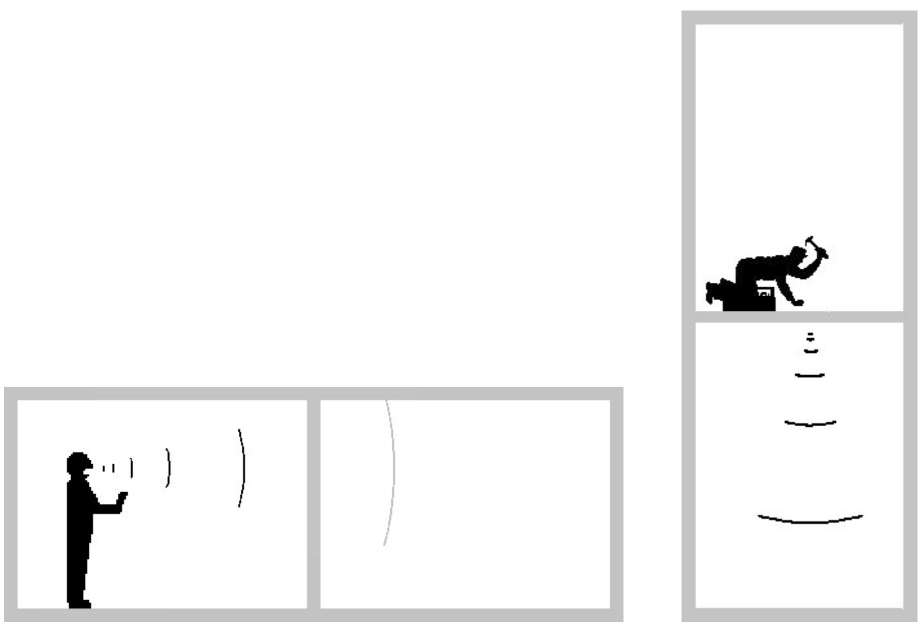
SOUND INSULATION: THEORETICAL BACKGROUND

1 Introduction

Sound insulation is the screening of a room against a noise source. Two types of sound insulation can be distinguished: airborne sound insulation and impact sound insulation. Airborne sound insulation is the insulation against sound that propagates by air (e.g. insulation against traffic noise). Impact sound insulation is the insulation against sound that arises by direct contact of an object on the building element (e.g. the impact of rain on a glazing). Figure 1 illustrates these types of sound insulation by means of two separated rooms.



(a) (b)

Figure 1: airborne sound insulation (a) and impact sound insulation (b) between two rooms.

Because façades mainly are liable to airborne sound, only airborne sound insulation will be further discussed.
The airborne sound insulation of a building element is determined by the difference between the sound level of the room in which a sound source is present (source room in figure 2) and the room that is screened by the building element from the sound source (receiving room in figure 2). Sound insulation depends on the frequency of the sound source.

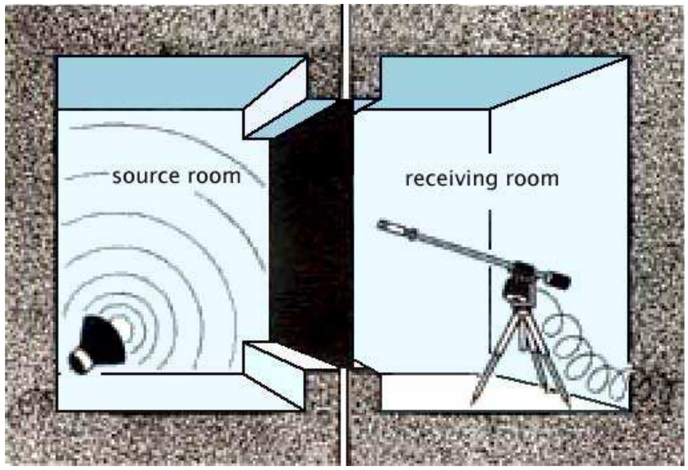


Figure 2: measurement of the airborne sound insulation of a building element.

The sound level is expressed in dB and determines the ‘strength’ of the sound source. The sound of a whistling bird (50 dB) is for example stronger than the sound of a falling leaf (10 dB); the key of a piano can be struck hard or soft.

Sound can be one single frequency (e.g. musical notes), but is usually made up of a number of frequencies (e.g. traffic noise). A frequency is expressed in Hz and determines the ‘pitch‘ of the sound source. Frequencies can be distinguished into three categories: low tones, mid tones and high tones (figure 3). The frequency range of urban road traffic is concentrated around the low tones whereas a singing teakettle rather consists of high tones. Figure 3 arranges examples of sound sources in order of their strength and frequency range.

