Revision of ISO 717: Future single-number quantities for sound insulation in buildings

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Introduction

ISO 717 [1] describes the rules, how to calculate so-called single-number values from given (mostly third-octave band) spectra of sound insulation. A few years ago the decision was made at ISO to revise both parts of ISO 717. Besides an update of references and some minor improvements, the corresponding working group (ISO TC43 SC2 WG18) was mandated to reduce the number of selectable single-numbers, like e.g. R_w, R_w+C, R_w+$C_{50\text{-}5000}$, R_w+C_{tr} etc. The present state of discussion is reported here as well as some new aspects concerning sound reduction indices and their single-number quantities.

The present state of discussion

The selection out of the plenty of offered single-numbers seemed quite simple: Including frequencies below 100 Hz into the single-number evaluation improves the correlation between the single-numbers and annoyance as well as loudness. So, quantities starting only at 100 Hz were eliminated. Furthermore, the "R_w-System" (comparing insulation spectra with a reference curve) and the "R_w+C-System" (representing – very different from the misleading name! – a difference of the total source and receiving powers) are equivalent with respect to psychoacoustic relevance, as long as they cover the same frequency range. Therefore, the quantities according to the R_w-System were removed. The remaining R_w+C-System is much better fitted to power considerations, as usual in building acoustics, and it allows a direct estimation of single-number uncertainty from the third-octave bands. Also, the question arose, why impact sound insulation should be represented by impact sound levels, whereas airborne sound is represented by sound-reduction indices. Along the way, a new quantity was created to represent the speech intelligibility reduction (or privacy) in buildings or by building elements. And finally, no longer an obstacle was seen to give the selected single-number quantities self-explanatory names, like R_{living}, $R_{traffic}$ etc. Table 1 shows the remaining quantities according to the present state of discussion and their existing 'old' equivalents. R_{speech} uses a new reference curve but is still based on the existing "R_w+C"-procedure. It has to be noted, that "R_w+C" does not at all mean to determine R_w first and then to determine an extra correction C. It is in fact a quantity of its own, namely a total level difference, in some cases an A-level difference. The general formula to evaluate all selected single-number quantities (impact sound reduction indices inclusive) is

$$R_{xx} = 10 \cdot \lg \frac{\sum_i 10^{L_i/10}}{\sum_i 10^{(L_i - R_i)/10}} \quad dB, \qquad (1)$$

where L_i are the corresponding reference source spectra for traffic, living, speech and impact noise. The first two spectra are known from the definition of the spectrum adaptation terms C_{tr} and C.

Table 1: The actual single-number quantity proposals and their old equivalents (R_{speech} has a new reference curve, but follows the same old procedure as $R_{traffic}$ e.g.).

main fields of sound insulation	single-number	equivalent to:
living noise from neighbour	R_{living}	R_w + $C_{50\text{-}5000}$
traffic noise	$R_{traffic}$	R_w + $C_{tr,50\text{-}5000}$
speech intelligibility	R_{speech}	R_w + C_{speech}
impact noise (from typical use of flat)	R_{impact}	109 – ($L_{n,w}$ + $C_{I,50\text{-}2500}$)

Points, which were discussed

Reference spectra to be used

For single-number evaluation according to eq.1, a so-called reference source spectrum has to be used, which is a test-signal, for which the total power level difference through a building element or between rooms is calculated to represent the sound insulation performance. The reference source spectra for traffic noise and living noise already exist since long ago, they are the spectra defined for C and C_{tr} in the existing ISO 717. Nevertheless, their validity – in particular in the case of living noise – was doubted. One argument was, that pink noise would not be representative for typical noise from neighbours in multi-family houses. The second argument was, that the applied A-weighting (to represent ear sensitivity at levels of about 30 dB) was not correct either. So, besides the existing living noise reference source spectrum, other proposals were made. One by Technologische Gewerbemuseum (TGM) on the basis of noise measurements in apartments, another one by a generalised noise spectrum, gained from a Monte-Carlo simulation of several hundred thousands of noises. Another proposal was presented by Seidel [2]. This proposal accounts for low frequencies much less (about 20 dB at 50 Hz) than the other proposals. The spectra are shown in Figure 1. When intending to quit the A-weighting, it should be kept in mind, that at present worldwide nearly all noise emissions (e.g. for technical equipment in buildings or from road traffic outside) are expressed in terms of A-levels. A sound reduction index deviating from this A-weighting would then no longer be applicable to such level declarations, when a receiving room level had to be determined. In other words, a change of the A-weighting would need a parallel change of all corresponding emission declarations and requirements.

