Reference Curves for Global Rating of Sound Insulation Improvement of Lightweight Wall Linings

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Abstract

After a brief view of single number quantities and psychoacoustic fundamentals used in sound insulation, reference curves provided in the new standard ISO/DIS 140-16:2003 [1] as a method for the global assessment of airborne sound insulation improvements of lightweight wall linings are dealt with. By using a numeric simulation model the properties of airborne sound insulation improvements of wall linings resulting from that single number ratings are discussed: among then the frequency intervals of higher efficiency and the insignificance of the incident noise spectrum are noteworthy. Another important conclusion concerns the variability of global improvement as a function of the reference curve, the two curves involved in the standard project represents a certain compromise of simplicity.

1. Introduction

Reference curve method as a way of deriving a single number quantity to represent, balancing frequency dependence, sound insulation of partitions acquired along sixties a considerable importance [2]. Soon after Gösele [3] proposed an approach to that quantity, based on A-weighting curves of sound levels, well adapted to in situ screening measurements. Some decades later a refinement of this quantity, colloquially named ‘insulation in dBA’, received psychoacoustic support [4] on the basis of theory of sound quality perception through loudness, a computable quantity [5].

By using loudness, a finely computable quantity, the main quality factor of sound signals, [6], Moreno et al. [4] ‘experimenting’ with most common noises and noise level ranges in environment and buildings, conclude on the equivalence, for engineering applications, between the loudness level reduction of a noise when passing through a partition and the global transmission loss ‘in dBA’ (R_a) of that partition, no matter what partition be.

On the other hand the nearness, on a statistical basis, of R_a regarding R_w gives psycho acoustical meaning and spectral corrective terms C_n should be applied, n representing the particular incident noise. Note that C_n terms are simply R_an - R_wn excepting a slight difference between R_an and X_n [7] arising from some reduction of the frequency interval and a rounding of A-weighting in ISO 717.

Reference curves used on deriving single number ratings on ISO/DIS have a quite different meaning: the important dependence of R_w upon the shape (profile) of the transmission loss curve [8] of the wall where lightweight lining is applied to. The influence on R of the wall is twofold: first during the measuring process because of the influence of the mutual coupling between the wall and the lining, and second during the computing process of R_w because the shape of the transmission loss curve, R, of the wall.

This contribution deals with the second influence mentioned above.

2. Reference curves to compute ∆R_A (Global improvement of air borne sound transmission loss)

Last years lightweight linings have played a decisive roll on high scores of sound insulation in buildings. This is partly due to high values of transmission loss improvement (20 dB and more) and partly to the possibility of a reliable definition of ∆R as a proper characterisation of the lining, admitted a high decoupling regarding the wall. Further reasons can be found in the fact that ∆R could be considered as a linear term that adds arithmetically to R of partitions either on the main direct transmission path or on every indirect transmission path interrupted by the lining [9].

In the following the quantity R_un will be used, n meaning, as before, a particular incident noise. Because of previous statements conclusions will hold for R_w + C_An.

Global improvement quantity for sound insulation (like its numeric value) is defined as the difference between the global (or single number) values of airborne sound transmission loss curves respectively corresponding to the reference curve (virtual partition)
increased by improvements of the lining to be characterised \((R_{ri} + \Delta R_i)\) and to the reference curve alone \((R_{ri})\). It could be computed from values frequency bands (f.e. 1/3 octave bands) by using the following expression

\[
\Delta R_i = \Lambda(L_{r,i} - R_{ri}) - \Lambda(L_{r,i} - (R_{ri} + \Delta R_i)) \tag{1}
\]

being,

\(\Lambda\) the common sound level operator acting on the set of level values \(L_i\), in dB

\[L_{r,i} = L_{r,i} + A_{r,i}\] the \(\Lambda\) weighted \((r)\) incident noise levels in bands \(i = 1, 2, \ldots\), submitted to the condition \(10 \cdot \lg \sum_{i} 10^{(L_{r,i})/10} = 0\), for the same frequency ban interval.

\(R_i\) airborne sound transmission loss in band \(i\)

A similar equation results for incident traffic noise. (If the meaning of operator \(\Lambda\) is changed to represent the procedure of ISO 717-1, equation (1) gives directly \(\Delta R_{wi}\) of the lightweight lining)

3. Reference curves of ISO/DIS 140-10

The following Figure shows reference curves of ISO/DIS 140 labelled L-coincidence, M-coincidence, and Floors. Under the label ‘Straight line’ a further reference curve \(R_{n0,i}\) complementary of the impact noise levels \(L_{n0,i}\) of the normalised reference floor (ISO 717/2), through equation:

\[R_{n0,i} + L_{n0,i} = 30 \log(f_i/[1Hz]) + 34\]

4. Analytic models of curves \(\Delta R(f)\)

Based on experimental results and existing theories \([10]\) a numeric model has been developed to produce simplified curves for \(\Delta R\), consisting on a ‘plateau’ with two lateral ramps. In this paper ramps with equal slopes were used. The following figure gathers two rather different experimental cases, who can be well matched by this model.