First this paper examines how airborne sound insulation can be characterized. Subsequently the importance of airborne sound insulation is discussed. Finally the factors that influence airborne sound insulation of windows are explored.

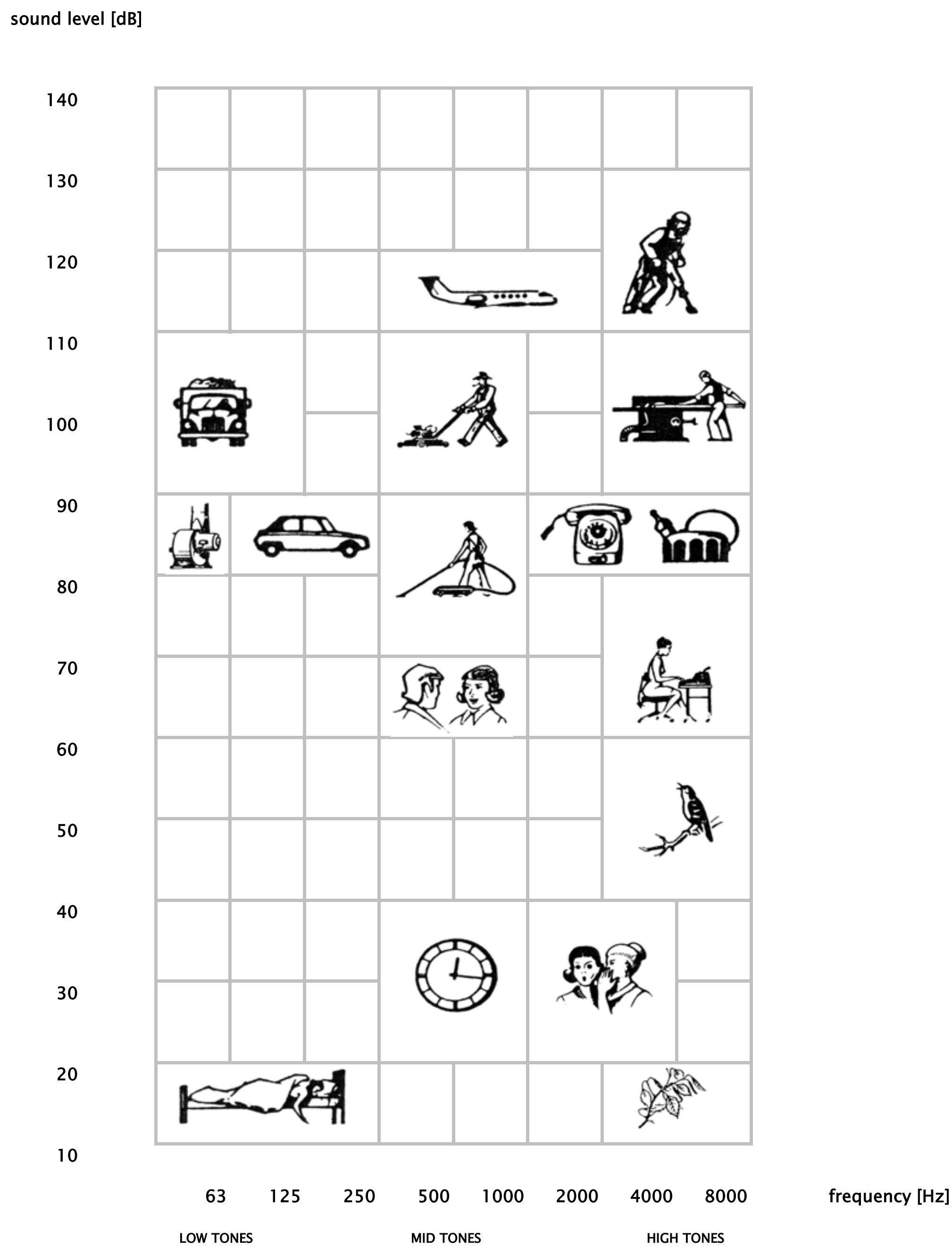


Figure 3: example sound sources arranged in order of sound level and frequency range.

2 Characterization

Instead of listing the airborne sound insulation by frequency, technical documentation usually indicates a concise global performance. The European standard EN ISO 717-1 describes a method to express the airborne sound insulation by the single-number quantity

R_w (C; C_{tr})

in which

R_w is the weighted sound reduction index in dB,
C the adaptation term for pink noise (i.e. sound dominated by mid and high tones) and
C_{tr} the adaptation term for road traffic noise (i.e. sound dominated by low and mid tones).