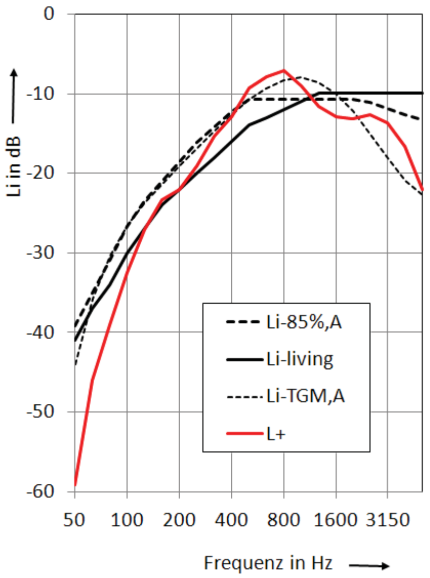

Figure 1: Different proposals for reference source spectra for living noise single-number rating. All but L+ contain A-weighting.

Bradley [3] has presented investigations of the correlation between single-numbers based on different reference source spectra and the annoyance of music and speech, transmitted through different walls. J. Lang determined the correlation between the loudness and the type of single-number rating for another 17 different heavy and lightweight walls. Both results are shown in Table 2. R_{living}, based on A-weighted pink noise, yields the best correlation values, closely followed by $R_{living,85\%}$ and R_{TGM}. R_w, which doesn't regard low frequencies at all, has the lowest values.

Table 2: Correlation of proposed single-number quantities with loudness (by J. Lang) and annoyance (by J. Bradley)

	R^2(annoy. music) (S.E.) R^2(annoy. speech) (S.E.)	R^2 (loudness, Li 75 dB)
R_{living}	0,98 (1,2) 0,66*) (5,8)	0,96
$R_{living,85\%}$	0,98 (1,3) 0,66 (5,5)	0,96
R_{TGM}	0,97 (1,3) 0,68 (5,4)	0,95
R+	0,92 (3,0) 0,46 (11,3)	0,81
R_w	0,80 (2,9) 0,89 (2,7)	0,72

*) Für R_{speech}: R^2(speech intelligibility) = 0,965

S.E. = standard error, accuracy in dB

As the discussion about typical noise from neighbours led to very detailed questions (what type of music is representative?) another approach was presented by the authors: It was assumed that all relevant noise events show spectra somewhere between an upper and a lower limiting spectrum, c.f. Figure 2. So, following the method of the proposed single-numbers, for hundreds of thousands of arbitrary spectra between the given limits the A-weighted level differences through building elements were calculated in a Monte-Carlo study. This results in a sound reduction index distribution for each regarded building element (or room situation). For the examples in Figure 3 the results are shown in Figure 4. The examples demonstrate the effect of an imbalance of the sound insulation spectrum: in the case of the masonry example, the achieved sound reduction index would lie closely around 50 dB, nearly independently from the neighbour's noise. In the other case it would scatter in a wide range between 45 and 65 dB, depending on what the neighbour emits. If the resulting single-number value was defined as the value which is undercut in only 15% of the neighbour's noises (and called thus $R_{living,85\%}$), then both examples would end up with nearly the same single-number value.

