***inter.noise 2000***
***The 29th International Congress and Exhibition on Noise Control Engineering***
***27-30 August 2000, Nice, FRANCE***

**I-INCE Classification:** 6.3

# SOUND QUALITY OF ROAD TRAFFIC NOISE TRANSMITTED THROUGH DIFFERENT TYPES OF SIMULATED WALL

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**Keywords:**
SOUND QUALITY, ROAD TRAFFIC NOISE, INDOOR NOISE

## ABSTRACT
Quality of sounds transmitted through walls is affected by the structures and the materials of walls. Sounds from four kinds of wall, i.e. concrete block, a single glass, double glasses and plaster board, were simulated using a digital filter and the sound quality of road traffic noise was tested using semantic differential. Under the same LAeq conditions, it was found that the impression of the sound quality, especially sharpness and roughness, was different among the stimuli. Physical measures were examined to predict the sound quality of road traffic noise transmitted through walls on the basis of these results.

## 1 - INTRODUCTION
The guideline of indoor noise level was determined to be lower than 45 dBA in LAeq in the Environmental Quality Standard [1]. Sound reduction index (R) is generally used for the evaluation of the efficiency of walls and windows. Only sound level is used in the measurement of 'R'. However, even if the indoor noise level is equal, the impression of sounds may differ depending on the frequency characteristics of the sounds transmitted through walls and windows. Many studies of sound quality indicate that the total impression of sounds including the loudness [2] and sound quality (e.g. Namba et al.[3-5], Hashimoto and Hatano [6]) varies according to the frequency characteristics. As one of the series of the studies of noise measures for evaluating road traffic noise, the present study was designed to investigate the effect of sound reduction of walls and windows on the impression of loudness and sound quality and the noise measure was examined taking the frequency characteristics into consideration.

## 2 - EXPERIMENT

### 2.1 - Stimuli
Five kinds of road traffic noise were used as stimuli. The duration was about 10 sec and the main sound sources were passenger cars passing by for stimulus 1, motor bikes passing by for stimulus 2, small trucks passing by for stimulus 3, heavy vehicles accelerating for stimulus 4 and heavy vehicles idling for stimulus 5. Their frequency characteristics of these sounds are shown in Fig. 1.
Five kinds of filters were prepared. They were simulated to direct sound for filter A, concrete block for filter B, a single glass for filter C, double glasses for filter D, and plaster board for filter E [7]. Their sound reductions are shown in Fig. 2. The frequency characteristics of the loudspeaker were checked at the position of subjects' ears using 1/3 oct. band filters. Three kinds of sound level were used, i.e. 43, 53 and 63 dB in LAeq. Therefore in total 75 kinds of stimulus were used.

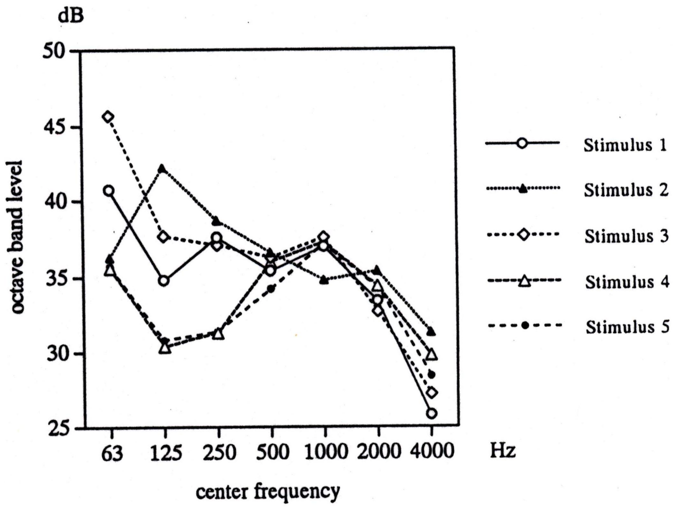


**Figure 1.**

### 2.2 - Procedure

The impression of the sounds was judged using semantic differential. 75 sounds were presented to subjects in random order. 19 pairs of adjective scales were prepared and each adjective scale was presented on a computer monitor one after the other in random order. Subjects were asked to judge the impression in 7-point scale and respond with a keyboard. Two trials were conducted after training by each subject in different days.

