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RATING OF SOUND INSULATION BY MEANS OF A-LEVEL REDUCTIONS.

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Legal requirements regarding tolerable indoor noise due to road-, air- and railtraffic are generally based on A-weighted sound levels. Consequently the acoustical performance of facade elements should be rated by the A-level reduction to be obtained.
However, acoustical specifications are given mostly in terms of a airborne sound insulation index I_A according the ISO-R 140 or in terms of a weighted sound insulation R_w, according to DIN 52210, similar to the ISO-procedure.
Also the classification system for windows with respect to road traffic noise as described in VDI 2719 uses R_w.

Problems arise by converting R_w into A-level reductions, due to the fact that for R_w the method of averaging over the various third-octave bands, is not based on an energy average and due to the fact that the R_w-value is independent of the outdoor spectrum.

This leads to intolerable discrepancies, particulary with the various types of glazing (singel pane, double glazing with small and with wide airgaps, gasfilled double glazing, laminating glazing, etc.)
In the case of double glazing the A-level reduction is mainly determined by the resonance dip at low frequencies, whereas the R_w-rating is less sensitive against such dips. This is the reason that for traffic noise the same A-level reduction can be obtained by R_w values that differ from each other by up to 8 dB.
For the case of aircraft-noise (descending DC-9) the variations in R_w are up to 4 dB for the same A-level reduction.
On the other hand, as is well known, the A-level reduction obtained by a certain type of glazing with a certain R_w-value, is strongly dependend on the spectrum of the outdoor noise.
A few examples are given in Tabel I, which shows the variation in

A-level reduction for the same R_w. For example, the double glazing 8/50/4 mm with R_w = 39 dB gives A-level reductions ranging from 32 to 40 dB, depending on the outdoor spectrum. Also it can be seen that no relation exists between the variation in R_w-values for the different types of glazing and the variation in A-level reductions.

Several authors, see for instance [1]have already suggested to use as a better criterion the A-level reduction instead of the weighted insulation R_w to classify facade elements.
We have calculated the A-level reductions for four typical source spectra, i.e. traffic-, aircraft- (descending DC-9), railroad- and industrial noise. Here the A-level reduction has been normalized as follows:

The level difference ΔL_A of a facade can be defined as

$$\Delta L_A = L_o - L_i \tag{1}$$

with

L_o = noise level outside the facade without reflection due to the facade (dB(A)).
L_i = required indoor noise level (dB(A)).

The sound reduction index of a facade can be written as (ISO-R140/4):

$$R\vartheta = L_o - L_i + 10 \log \frac{4S}{A} \cos \vartheta \tag{2}$$

with

S = area of the facade
A = the equivalent absorption area in the receiving room.
ϑ = the angle of incidence

With a reverberation time of T = 0,5 s in the receiving room and an angle of incidence of the outdoor noise of 45° (this seems to be a good compromise for most practicable situations) the sound reduction of the whole facade becomes:

$$R_{45} = L_o - L_i - 10 \log \frac{V}{S} + 9{,}5 \text{ dB} \tag{3}$$

with

V = the volume of the receiving room.

If the facade is built up from several elements with their respective surfaces S_i, such as ventilationopening, panels, doors etc. Eq (3) for one element, e.q. the window can be written as:

$$L_o - L_i = R_{45} + 10 \log \frac{V}{S_i} - 9{,}5 \text{ dB} \quad (4)$$

with
S_i = the area of the facade element.

In analogy to this relation the A-level difference ΔL_A of the facade due to an element with a surface S_i can be written as:

$$\Delta L_A = D_{An} + 10 \log \frac{V}{S_i} - 9{,}5 \text{ dB} \quad (5)$$

with
D_{An} = a normalized A-level reduction of the facade element.

This D_{An} can be calculated from the sound reduction R as measured in a laboratory:

$$D_{An} = 10 \log \sum_j 10^{-(R_j - W_j)/10} \quad (6)$$

with
R_j = sound reduction index in the octave band j as measured in a laboratory
W_j = to 0 dB normalized outdoor spectrum in the octave band j, $L_{A,j} - L_A$

This relation is shown in figure 1 for a typical road traffic spectrum.

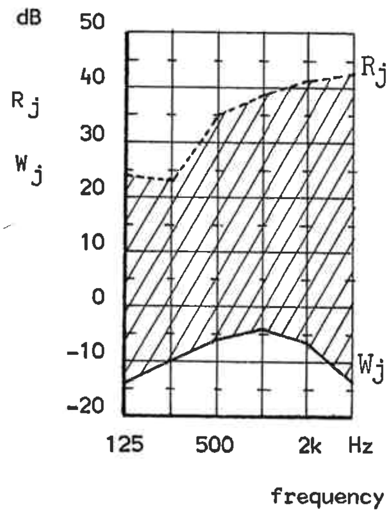


Figure 1: Illustration how to use eq. (6): Take the difference $R_j - W_j$ per octave-band and add up energetically to obtain D_{An}

In most cases it seems that for the state-subsidized housing schemes in the Netherlands the factor $10 \log \frac{V}{S_i}$ lies between:

$$9{,}5 < 10 \log \frac{V}{S_i} < 12{,}5 \qquad (7)$$

with

S_i = the area of the window.

Eq. (5) now becomes:

$$L_A = D_{An} \begin{matrix} +3 \text{ dB} \\ +0 \text{ dB} \end{matrix} \qquad (8)$$

With the relation (7) and (8) the designer of the facade can make an estimate of the level difference for the whole facade in dB(A) out of the normalized A-level reduction D_{An} of the glazing. The 0-3 dB higher level difference due to relation (7) can be used as a safety margin to allow for the sound transmission through the other elements of the facade.