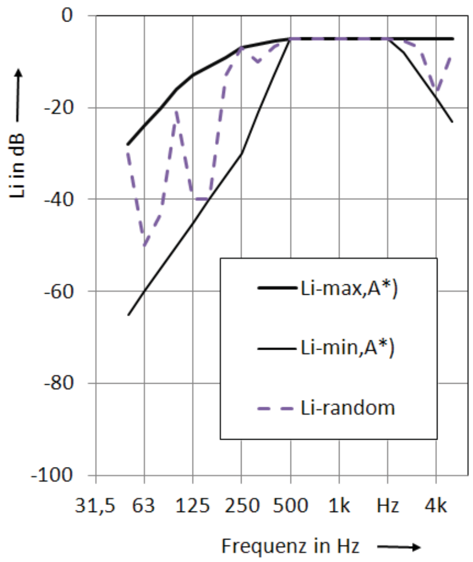

Figure 2: Limiting curves for the applied source spectra to calculate the A-weighted sound power level differences of building elements to represent their sound reduction performance. Based on [4].

Although the $R_{living,85\%}$-approach has the big advantage to disconnect the reference curve discussion from special audio material (Chopin or AC-DC?), it can be taken from Table 2, that R_{living} does quite as well, and it has the enormous advantage, that it is already existing as the well known and since many years used "R_w+$C_{50-5000}$", which means: no change in the product rating by this quantity, and no recalculation to get the new single-numbers.

Influence of including frequencies below 100 Hz

It was feared, that the inclusion of third-octave band values of the sound reduction index between 50 and 100 Hz could devalue the corresponding single-number quantities, because these frequency bands are connected with the highest uncertainty within the total frequency range. This has been examined by V. Wittstock by evaluating the standard deviation of single-number results from many Round-Robin tests in two ways: once, by calculating R_{living} from 50 to 5000 Hz, and secondly, by taking only 100 to 3150 Hz. The results are shown in Figure 5. It shows, that including low frequencies does not necessarily increase the spread or uncertainty of the single-numbers. In fact, some examples even show a decrease, owing to the fact, that scatter of neighbouring third-octave band values at low frequencies is mostly statistically independent, thus making an enlarged averaging more stable. But indeed, there are examples with increased uncertainty. These examples show predominant lack of sound insulation below 100 Hz and therefore their single-number values converge to the uncertainty of the relevant third-octave band. But this problem is a fact, which cannot be solved by simply omitting a perception relevant frequency range from the single-number evaluation. It should be noticed, by the way, that some building elements show larger uncertainty even in the reduced range 100-3150 Hz than others in the enlarged range from 50 to 5000 Hz, which is a hint, that reproducibility problems may be more severe than low frequency problems.

Impact sound reduction index instead of levels

Representing impact sound insulation by impact **sound pressure levels** instead of impact **sound reduction indices** has major disadvantages: The impact sound levels are strictly attached to a source which is very seldom in usual multi-family buildings: the ISO standard tapping machine. Thus, the advantage of levels instead of sound reduction indices, namely that they 'can be heard', doesn't count very much. Furthermore, the lack of appearance of the impact source in the insulation definition prevents this quantity to be used for more important cases, like impact noise from walking people. A calculated conversion from one source to another is not possible. An impact sound reduction index, however, allows to state clearly the impact sound insulation performance of building elements with regard to different sources. The following rules apply: The impact sound reduction is measured by **applying the source which shall be considered** – a tapping machine, when falling hammers or similar are of interest, or the modified ISO tapping machine e.g., when walking people are of interest. The sound reduction index is, exactly as in the case of airborne sound, the power level difference of the 'offered' source power (i.e. the characteristic source power) and the power radiated into the receiving room. Sound reduction indices for hammers and those for walkers cannot be converted into each other in a simple way, because the difference depends not only on the change of source but also on the mobilities of the tested building elements, which usually are unknown. Therefore, the 'correction' would be different for each type of building element.

After measuring the impact sound insulation spectrum in the correct way, i.e. with the intended source, a single-number can be evaluated by applying eq.1. Although theoretically an arbitrary reference source spectrum could be used here, it would not make much sense to choose one completely different from the characteristics of the source used for the measurement. However, a meaningful modification could again be an A-weighting of the reference source spectrum, thus approximating the hearing impression of the transmitted noise from that kind of source. Separate impact sound reduction indices could be defined for the most important impact sources of everyday life, maybe for falling hard objects and walking people, where adequate measurement sources already exist in the form of ISO and modified ISO tapping machines. In this case, the general index 'impact' for the sound reduction index should be replaced by more descriptive indices, e.g. R_{hammer} and $R_{walking}$.

