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PERFORMANCE CRITERIA

Acoustic performance of buildings

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Acknowledgements

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1 Introduction

Although a thorough understanding of the physics of sound is an advantage when dealing with the acoustical aspects of buildings and building components, it is not a prerequisite for a basic understanding of the main issues. This section provides some basic explanations regarding acoustical terminology and requirements.

1.1 Human hearing and sound pressure levels in dB or dBA

The human hearing mechanism (the basic determinant for building acoustics) reacts to sound pressure (fluctuations in the air pressure caused by a sound source) but is not equally sensitive at all audible frequencies which are often quoted as spanning from 20 to 20000 hertz. At the low notes or frequencies (especially below 250 hertz) and the very high notes (above 8000 hertz) the hearing mechanism is notably less sensitive, while maximum sensitivity normally occurs between 3000 and 4000 hertz. This characteristic is electronically simulated in a sound level meter by the so-called A-frequency-weighting network. Sound measurements done with this network in operation, are usually denoted by adding an A to the dB 'unit', for example 75 ***dBA***, or by adding ***A*** to the subscript of ***L*** in ***LAeq*** as explained later in this section.

The real physical unit of sound pressure is the pascal, and sound pressure levels given in dB or dBA are expressing twenty times the logarithm (to the base 10) of a ratio between the alternating sound pressure under discussion, and the universally accepted ***reference sound pressure of 2 x 10^{-5} pascal***, which is just audible at 1000 hertz with normal hearing. There are valid acoustical reasons for this complication. The alternating air pressure of sound waves actuates the eardrum. The ratio between the audibility threshold (2 x 10^{-5} or 20 x 10^{-6} pascal) and the pain threshold (20 pascal) is 1 to 1 000 000. This wide range is cumbersome and does not effectively interpret the loudness of a sound because the human hearing response is not linear – a doubling of the sound pressure or the sound power (the amount of sound energy emitted per second) does not necessarily make the sound subjectively twice as loud.

The dB (decibel) notation is therefore used in building acoustics and related acoustical fields. It expresses a ratio which indicates on a logarithmic scale how much more intense or louder a specific sound is than the reference sound pressure, being a just audible sound, for example:

- by definition, sound pressure level in dB
  = 20 log{(sound pressure)/(reference sound pressure)}
- normal conversation generates pressures of about 36 x 10^{-3} Pa at a distance of 1 metre from the speaker. This can be expressed as
  20 log{(36 x 10^{-3})/(20 x 10^{-6})} = 65 dB

In lay terms, dB and dBA can be considered to be typical units.

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However, care should be taken when combining sound levels expressed in dB or dBA. Due to the influence of the logarithms, these cannot be added or subtracted in a direct numerical way where sound sources are involved. For example, if one machine in a reflective room generates a sound level of 90 dBA, two similar machines will generate a level of 93 dBA and not 180 dBA. Doubling of the sound power emitted increases the level by 3 dBA, while doubling of the sound pressure (which implies a fourfold increase in sound power) increases the level by 6 dBA. Due to the characteristics of the human hearing mechanism and depending on the nature of a specific sound, an increase of 6 dBA to 10 dBA will subjectively make the sound approximately twice as loud.

1.2 Equivalent A-weighted sound pressure level L_{Aeq}

The equivalent sound pressure level is measured with an integrating sound level meter which electronically integrates the sound pressure over the measuring period on an energy base, providing a result which is similar to a continuous and constant sound pressure level associated with identical sound energy during the specific measuring period. This equivalent sound pressure level is denoted by L_{eq} and L_{Aeq} if the A-frequency-weighting network is used. Some organisations prefer to omit the A from dBA and indicate that the A-weighting frequency network was used for a given measurement by writing the resultant sound pressure level as say L_{Aeq} = 70 dB. Repetition of "L_{Aeq} =" is cumbersome, therefore this document will rather add the A to dB where applicable.

1.3 Insulation and absorption

It is of major importance to clearly discern between the acoustical performance and physical composition of materials which offer ***airborne sound insulation*** and ***sound absorption***:

- a proper airborne ***sound insulating material*** (like a solid, plastered brick wall) reflects most of the sound power impinging against it and transmits only a small percentage to the other side by means of wall vibration, because it is both ***massive*** and ***airtight***
- a proper ***sound absorbing material*** (like 100 mm thick mineral wool) is ***porous*** and absorbs most of the impinging sound power, because it allows the sound waves to enter the fibrous structure of the material, where most of the mechanical power of the sound wave is converted to (minute) heat, and only a fraction of the sound power gets reflected. However, being porous, it will allow an unacceptable percentage of the sound power to move completely through the material and therefore provide poor sound insulation.

This simplified explanation of sound insulation and absorption implies that a decent airborne sound insulator cannot be a good sound absorber, and vice versa.

1.4 Human requirements for sound insulation

Where people live or work, they have two basic acoustical requirements which are directly related to sound insulation:

- the natural requirement to continue with their chosen activities in a reasonably unrestrained way, eg to produce some activity related sound (speech during a meeting, machine noise while using tools in a workshop, music while relaxing at home, etc) without continuous fear of annoying occupants of adjacent facilities, or of being overheard in confidential situations.
- vice versa, intruding sound generated by someone else's activities in a nearby room or building, can be annoying and therefore unacceptable in one's own workplace or residence.

