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AVERAGED AND TIME VARIANT AIRBORNE SOUND INSULATION

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ABSTRACT

The work presents the measurement results of airborne sound insulation between rooms of a party wall that have been carried out in a real life building site using different noise sources (white noise, vacuum cleaner, "I want it all" by QUEEN and "The Tempest" by Vivaldi). The single-number quantities (R'_w, R'_A, R'_{Atr}) used to rate objectively airborne sound insulation of building elements are calculated for each stimuli both as time averaged and time variant values. Time variation and its depth of fluctuation are pointed out to investigate a possible correlation between objective and subjective evaluation of airborne sound insulation.

Keywords: *airborne sound insulation, single-number evaluation index, time variation.*

1. INTRODUCTION

Noisy neighbours are considered a primary cause of annoyance and the various noises are complex and generally hardly quantifiable for their unpredictable nature. Furthermore, to determine airborne sound insulation, according to international standards, a broadband noise is used as source signal for the measurement. Considering the quality assessment of sound insulation in dwellings [1], a correlation between objective sound insulation of walls and subjective assessments of noise transmitted between neighbouring apartments is still under investigation .

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2. MATHERIALS AND METHODS

To quantify the sound insulation effect of different sound stimuli, measurements have been carried out to numerically investigate the results. Using filed sound pressure measurements in a real life building site, apparent airborne sound insulation between rooms of a party wall have been determined in the frequency range from 50 Hz to 5000 Hz, according to ISO 16283-1 [2]. White noise and other different stimuli were used for the omnidirectional sound source: vacuum cleaner, "I want it all" by QUEEN and "The Tempest" by Vivaldi. Fixed microphone and manually-scanned microphone techniques were adopted for the white noise source measurements. Fixed microphone technique was used to compare the other stimuli.
Experimental survey has been carried out using following measurement set-up:

- dodecahedral sound source Lookline DL 301 used in max linearity mode
- Sinus Soundbook_MK2 and Samurai measurement and post-processing software
- ½" PCB Model 378A21 microphone
- Impulse source for reverberation time measurements

Frequency-dependent spectrums were converted into a single number quantity using the rating procedures described in the ISO 717-1 [3].

3. RESULTS

The single-number quantities (R'_w, R'_A, R'_{Atr}) used to rate objectively airborne sound insulation of building elements are determined for each stimulus used as noise sources and values are summarized in figure 1.

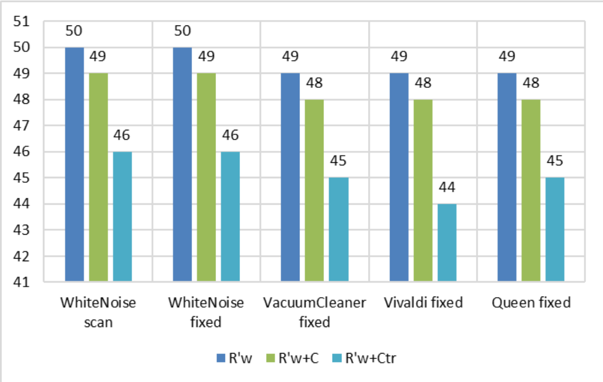

Figure 1. Single-number quantities for noise source.

The measurements done with different stimuli used as excitation source led to very similar apparent airborne sound insulation spectrum. Figure 2 depicts apparent sound insulation for each of the noise spectrum used as excitation source. As a result the insulation performances of the wall expressed as single number quantities register a small variation of approx. 1 dB in terms of R'_w, R'_A, R'_{Atr}. As shown in Figure. 1, it cannot be pointed out a clear dependency of the sound reduction index on the sound source type.

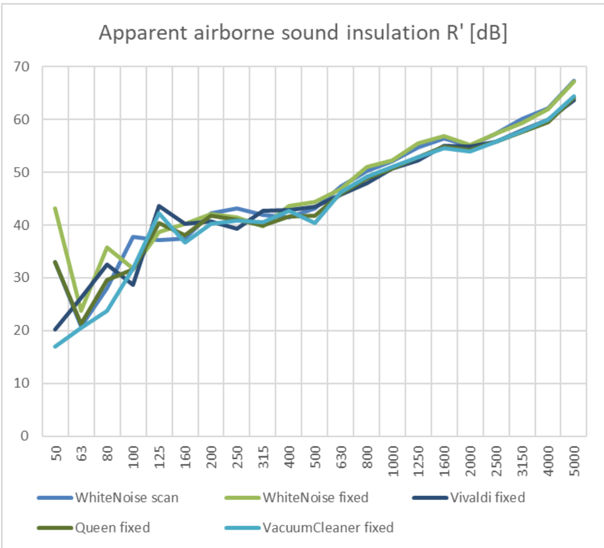

Figure 2. Apparent airborne sound insulation spectrum for each noise source.