In the following, \(\Delta R\) curves will be gathered in two-dimensional (18x18) arrays. An array corresponds to a curve family \(F(h:s)\), characterised by two constant parameters: plateau height (\(h\)) and slopes (equal slopes, \(s\)) of raising and decaying ramps. Inside a family two arbitrary curves differ either on the plateau width or on the plateau position in the frequency axis. For simplicity whole numbers will be used for both plateau width and plateau position. This particular choice facilitates interpretation of result arrays. An array cell is denoted by two numbers: the file number indicating the plateau width (accounted by the number of frequency bands, 1/3 octave wide) and the column number that indicates the 1/3 octave frequency band where the plateau centre locates. Every \(\Delta R\) curve is formed by a plateau, one or two ramps and zeroes, to complete a total of 18 digits. Therefore \(\Delta R\) curves of first and last cells in every file have only a half of plateau width. The following Figure shows \(\Delta R\) curves of family \(F(8:6)\), corresponding to cells (1:1), (2:2), (3:4) and (5:12).
5. Results directly concerning $\Delta R_A$

5.1. Effects of plateau width and plateau position

For a large set of family curves $F(h; s)$, ($6 \leq h \leq 22$, $6 \leq s \leq 18$), global transmission loss improvements, $\Delta R_A$ and $\Delta R_{At}$, increase as the plateau width increases. They also increase as the plateau position increases up to the critical frequency of the reference curve, then decreasing towards zero. Values range from 0 dB for very narrow plateau widths until plateau height values, in dB. These facts are shown in the following Figure.

As it can be seen the maximum value for $\Delta R_A$, the plateau height, is attained asymptotically and usually a width of seven 1/3 octave bands suffice to nearly reach it. This is a generic result obtained for all analysed cases is of great importance in practice.

Traffic noise leads to quite similar results.

6. Influence of the reference curve on $\Delta R_A$

Previous Figure clearly shows analogies of ‘surfaces’ of obtained for the various reference curves considered. In the following these analogies will be studied more deeply. To this end a significant sample of transmission loss reduction improvement curves $\Delta R_n(f)$, $n = 0, 1, 2, \ldots$, likely representing actual cases is to be tested to obtain the set of results

$$\partial \Delta R_{A(a-b)} = \Delta R_{A,a} - \Delta R_{A,b}$$

where

- $a$, $b$ mean the two reference curves to be compared
- $n$ sweeps the curves sample

Images of $\delta$ for traffic noise and curves of family $F(8; 6)$, are shown in the two following figures, respectively taking $L_c – M_c$ and $L_c – S_c$ as parameters. The particular order of $\Delta R(f)$ curves on the array associated of a family, as explained facilitates an easy relationship of $\delta$ with plateau width and plateau position.

Traffic noise: comparison $L_c – M_c$

Traffic noise: comparison $L_c – S_c$

All cases studied lead to smooth variations of $\delta$ with plateau width and plateau position, that joined to slopes constitute the shape parameters of $\Delta R(f)$.

Additionally to the previous ‘deterministic’ analysis relating $\delta$ to shape parameters of $\Delta R(f)$, some further conclusions can be draw from statistical analysis of $\delta$ obtained with a proper sample of $\Delta R_n(f)$ curves.
There are no studies, at least in our knowledge, about a sample that likely represents a proper statistics of actual curves $\Delta R_n(f)$. Then all likely curves from all likely families, among the previously indicated, will be taken as a first approach of proper sample. More precisely the families of the following table have been taken:

<table>
<thead>
<tr>
<th>F(6 18)</th>
<th>F(12 18)</th>
<th>F(16 12)</th>
<th>F(18 18)</th>
<th>F(20 12)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F(6 6)</td>
<td>F(12 12)</td>
<td>F(12 6)</td>
<td>F(18 6)</td>
<td>F(20 6)</td>
</tr>
</tbody>
</table>

And the 5 first and last, files and columns have been eliminated. Histograms of $\delta \Delta R_A$ are shown in the following Figure:

Differences $\delta$ among values $\Delta R_A$ obtained with reference curves Mc and Lc can attain values up to 5 dB in favour of Mc, 2 dB being the average.

The histogram of $\delta$ comparing pink and traffic noises, shown in the previous Figure, confirms the equivalence of results for both types of noise.

7. Conclusions
Dependence of $\Delta R_A$ (or $\Delta R_w$) of lightweight partition linings has been analysed as a function of shape factor of $\Delta R(f)$ curve.
Reference curve Mc affords values of $\Delta R_A$ (or $\Delta R_w$) exceeding values by curve Lc, from 0 dB to 5 dB.
Reference curve stated for floors is indistinctive from Lc for walls: both leads to equal $\Delta R_A$ (or $\Delta R_w$), then being meaningless.
Previous conclusions also apply to traffic noise.

8. Acknowledgements
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9. References
[5] ISO 532
[7] ISO 717