### 2.3 - Apparatus

Stimuli were reproduced with a DAT recorder (Pioneer D-05) and presented to subjects through an amplifier (Sony F222WSJ) and a loudspeaker (Diatone DS-1000ZX) in a sound proof room.

### 2.4 - Subjects

Six female and fourteen male subjects aged between 20 and 40 participated in the experiment.

## 3 - RESULTS AND DISCUSSION

### 3.1 - Reliability of the judgments

The coefficient of correlation between two trials was calculated for each subject. Statistically significant correlation was obtained for all the subjects except for one subject. Therefore, the following analyses were conducted with the data of two trials of 19 subjects.

### 3.2 - Impression of the sound

(1) Effect of sound level

An example of the effect of sound level is shown in Fig. 3. Statistically significant effect of sound level was found in most of the adjective scales. However, in some adjective scales such as "calm-shrill" and "metallic-deep" other factors seem to play more important role than sound level.

(2) Effect of frequency characteristics of sound transmission

An example of the effect of frequency characteristics of sound transmission (filters) is shown in Fig. 4. It can be seen that e.g. the impressions "hard" and "rough" are different among filters. Statistically significant difference was found among filters in all the five sounds in the impressions "distinct", "shrill", "metallic", "hard" and "rough" when LAeq was 63 dBA and "distinct", shrill", "metallic", and "hard" when LAeq was 53 dBA. There was no adjective scale which showed statistically significant difference among filters when LAeq was 43 dBA.

### 3.3 - Factor analysis

The result of factor analysis is shown in Table 1. As in our former studies [3-5], three factors were extracted. They were "metallic" factor, "pleasant" factor and "powerful" factor.

### 3.4 - Relation between subjective impressions and physical measures

It was found that the sound level has a great effect not only on the impression of loudness but on various impressions. On the other hand, the effect of frequency characteristics of sound transmission was mainly found on the "metallic" impression even when the LAeq values were equal.