For design purpes D_{An} as defined by (6) can be calculated from the known sound reduction index R for any desired outdoor spectrum. The most frequently used normalized outdoor spectra have been chosen as follws:

- traffic noise;
- rail noise;
- aircraft noise (descending DC-9);
- industrial noise (chemical plant)

and are given in figure 2.

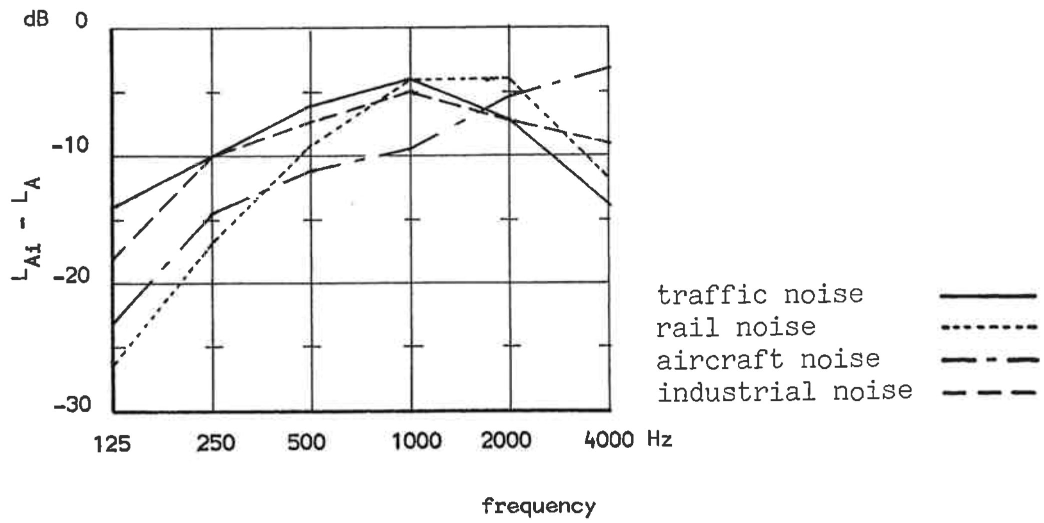


Figure 2: Typical outdoor spectra in A-weighted octave-bands normalized on L_A, to be used for converting R into D_{An}

The D_{An}-values as given in Tabel I for several types of glazing are based on these spectra:

Tabel I: R_W -value and A-level reduction of some glazings for different spectra.

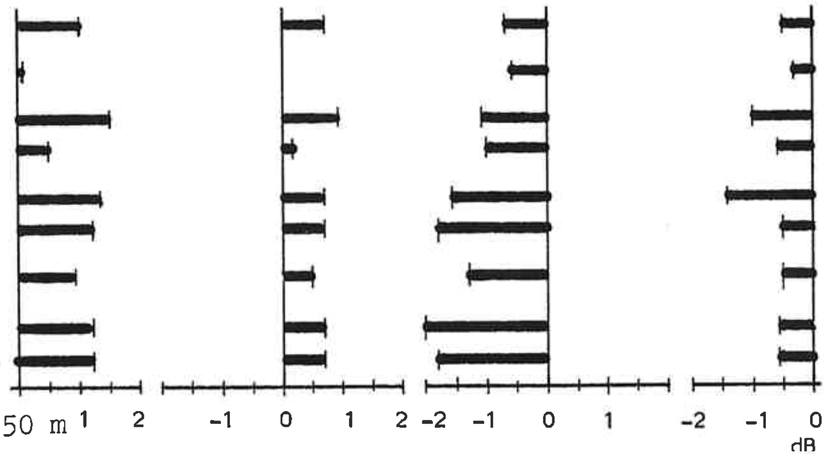
Glazing		D_{An} traffic	D_{An} aircraft	D_{An} rail	D_{An} industry	R_W
4 mm single		27	28	29	27	29
8 mm single		29	31	30	29	31
thermopane	4/12/4	29	33	33	29	33
	6/12/8	30	32	31	30	32
gasfilled	10/12/4	31	36	36	32	36
	8/24/5	34	39	40	36	40
laminated	6/4/8	32	33	35	33	36
double	8/50/4	32	39	40	35	39
	4/200/8	42	47	48	44	47

For the standard traffic noise spectrum the influence of spectrum variations due to barriers and distances on D_{An} have been investigated. The results are shown in figure 3.

Figure 3: Difference in A-level reduction D_{An} between the typical traffic noise spectrum and the calculated spectrum.

Glazing

4 mm single
8 mm single
thermopane 4/12/4
6/12/8
gasfilled 10/12/4
8/24/5
laminated 6/4/8
double 8/50/4
4/200/8



with A = distance 50 m

B = distance 100 m

C = distance 500 m

D = distance 100 m + 4 m barrier along the road at 20 m distance.

It can be seen that for distances up to 500 m and barriers with a hight of up to 4 m the difference between the A-level reduction D_{An} for the typical traffic noise spectrum and the actual spectrum is smaller than 2 dB.
This holds for most of the situations in practice.

By using the D_{An} -value the sound reduction of different facade elements can easily be compared with each other and the comparisation is based on the same criterion as the performance requirement, that is the tolerable A-level in the receiving room.

[1] Schultz, T.J., NCE, 13, 3, 105 (1979).