Furthermore, the set of sound spectra in one-third-octave bands of each stimulus are used to calculate the "spectrum adaptation terms" C_i (i.e. C_{white}, C_{vac}, $C_{vivaldi}$, and C_{QUEEN}) and rate the R'_w+C_i single-number quantities. The different stimuli spectra depicted in Figure 3 are A-weighted and the overall spectrum level is normalized to 0 dB. The calculation follows the procedures described in paragraph 4.5 of the ISO 717-1:2020 standard. A summary of results is collected in Table 1 and 2.

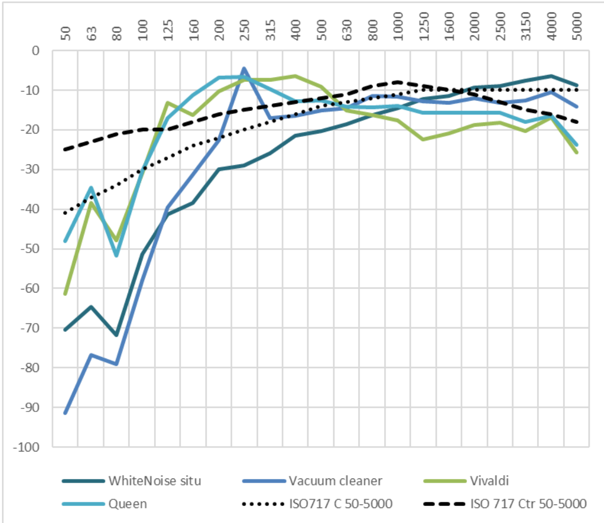

Figure 3. A-weighted and normalized to 0 dB sound level spectra of different stimuli.

Table 1. Spectrum adaptation terms.

	C	C_{tr}	C_{white}	C_{vac}	$C_{vivaldi}$	C_{QUEEN}
100-3150	-1	-3	5	-4	-7	-4
100-5000	0	-3	4	-4	-7	-4
50-3150	-1	-4	5	-4	-7	-4
50-5000	0	-4	4	-4	-7	-4

Table 2. Single-number quantities R'_w+C_i.

	R'w +					
	C	C_{tr}	C_{white}	C_{vac}	$C_{vivaldi}$	C_{QUEEN}
100-3150	50	48	56	47	44	47
100-5000	51	48	55	47	44	47
50-3150	50	47	56	47	44	47
50-5000	51	47	55	47	44	47

The spectrum adaptation terms have been introduced [1] to take into account different spectra of noise sources for

airborne sound insulation: C corresponding to pink noise and C_{tr} and road traffic noise.
As shown in table 1, if compared with the C spectrum adaptation term, C_{tr} seems to be more representative of the spectrum adaptation terms gathered from the vacuum cleaner and Queen stimuli. On the other hand, relevant discordance can be pointed out comparing with the spectrum adaptation terms gathered from Vivaldi stimulus. Looking at the spectrum adaptation term gathered form the white noise stimuli, a positive valued is pointed out. This might lead to consider not representative the standard SNQs for a noise source whose power spectral density is essentially independent of frequency.
The white noise if compared to the pink noise on which the C spectrum is based [1], is a signal with a much higher content of high frequencies that are better isolated by the tested wall. This lead to consider that heavyweight masonry cavity wall behaves better in terms of insulation (reduction of disturbance to the receiver) if white noise is emitted instead of pink noise. On the other hand, for music tracks and vacuum cleaner (which are generally characterized by a higher content of low frequencies) the situation is reversed with respect to pink noise. In this case, the disturbance appears to be greater because low frequencies are prevalent in the stimulus signal and less isolated by the wall.
Finally, to investigate the time variation and its depth of fluctuation apparent airborne sound insulation was calculated for each stimulus with an averaged sound pressure level in the time period of 0,5 s. Calculating the single-number quantities of each spectrum it is therefore possible to show the time history of the apparent airborne sound insulation index over the entire measurement period.
For each stimulus used as sound source, Figure from 5 to 15 show the apparent airborne sound spectrum calculated for each time interval od analysis, the time history variation and the distribution of SNQ R'_{w}.
Despite the coherence of the apparent airborne sound insulation spectrum averaged in the overall time period (as shown in Figure 2), the individual spectrums of the apparent airborne sound insulation calculated in the time period of 0,5 s reveal substantial deviation from the average spectrum especially for music tracks. Furthermore music tracks are characterized by the presence of signal pauses in which the effect of background noise in the receiving room may not be negligible. All this is clearly reflected in the time history of SNQ R'_{w} and in the resulting frequency distribution of values.