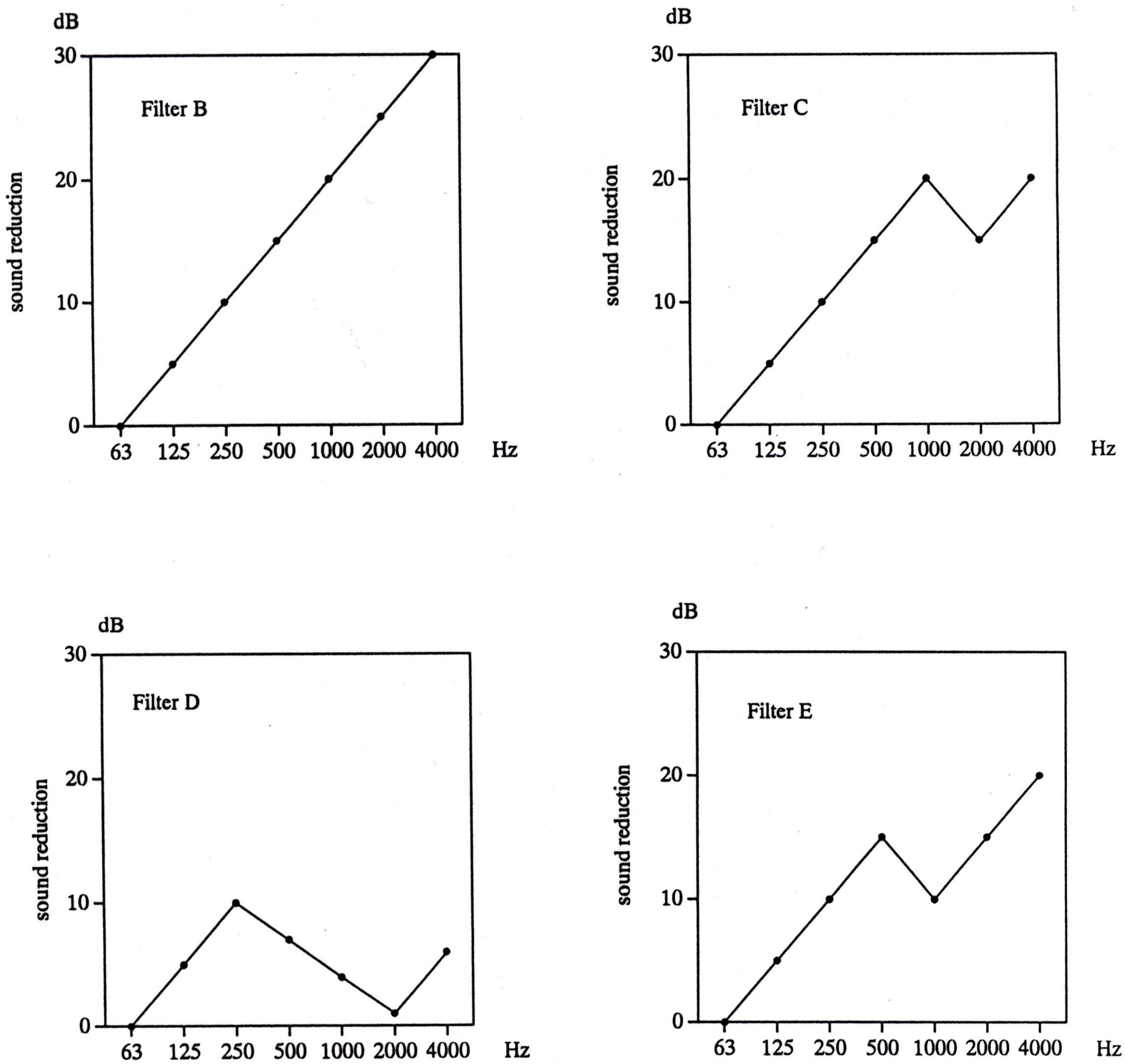


**Figure 2.**

In order to predict the sound quality of road traffic noise transmitted through walls, various physical measures were calculated and related to the subjective impressions. They were: loudness level based on ISO 532B [8] where the fluctuation of sound level was averaged on energy basis (abbreviated as LLz), sharpness, fluctuation strength, roughness and octave band levels from 125 Hz to 8 kHz. Sharpness, fluctuation strength and roughness were measured by the work station (Cortex Psychoanalyzer CF90) and maximum values were used in the data sampled every 2, 1000 and 100 msec, respectively.

The coefficients of correlation between each physical measure and subjective impression were calculated. When LAeq values were equal, calculated sharpness and mean energy levels of octave band levels whose center frequency were higher than 2 kHz showed high correlation with the impression of "pleasant" factor and "metallic" factor. Examples are shown in Fig. 5, Fig. 6. This suggests that it is effective to reduce the sound levels of frequency components higher than 2 kHz in order to improve sound quality. On the other hand, frequency components lower than 500 Hz gave the impression of impure. Calculated roughness also showed fairly good correlation with the unpleasant impression.

