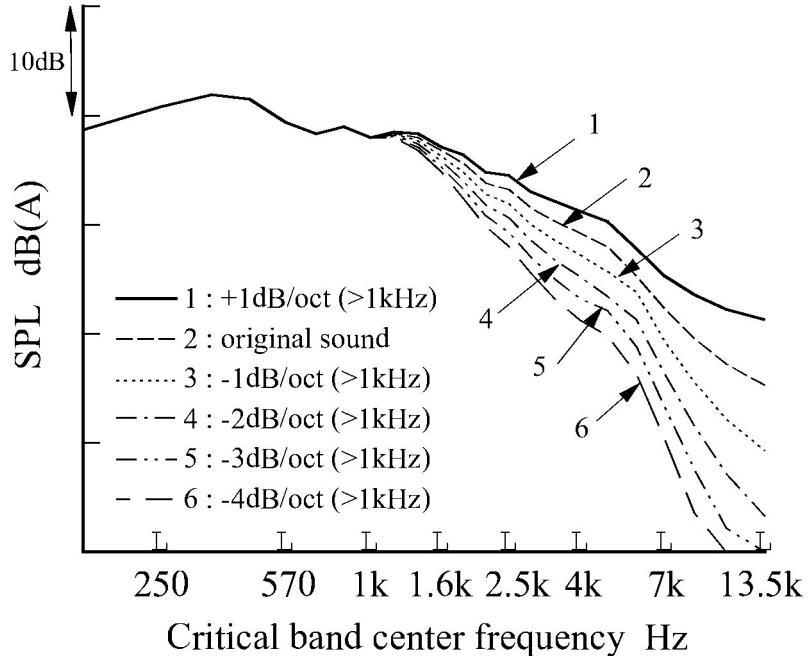

Figure 3: Frequency spectra of test sounds (Test 2-1, Test 2-2).

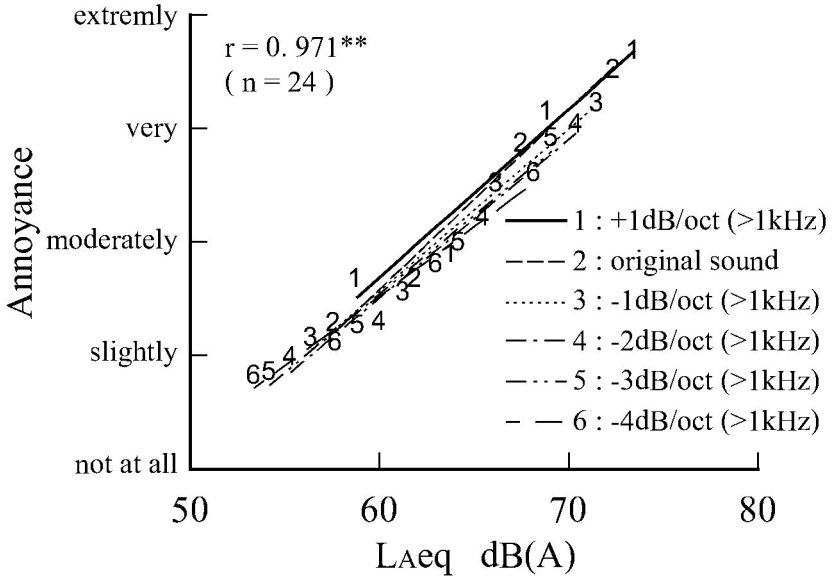

Figure 4: Relationship between annoyance and LAeq (Test 2-1, **: significant, $P < 0.1$).

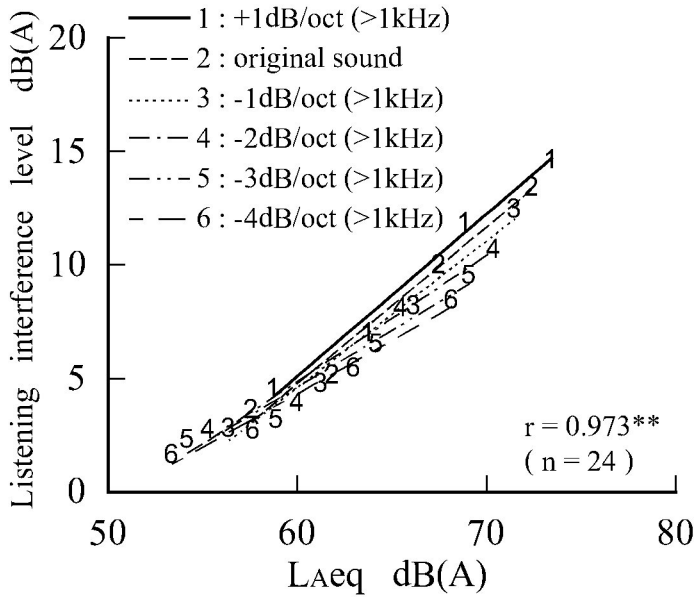

Figure 5: Relationship between listening interference level and LAeq (Test 2-2, **: significant, $P < 0.01$).

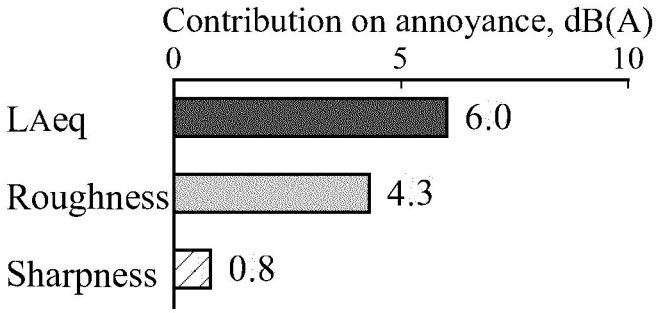

Figure 6: Contribution of LAeq, roughness, sharpness on annoyance (Test 2-1).