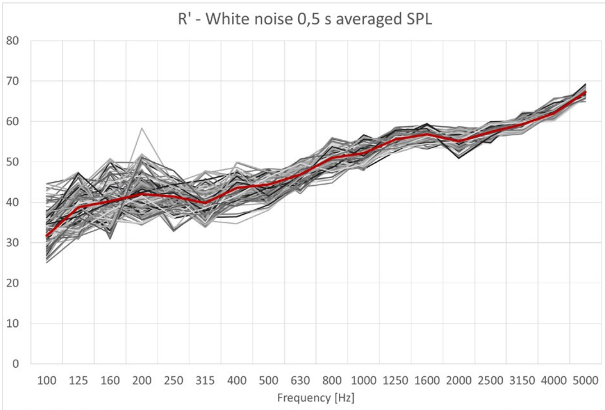

Figure 4. Apparent sound pressure level for white noise stimuli calculated with 0,5s averaged SPL.

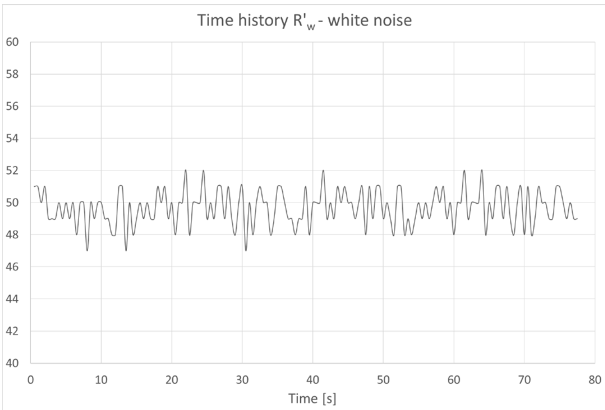

Figure 5. Time history of R'_{w} calculated with 0,5s averaged SPL with white noise stimuli.

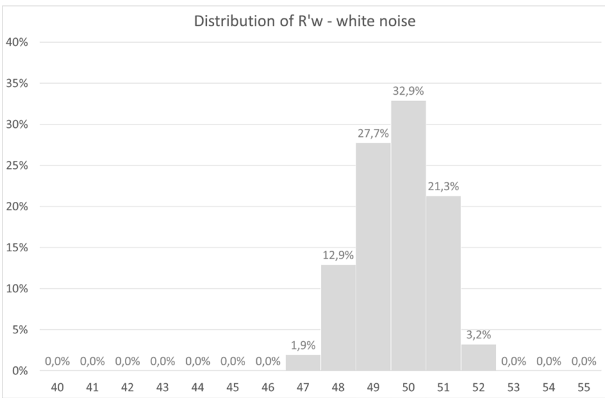

Figure 6. Distribution of $R'_{w,white}$ over the entire measurement period.

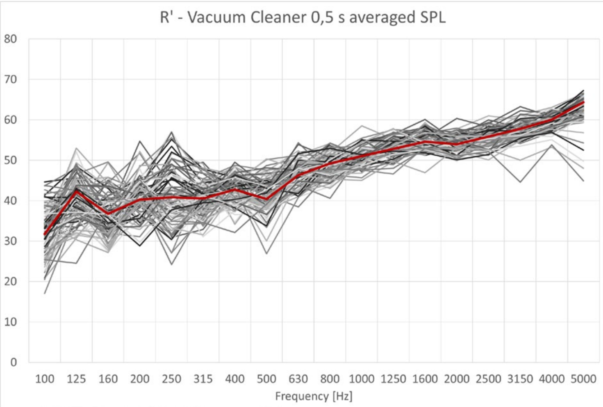

Figure 7. Apparent sound pressure level for vacuum cleaner stimuli calculated with 0,5s averaged SPL.

