Evaluation Method of Annoyance due to Low-Frequency Noise from Large Vehicles

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This study investigates the effect of low-frequency components in noise generated by heavy vehicles on annoyance, with particular emphasis on the relationship between level differences and subjective responses. A laboratory experiment using a paired comparison method was conducted to quantify how low-frequency content influences annoyance when conventional acoustic metrics are controlled. Traffic noise is typically evaluated using A-weighted sound pressure level (L_{Aeq}), which has been widely accepted as a reliable index of community responses. However, its applicability becomes limited when spectral characteristics deviate from broadband conditions, particularly in the presence of dominant low-frequency components. Previous studies have suggested that low-frequency noise can induce additional sensations such as oppressive and vibratory feelings, which may contribute to increased annoyance beyond what is predicted by A-weighting alone. Based on this background, the present study aims to clarify the extent to which low-frequency components affect annoyance and to examine whether alternative metrics such as loudness level provide a better representation.

The experiment was conducted in a controlled laboratory environment using recorded sounds of heavy vehicles. Two types of stimuli were prepared: (1) “Low-Freq” stimuli containing original low-frequency components and (2) “Low-Cut” stimuli in which frequencies below 80 Hz were removed using a high-pass filter. These stimuli were presented in pairs, and participants were asked to indicate which sound was more annoying. A total of eight stimulus pairs with varying level differences were tested, including conditions where the L_{Aeq} of the two stimuli were approximately equal. The primary results are summarized in Fig. 1, which shows the relationships between the level difference in A-weighted sound pressure level (ΔL_A) and the proportion of participants who judged the Low-Freq stimulus as more annoying (%LFA). The %LFA values were transformed into z-values to examine the linear relationship. In this representation, the point where z = 0 corresponds to the subjective point of equality (PSE), at which both stimuli are perceived as equally annoying. The regression line in Fig. 1 reveals a clear systematic relationship between ΔL_A and annoyance judgments. Notably, the intersection with z = 0 occurs at negative ΔL_A values, indicating that the Low-Freq stimulus is perceived as equally annoying as the Low-Cut stimulus even when its A-weighted level is lower. Specifically, the PSE values derived from the data indicate that the Low-Freq stimulus requires approximately 2.0 dB to 4.2 dB lower L_{Aeq} to achieve the same annoyance as the Low-Cut stimulus. This finding demonstrates that low-frequency components increase perceived annoyance beyond what is captured by A-weighting.

To further examine this discrepancy, loudness levels based on ISO 532 were analyzed. When the results were organized using loudness level, the level difference at the PSE was reduced to approximately 2 phon, which is smaller than the difference obtained using A-weighted sound pressure level. This indicates that loudness-based metrics can partially account for the additional annoyance caused by low-frequency components. In other words, the unexplained contribution of low-frequency sound observed in A-weighted evaluations is better represented when loudness is used as the evaluation index. These findings suggest that, in the assessment of traffic noise containing low-frequency components, the use of loudness level provides a more appropriate evaluation framework than A-weighted sound pressure level alone. Although residual effects such as pressure and vibration sensations may still remain, incorporating loudness metrics improves the representation of perceptual responses to low-frequency noise.

In conclusion, the analyses demonstrate that low-frequency components significantly increase annoyance, even when A-weighted levels are equal. Furthermore, the reduction in PSE differences when using loudness level highlights its potential as a more suitable indicator for evaluating annoyance due to low-frequency noise. These results provide useful insights for developing improved evaluation methods for traffic noise that includes substantial low-frequency content.

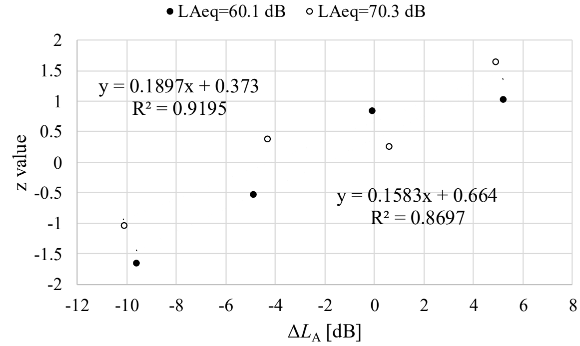

Fig. 1 Relationship between ΔL_A and %LFA