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The sound insulation of façades at infrasound frequencies

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Abstract
Our purpose was to provide experimental information on the indoor-outdoor level difference, DL, of typical façade constructions in Finland and to present feasible estimation of DL that can be used to assess the indoor SPL of environmental noise in any building. The DL of 26 façade constructions were measured for 13 residential houses within 4–200 Hz. Statistical methods were used to derive a feasible estimate of DL that is exceeded in 84% of cases. The estimate can be used to assess the sound pressure level of environmental noise indoors in cases when the level difference of the façade cannot be measured but the outdoor sound pressure level of environmental noise is available.

Keywords: low-frequency noise, sound insulation, façades

1 Introduction

In Finland, the sound pressure level (SPL) of low-frequency environmental noise indoors shall not exceed the values of Table 1 [1]. The SPL caused by environmental noise inside a dwelling at low frequencies is calculated by subtracting the outdoor-indoor level difference (*DL*) of the façade from the outdoor SPL. During area planning stage, it is usually not possible to measure the façade *DL* of every dwelling of the inspected area since the number of inspected dwellings can be very large. Therefore, politically accepted estimations of *DL* need to be used. They are most probably exceeded in most façade constructions. There is very little data available of the *DL* of façade constructions during the last decades as reviewed by Keränen et al. [2]. Our purpose was to provide experimental information on the *DL* of typical façade constructions in Finland and to present feasible estimation of *DL* that can be used to assess the indoor SPL of environmental noise in any building. This paper is a summary of Ref. [2].

Table 1: The action values of equivalent unweighted SPL, $L_{pZ,eq,1h}$, in rooms used for sleeping for night-time hours (22–07) and daytime hours (07–22) given by the Finnish Ministry of Social Affairs and Health [1].

f [Hz]	20	25	31.5	40	50	63	80	100	125	160	200
Night [dB]	74	64	56	49	44	42	40	38	36	34	32
Day [dB]	79	69	61	54	49	47	45	43	41	39	37

2 Methods

We chose 13 single-family houses built during different decades (1921–2016) and built using different materials (timber, brick, hybrid) under inspection. If the house had different constructions on different façade sides, two or three façades of the same house were measured. Altogether 26 façades were measured.

Test sound was produced using a custom-made infrasound subwoofer (5–20 Hz), a standard subwoofer (Genelec 7050B, 20–80 Hz), and an omnidirectional sound source (NOR276). The three sound sources were located 5 meters from the measured façade. Since the loudspeakers were located on the ground, we assume that the vertical façade was the dominant sound transmission path. Measurements were conducted under low wind speed conditions to avoid wind-generated pseudo-noise due to airflow turbulence in the microphone. Despite of low wind speed, we used windscreen around the microphone.

ISO 16283-3 describes a method to determine the sound reduction index of façade within 50–5000 Hz. We focused on low frequencies and used a non-standard method. The level difference to a corner position i of the room, DL_{Ci} [dB], was determined by

$$DL_{Ci} = L_{p1} - L_{p2,Ci} - 6 \tag{1}$$

where $L_{\mathrm{p,1}}$ [dB] is the energy average of outdoor SPL in the vicinity of the façade surface, and $L_{\mathrm{p2,Ci}}$ [dB] is the SPL in the corner position i of the receiving room. We used four positions in the room corners, C1−C4, 0.3–0.4 m from the corner. The level difference to a middle position j of the room, DL_{Mj}, was determined by

$$DL_{Mj} = L_{p1} - L_{p2,Mj} - 6 \tag{2}$$

where $L_{\mathrm{p2,Mj}}$ [dB] is the SPL in the middle position j of the receiving room. We used five positions in the middle of the room: M1−M5. The average level difference of four corner positions, DL_{C}, was determined by

$$DL_C = -10 \cdot \log_{10}\left[\frac{1}{4}\sum_{i=1}^{4} 10^{-DL_{Ci}/10}\right] \tag{3}$$

Correspondingly, the average level difference of five middle positions, DL_{M}, was determined by

$$DL_M = -10 \cdot \log_{10}\left[\frac{1}{4}\sum_{j=1}^{5} 10^{-DL_{Mj}/10}\right] \tag{4}$$

We determined the 84th percentile level from the 26 measured level differences $DL_{\mathrm{C}\sigma}$ and $DL_{\mathrm{M}\sigma}$ to represent sophisticated lower limit of level difference among the sample as suggested by Hoffmeyer and Søndergaard [3]. Because the level difference values are planned to be used in assessing the SPL of environmental noise indoors, and the occupant can spend time in any position in the room, we determined first the data-based value, called $DL_{\sigma,\mathrm{data}}$, by giving a weight of 1/3 to $DL_{\mathrm{C}\sigma}$ and a weight of 2/3 to $DL_{\mathrm{M}\sigma}$, as Hoffmeyer and Søndergaard [3] did. Both outcomes had a specific frequency dependence. Because of political reasons, we derived the final DL_{σ} by applying a polynomic fit to $DL_{\sigma,\mathrm{data}}$. The outcome, DL_{σ}, was then monotonically growing as a function of frequency. It was also rounded to the nearest integer.

3 Results

The *DL* values of the 26 façade constructions and the 84th percentile values are shown in Fig. 1. The main outcome of this work, DL_{σ}, as a function of frequency, is shown in Table 2.