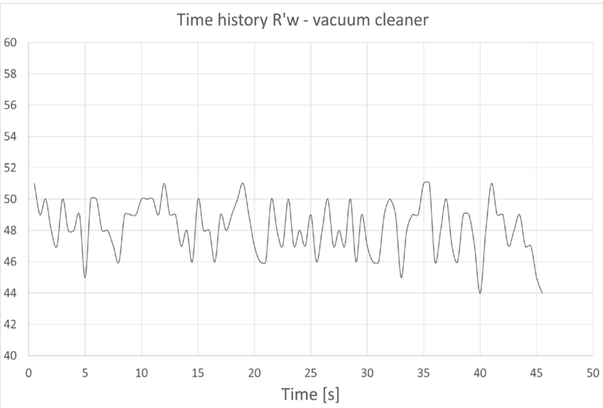

Figure 8. time history of R'$_w$ calculated with 0,5s averaged SPL with vacuum cleaner stimuli.

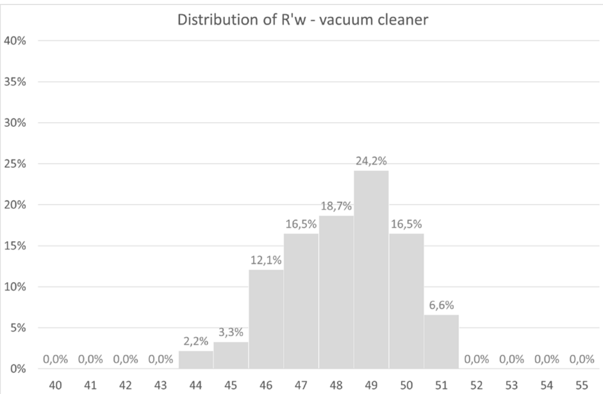

Figure 9. Distribution of R'$_{w,vacuum}$ over the entire measurement period.

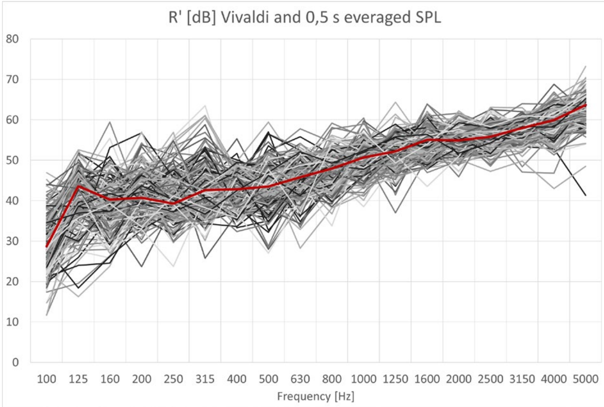

Figure 10. Apparent sound pressure level for Vivaldi stimulus calculated with 0,5s averaged SPL.

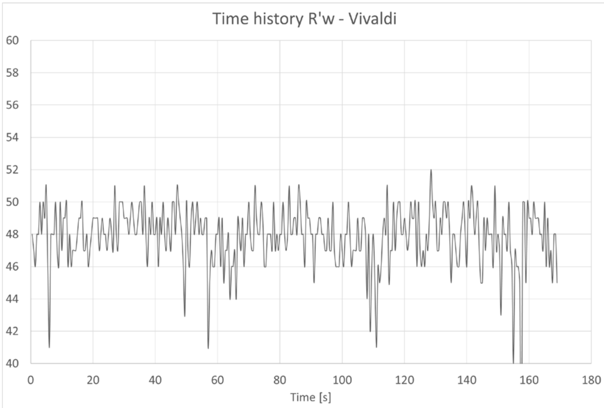

Figure 11. time history of R'$_w$ calculated with 0,5s averaged SPL with Vivaldi stimulus.

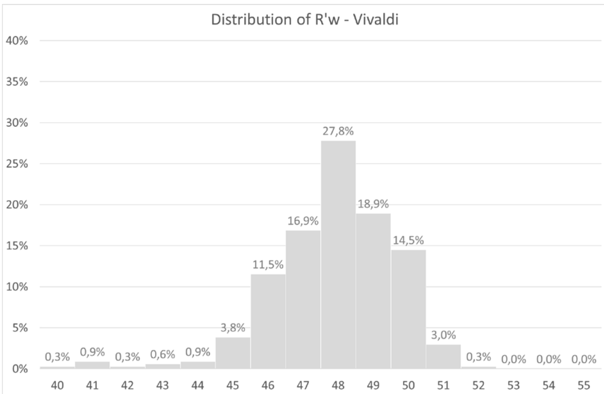

Figure 12. Distribution of R'$_{w,Vivaldi}$ over the entire measurement period.