According to the nature of the sound source to be insulated the right adaptation term can be chosen (table 1). The airborne sound insulation then simply is the sum of the weighted sound reduction index and the adaptation term, i.e. $R_w + C$ or $R_w + C_{tr}$. The higher the value $R_w + C$ or $R_w + C_{tr}$, the better the airborne sound insulation. If for example the acoustic performance of a window is characterized by 40 (-2; -6) dB and disco music has to be suppressed, the airborne sound insulation is 40 – 6 = 34 dB.

Table 1: adaptation term for different noise sources.

type of noise source	adaptation term
living activities (talking, music, radio, tv) children playing railway traffic at medium and high speed highway road traffic > 80 km/h jet aircraft, short distance factories emitting mainly medium and high frequency noise	C
urban road traffic railway traffic at low speeds aircraft, propeller driven jet aircraft, large distance disco music factories emitting mainly low and medium frequency noise	C_{tr}

However the in situ airborne sound insulation of a window will usually turn out lower than the insulation measured in a lab. Some causes are mentioned hereafter. A façade or room is usually made up of different building elements (e.g. a window in a wall) and thus the composite airborne sound insulation determines the final acoustic performance. Moreover the sound reduction index is measured in a lab which usually has different characteristics than the real construction. Thirdly sound not only goes directly through the window but also has indirect paths, like the floor or the ceiling (figure 4). This transfer of sound is known as flanking sound transmission.

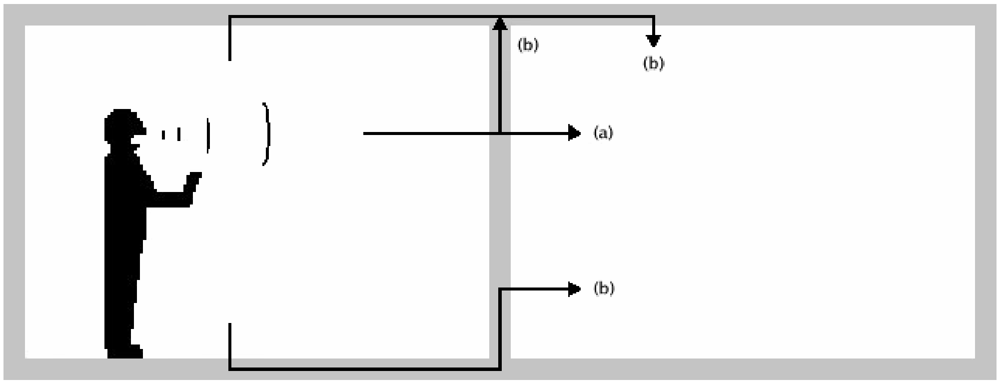


Figure 4: direct (a) and flanking sound transmission (b).

3 Significance

Airborne sound insulation is an important issue in combating sound nuisance (figure 5). Sound is annoying when it is experienced by the person in question contrary to his present intentions. The main consequences of sound nuisance on man are: influence on the hearing (feeling of pain, reduction of the hearing sensitivity…), influence on other sensing organs (equilibrium disturbances…), psychic consequences (anxiety phenomena…), physiologic consequences (neurovegetal disturbances…) and influence on sleep.
Sound comfort is associated with a maximal permissible sound level. This limitation mainly depends on the nature of the sound source, the background noise, the inhabitant and his activities. Each item is briefly explained below.

Figure 5: sound nuisance.

3.1 Nature of the sound source

Sound nuisance depends on the strength of the noise as well as on its frequency range and its fluctuations in time.
Not all frequencies are as much perceived by the human ear, even if their sound level is the same (figure 6). A person experiences for example a tone of 100 Hz less loud than a tone of 1000 Hz. The sound level perceived by the ear doesn't correspond to the physically measurable sound level. Halving the noise results physically in a reduction of the sound level with 3 dB, whereas this is only

a perceptible difference for the human ear. A reduction of 10 dB is a halving of the noise to the humane ear. 5 dB is a class difference for our perception.
The curves of Fletcher and Munson show the perceived sound levels in function of the frequency and the physical sound level (figure 7).

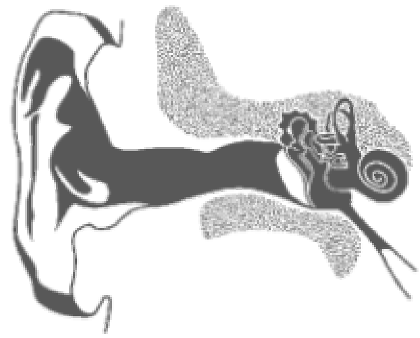


Figure 6: the human ear.