4 Practical utilization

Because the values of DL_{C} and DL_{M} varied significantly between the studied 26 façade constructions, it is important to know the actual *DL* if the indoor SPL of environmental noise needs to be known precisely. However, the measurement of *DL* for every façade is not realistic during area planning. In 84% of cases, DL is larger than the DL_{σ} of Table 2. The indoor SPL can be assessed by

$$L_{p,in} = L_{p,out} - DL_{\sigma} \tag{5}$$

where $L_{\mathrm{p,out}}$ [dB] is the SPL of environmental noise outdoors and DL_{σ} [dB] is obtained from Table 2. It is assumed that indoor SPL exceeds $L_{\mathrm{p,in}}$ only in 16% of cases. $L_{\mathrm{p,out}}$ is obtained either by measurement or simulation. It shall not contain any reflections from the studied building. In Finland, $L_{\mathrm{p,in}}$ is compared to the action values of Table 1. If they are exceeded in a specific dwelling, it is justified to determine the façade level difference in that dwelling by measurements.

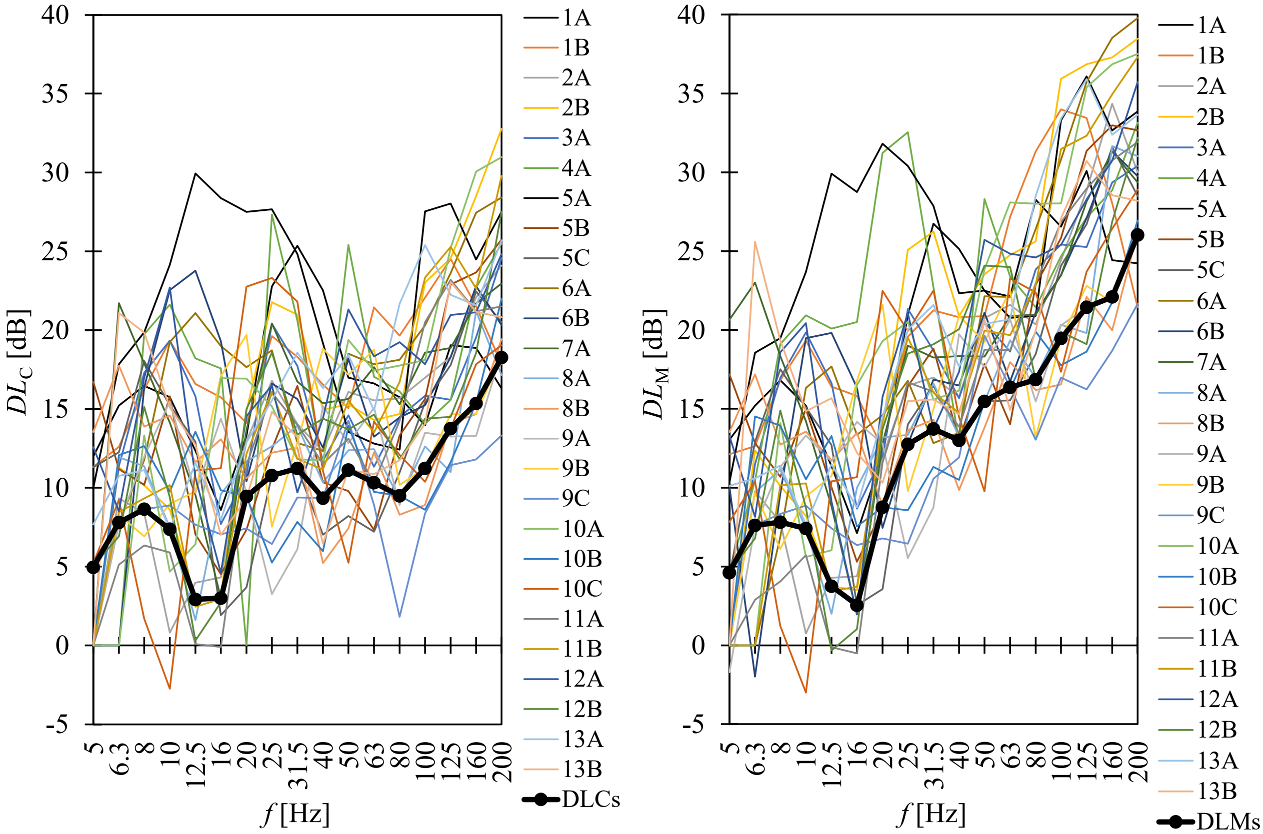

Figure 1: Left) Outdoor-indoor level difference measured in the corner positions, DL_C, as a function of frequency, f, for the 26 measured façade constructions. DLCs shows the 84th percentile of the 26 façades. Right) Outdoor-indoor level difference measured in the middle area positions, DL_M, as a function of frequency, f, for the 26 measured façade constructions. DLMs shows the 84th percentile of the 26 façades.

Table 2: Outdoor-indoor level difference, DL_σ, as a function of frequency, f.

f [Hz]	5	6.3	8	10	12.5	16	20	25	31.5	40	50	63	80	100	125	160	200
DL_σ [dB]	6	6	6	6	7	7	8	8	9	10	12	13	15	17	19	21	23

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