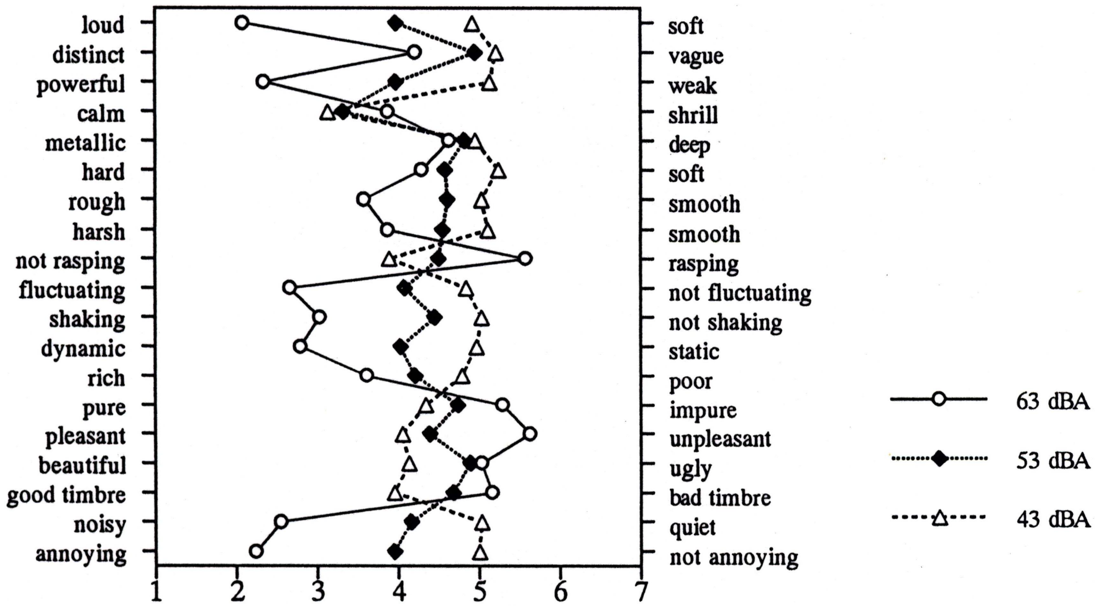


**Figure 3.**

| | I | II | III |
|---|---|---|---|
| loud - soft | 0.30 | -0.47 | 0.65 |
| distinct - vague | 0.68 | -0.13 | 0.42 |
| powerful - weak | 0.31 | -0.39 | 0.72 |
| calm - shrill | -0.73 | 0.26 | -0.21 |
| metallic - deep | 0.81 | -0.15 | 0.11 |
| hard - soft | 0.77 | -0.29 | 0.33 |
| rough - smooth | 0.67 | -0.39 | 0.39 |
| harsh - smooth | 0.65 | -0.39 | 0.36 |
| not rasping - rasping | -0.40 | 0.76 | -0.21 |
| fluctuating - not fluctuating | 0.38 | -0.25 | 0.70 |
| shaking - not shaking | 0.37 | -0.27 | 0.71 |
| dynamic - state | 0.43 | -0.34 | 0.67 |
| rich - poor | 0.03 | -0.01 | 0.58 |
| pure - impure | 0.05 | 0.61 | -0.18 |
| pleasant - unpleasant | -0.38 | 0.75 | -0.24 |
| beautiful - ugly | -0.30 | 0.78 | -0.21 |
| good timbre - bad timbre | -0.39 | 0.76 | -0.14 |
| noisy - quiet | 0.45 | -0.54 | 0.57 |
| annoying - not annoying | 0.40 | -0.57 | 0.54 |

**Table 1:** Result of factor analysis.

Multiple regression coefficient was calculated using "unpleasant" impression as a dependent variable and LAeq, calculated sharpness and calculated roughness as independent variables. Multiple regression coefficient was 0.95. The coefficient of correlation of the "unpleasant" impression was 0.92 for LAeq alone, 0.20 for calculated sharpness alone and 0.78 for calculated roughness alone. This result suggests that when these three measures are combined, the "unpleasant" impression can be predicted better than each measure alone.

## 4 - CONCLUSION

The result of this study suggests that the calculated sharpness, calculated roughness and octave band levels higher than 2 kHz have a significant effect on the "unpleasant" impression of road traffic noise if the level exceeds the guideline. It is important to take the frequency characteristics of walls and windows in order to improve the sound quality of indoor noise.