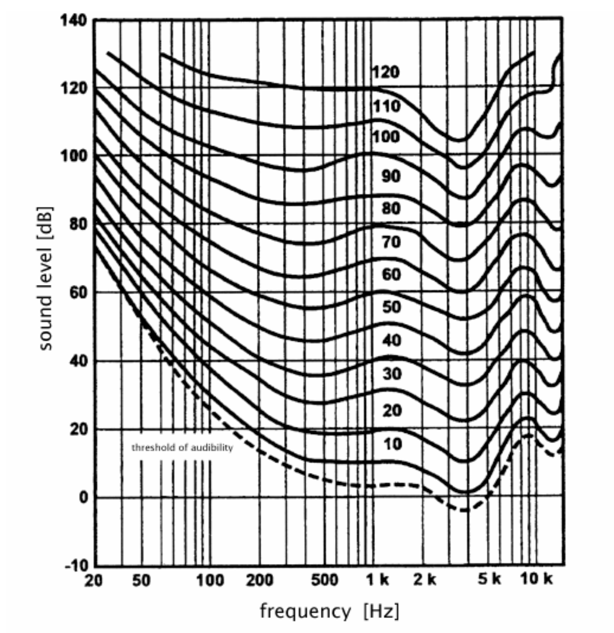


Figure 7: the curves of Fletcher and Munson.

The duration of the sound events and how frequent they occur, also play an important part in the nuisance experience, e.g. a plane which flies over a couple of times a day can be more annoying than a plane which produces more noise but passes only once a day.

3.2 Background noise

The relative magnitude of the sound source compared to the background sound in the room is another important issue. A crossing motor bicycle will be more annoying in a rural environment than in the city.

3.3 Inhabitant

Psychological aspects also influence the experience of nuisance. For the same perceptible sound level noise from airplanes often appears more annoying than city noise. The idea that airplanes can crash sometime is probably the cause of this. Another phenomenon has to do with people who have experienced specific noise nuisance for a long time. These people often seem to have developed sentimentality for this nuisance.

3.4 Activity

Sleeping, studying… are activities which require more sound comfort than for example shaving or ironing.

4 Specification

The airborne sound insulation of windows mainly depends on the type of the glazing and the frame. Hereafter the individual acoustic performance of different glazings is treated as well as the influence of the frame on the total acoustic performance.

4.1 Airborne sound insulation of glazing

4.1.1 Single glazing

Globally the acoustic performance of single glazing increases with its thickness (table 2). The sound insulation of sound sources characterized by C is a bit higher than the insulation of sound sources characterized by C_{tr}. If the glazing thickness increases from 4 to 19 mm, an extra sound insulation of ca. 7 dB is obtained.

Table 2: acoustic performance of single glazing.

thickness [mm]	$R_w + C$ [dB]	$R_w + C_{tr}$ [dB]
4	29	27
5	29	28
6	30	29
8	31	30
10	32	31
12	34	32
19	36	34

4.1.2 Thermal glazing

Thermal glazings cover all glazings that are treated to have a better thermal performance (e.g. double or triple glazings, coated glazings, glazings containing thermally insulating gases…).
In general thermal glazings perform acoustically better when the thickness of the individual glass panes is increased and the air gap between the glass panes is expanded. Table 3 illustrates this statement on the basis of some examples. It appears that for standard thermal glazings the effect of the thickness of the glass panes is more efficient. However this statement doesn't count for large air gaps. Comparing table 2 to table 3 makes clear that standard double glazing is less sound insulating than single glazing with the same total glazing thickness.
Triple glazing doesn't improve the sound insulation compared to double glazing, unless the air gaps become large.

Table 3: acoustic performance of double glazing.

type	$R_w + C$ [dB]	$R_w + C_{tr}$ [dB]
4-12-4	30	27
4-16-4	30	27
6-12-6	32	30
6-16-6	32	28
8-12-8	32	31
8-16-8	33	30

4.1.3 Acoustic glazing

Acoustic glazings cover all glazings that are treated to have a better acoustic performance. An acoustic glazing simultaneously can be a thermal glazing and vice versa.
The first way to improve the sound insulation of a glazing is to combine glass panes with a different thickness. These 'asymmetric' glazings lead to a perceptible difference compared to standard double glazing with the same glazing thickness (table 4).