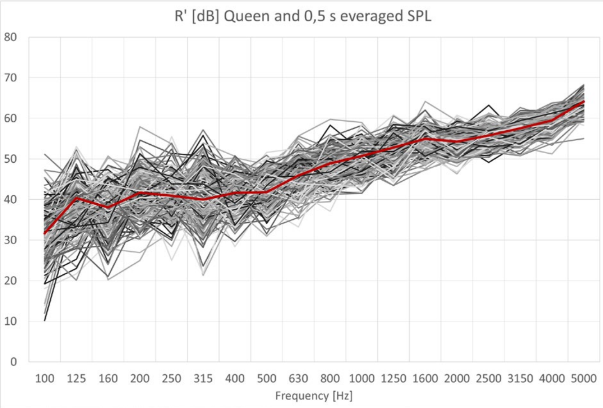

Figure 13. Apparent sound pressure level for Queen stimulus calculated with 0,5s averaged SPL.

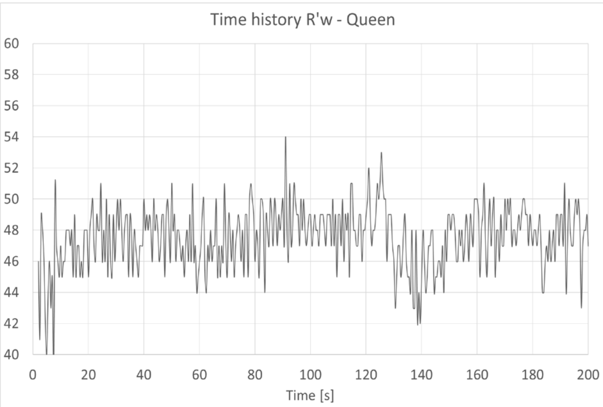

Figure 14. Time history of R'$_w$ calculated with 0,5s averaged SPL with Queen stimulus.

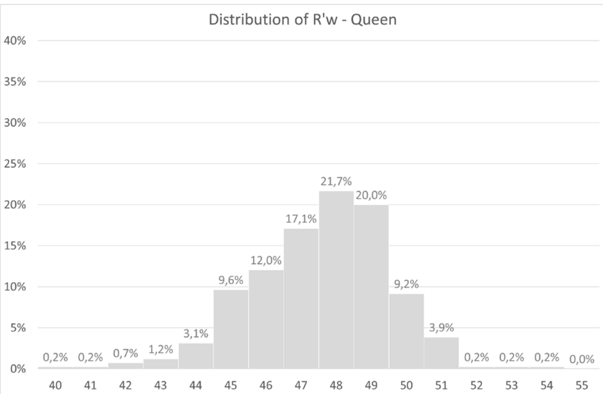

Figure 15. Distribution of R'$_{w,Queen}$ over the entire measurement period.

4. CONCLUSION

As quoted in 4.5 of the 717-1 [3] the spectra of most of the usual prevailing indoor and outdoor noise sources lie in the range of spectra Nos. 1 (A-weighted pink noise) and 2 (A-weighted urban traffic noise) but it could be pointed out that they are not representative of the stimuli used in the current research and, as a result, the spectrum adaptation terms C and C_{tr} cannot therefore be used to fully characterize the sound insulation with respect to these noise sources. The optimization of noise spectra for the valuation of airborne sound insulation [1] is still an open topic that was not overcome in the latest revision of the ISO 717:2020.

Looking at the time history, except for the white noise (±2dB), the fluctuation of apparent airborne sound insulation for each stimuli R'$_{w,stimuli}$ ranges above +4 dB and below -8 dB the mean value. If, for broad-band noise, it could be generally accepted [4] that a change of about 10 dB in SPL corresponds to a doubling or halving of perceived loudness, the depth of fluctuation in loudness can be clearly perceived. To asses a correlation between an objective and a subjective evaluation of loudness further investigation would be needed taking into account a "realistic volume level" of the sound source.

5. ACKNOWLEDGMENTS

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6. REFERENCES

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