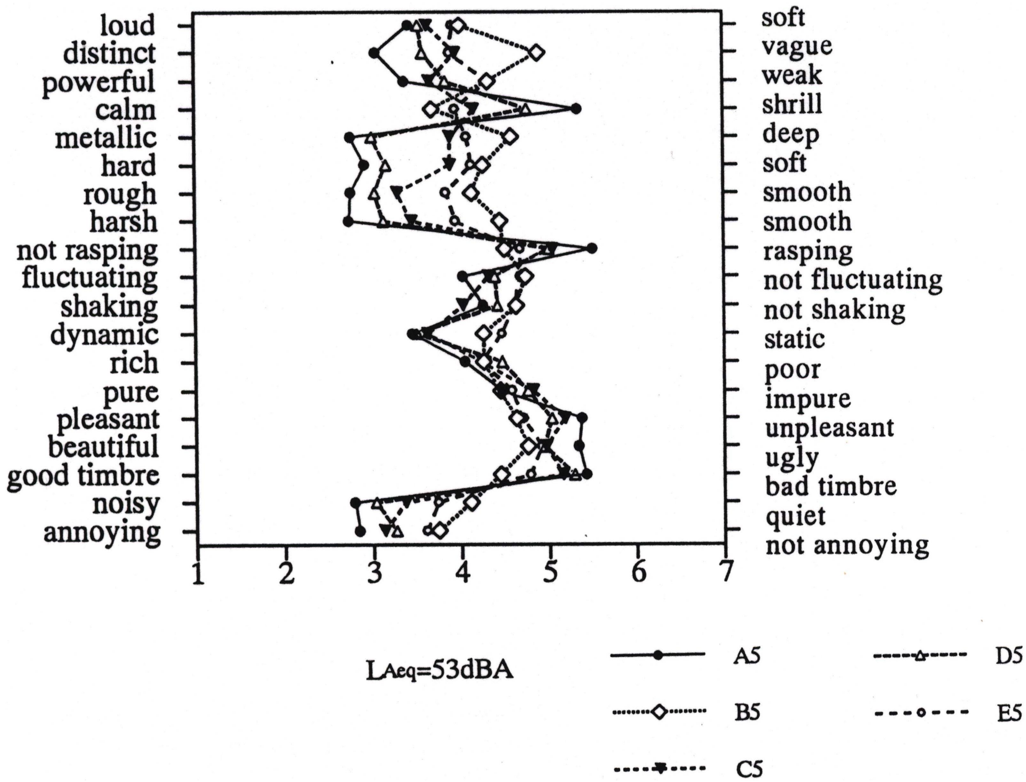


**Figure 4.**

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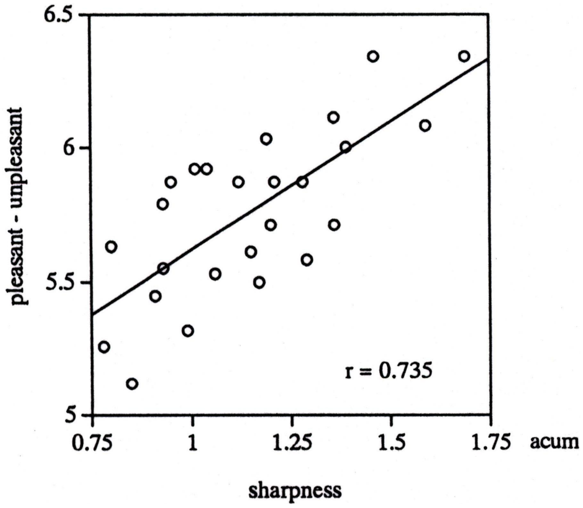


**Figure 5.**

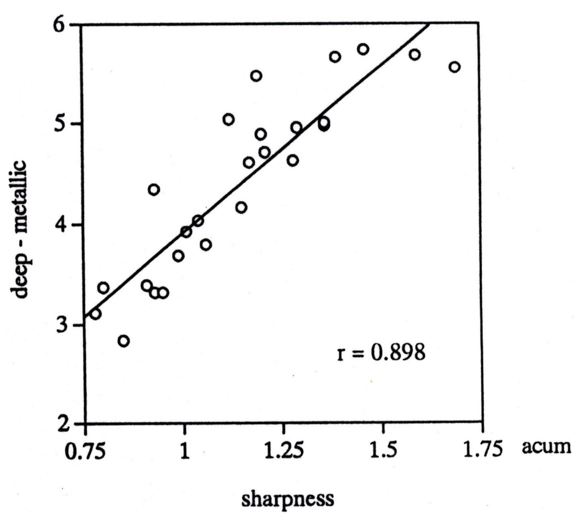


**Figure 6.**