Table 4: acoustic performance of asymmetric glazing.

type	$R_w + C$ [dB]	$R_w + C_{tr}$ [dB]
4-12-6	32	29
4-12-8	33	30
4-16-8	34	30
6-12-8	33	30
6-12-10	36	33

The use of laminated glazing is another way to improve the acoustic performance of windows. Laminated glazing is made up of glass panes which are joined together by a transparent elastic layer. In this text two glass panes of 3 mm thickness divided by one elastic layer is indicated by 33.1. A double layer gives 33.2. Laminated single glazing can lead to a class difference and this rather for sound sources characterized by C (table 5). When one glass pane of a double glazing is laminated, a similar conclusion can be drawn.

Table 5: acoustic performance of laminated glazing.

type	$R_w + C$ [dB]	$R_w + C_{tr}$ [dB]
33.1	35	33
44.1	36	35
6-12-33.1	36	32
8-12-44.1	38	35
8-12-44.2	39	35

Finally the dry air in double or triple glazing can be replaced by special gases (like SF_6…). Generally these gases create a better sound insulation for sound sources characterized by C. Sound sources characterized by C_{tr} usually are less insulated.
The former three techniques can also be combined to obtain an even better acoustic performance. Table 6 lists a number of glazings which are both laminated and asymmetric.

Table 6: acoustic performance of asymmetric and laminated glazing.

type	$R_w + C$ [dB]	$R_w + C_{tr}$ [dB]
4-12-33.1	33	30
6-12-44.1	37	33
44.2-20-64.2	45	40

4.2 Influence of the frame on the sound insulation of windows

4.2.1 Gaskets

A direct correlation exists between the airborne sound insulation of a window and its air tightness, i.e. the more tight a window the better its insulation. The tightness of a window mainly depends on the performance of the gaskets and the installation accuracy (figure 8). Poorly installed windows bring along chinks which can reduce the sound insulation 5 to 10 dB. This reduction particularly has an effect on the insulation of sound sources characterized by C.

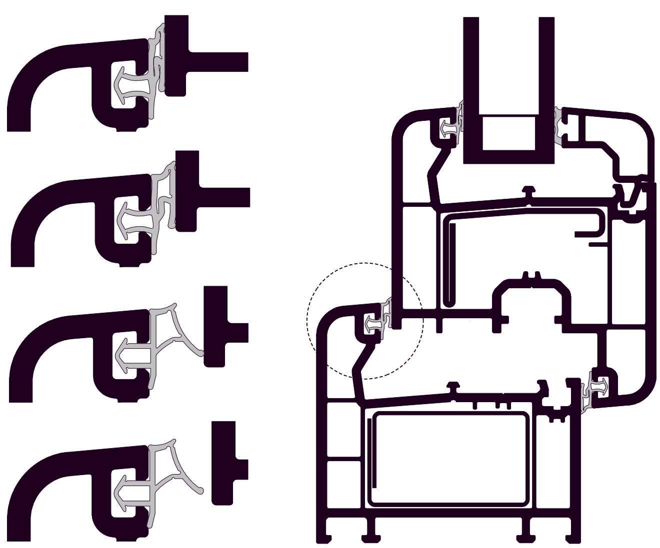


Figure 8: performance of gaskets in the zone between frame and sash.

4.2.2 Frame construction

As long as R_w of a window remains under 35 dB and the frame area doesn't exceed 30 % of the window area, the influence of the frame on the total acoustic performance can be neglected. However as soon as R_w lies between 35 and 40 dB, it is advised to reinforce each frame element. Windows with an R_w value larger than 40 dB are specific for the window concept itself which makes special advice necessary.

5 Conclusion

The airborne sound insulation of a window can be characterized by the single-number quantity R_w (C; C_{tr}). $R_w + C$ is the insulation of sound sources dominated by mid and high tones. $R_w + C_{tr}$ is the insulation of sound sources dominated by low and mid tones. The importance of sound insulation is the reduction of nuisance. The sound insulation of windows depends on the glazing and the frame. The glazing can acoustically be improved by thickening glass panes, expanding the gas space, combining asymmetric glass panes, using special gases or laminating glass panes. The frame should be carefully installed avoiding any chinks. Reinforcing the frame is advised when an acoustic performance between 35 and 40 dB is required.

References

[1] EN ISO 717-1 Acoustics - Rating of sound insulation in buildings and of building elements - Part 1: Airborne sound insulation, December 1996

[2] "Geluidsisolatie van vensters. Toepassing van de nieuwe norm EN ISO 717-1:1996. Deel 1: akoestische prestaties van glas", Bart Ingelaere, WTCB-Tijdschrift, lente 1998

[3] "Geluidsisolatie van vensters. Deel 2", Bart Ingelaere, WTCB-Tijdschrift, zomer 1998