Conclusions

There is a vivid discussion about new and better single-number quantities for sound insulation in future. Proposals have been made, and by their discussion, new findings appeared which indicate good solutions for the revision of ISO 717. In fact, most of the 'old' single-number quantities can be used in future, but with easier to understand names. The revised version, however, will have a number of its own, ISO 16717, to allow a parallel existence for a limited period and thus to attenuate the shock of renewal.

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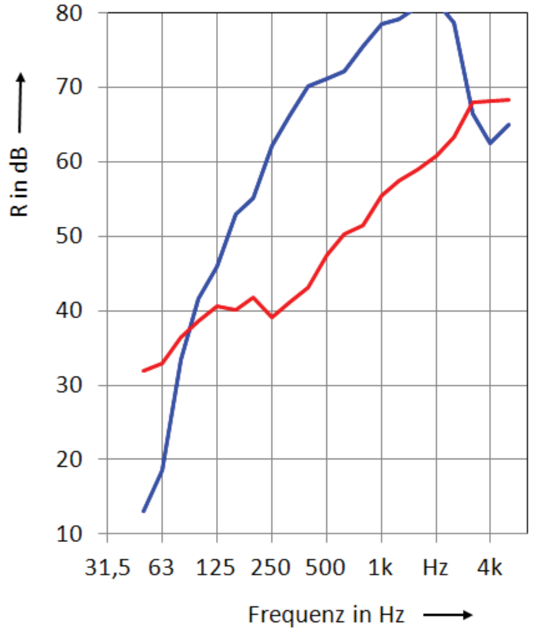

Figure 3: Examined sound reduction index spectra. Blue: lightweight double wall. Red: masonry wall

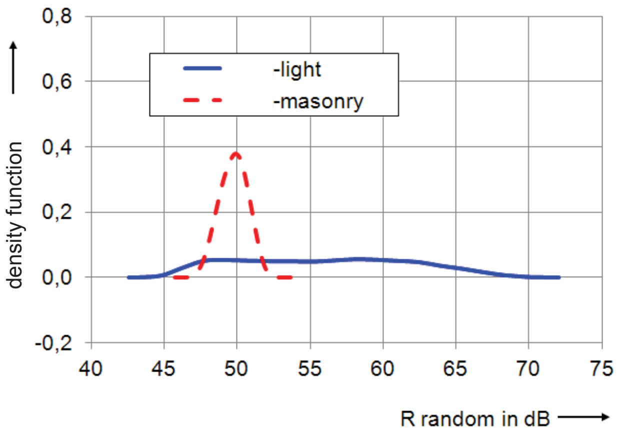

Figure 4: Resulting sound reduction index distributions for the walls in Figure 3.

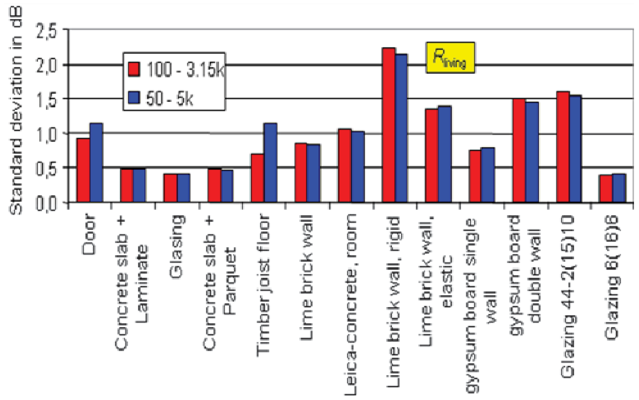

Figure 5: Standard deviation of R_{living} of different Round-Robin tests. Blue: full frequency range from 50 to 5000 Hz regarded. Red: only 100 to 3150 Hz regarded.