Therefore, one of the important general requirements of a building is that the amount of noise transmitted from both outside and inside the building to a specific room should be reduced to acceptable levels for the room application. (An open plan banking arrangement with one-to-one communication at a counter can typically cope with higher intruding noise levels than a boardroom or auditorium where speech intelligibility from one speaker to a number of listeners is important.) To achieve satisfactory acoustical performance, a building should therefore be designed with sufficient sound insulation to cope with the following three specific functions:

- to reduce the ingress of noise into a room from outside (e.g., road traffic noise) or from other rooms in the same building (e.g., an air-conditioning plant room to an adjacent office area).
- to prevent noise generated within a building from annoying persons inside the building or in other buildings (e.g., from a disco in a hotel, to hotel bedrooms inside the same building; or to residential units in a block of flats next-door).
- to provide acoustic privacy between rooms in a building. (Sufficient acoustical privacy is experienced between adjacent rooms when adequate sound insulation exists to ensure, in conjunction with the prevailing background noise in the receiving room, that acoustical activities in one room need not be inhibited for fear of being overheard at an unacceptable level or degree of intelligibility next-door.)

The degree of sound insulation required in a particular instance will depend on the loudness of the noise (unwanted sound to be excluded), and the type of acoustical activity contemplated within the space concerned (in a sound recording studio, all intruding noise should preferably be inaudible; in the busy entrance foyer of a large office block, some intruding traffic noise can be tolerated).

1.5 Secondary sound transmission

Apart from sound transmission directly through a partition separating two adjacent rooms, sound generated in one room can reach the room next-door by means of two secondary sound transmission mechanisms:

- flanking, where some of the generated noise enters a side wall, floor or ceiling construction and is transmitted via this medium to the room on the other side of the separating partition, where it is emitted
- leakage via weak spots in the separating partition itself (joints not sealed properly; back-to-back power, telephone or other service boxes, etc).

1.6 Criteria

In acoustics, there is often a large grey area between a situation with which almost everybody will be completely satisfied and one which almost everybody will find totally unacceptable. The criteria used by Agrément South Africa and listed in this document do not cater for provision of very high quality to satisfy most people even under extreme conditions. It should rather be seen as criteria to promote a minimum standard where acoustical performance has been attended to, but where it is accepted that economic considerations will somehow negatively affect the intended function of a facility.

Conformance of a building element or system to any acoustical requirement published by Agrément South Africa in this or other documentation, does not obviate the necessity of an acoustical investigation as part of a design procedure to obtain the best practicable results achievable for a given budget and other constraints; neither can it guarantee acoustical satisfaction.

2 Laboratory and field tests

2.1 Octave and third octave bands

It is normally necessary to do acoustical measurements in several octave or third octave frequency bands (which together constitute the original broadband signal), because the acoustical characteristics of all materials used in building acoustics are frequency dependent. The sound insulation and sound absorption performance changes with frequency by usually giving better results at the higher frequencies. The octave bands typically run from 63 hertz at the low frequency end to 4000 or 8000 hertz at the high frequency end or similarly, third octave bands from 50 hertz to 5 000 or 10 000 hertz. Each octave or third octave frequency band is denoted by its centre frequency, for example 250 hertz or 4000 hertz. For Agrément South Africa's purposes, the five octave bands with centre frequencies from 125 to 2 000 hertz are considered adequate.

2.2 Laboratory tests

Airborne sound is defined as sound which is initiated as a vibration of air particles by a sound source (e.g., the sound of the human voice or of a musical instrument). The potential ability of a specific building element to reduce airborne sound power passing through it in the absence of flanking and leakage paths, is known as its sound reduction index, denoted by R. When the airborne sound insulation of a wall is tested in an acoustics laboratory, the main concern is to ensure that the sound measured on the receiving side is only that which is transmitted through the test wall, and not that which reaches the receiving room via any leakage or flanking paths through or around the wall. The test wall is therefore mounted in a massive surrounding structure which transmits a negligible amount of sound in comparison to the test wall. Any gaps between the perimeter of the test wall and the surrounding structure are caulked and sealed. These precautions ensure that during the laboratory test only the inherent sound insulation capacity of the wall is measured. The sound reduction index R in each applicable third octave band and the single-number weighted sound reduction index Rw can be calculated from the results, both being ratios and quoted in dB (A-weighting is not applicable here, therefore dB and not dBA).

Typical examples of airborne sound insulation summarised in terms of weighted sound reduction indices obtained in the laboratory for different masonry walls, are given in Table 1.

Table 1: Examples of weighted airborne sound reduction indices obtained in a laboratory

Nominal thickness (mm) and wall type	**Finish**	R_w (dB)
90 burnt clay brick wall	Unplastered	43
	Plastered both sides	46
110 burnt clay brick wall	Unplastered	46
	Plastered both sides	48
190 burnt clay brick wall	Unplastered	50
	Plastered both sides	53
220 burnt clay brick wall	Plastered both sides	54
105 hollow concrete block wall	Plastered both sides	38
	Plastered both sides	48

2.3 Field tests

In field tests, where the wall being tested has been constructed under normal site conditions as a component of a building, ideal laboratory conditions can seldom be reproduced. The main sources of additional sound transmission between rooms are flanking transmission and direct sound leaks. Common flanking paths between rooms are external windows adjoining the test wall on both sides or extending across the wall, common roof/ceiling space, common floor or ceiling joists and a common corridor leading to both rooms. Direct leaks occur, for example, through back-to-back outlet boxes for electrical or other services, or through power and communication skirtings which pass through the separating wall. The doors and windows of the test rooms are closed but may nonetheless contribute to sound leakage. Under field conditions, the ***apparent sound reduction index R'*** and the ***weighted apparent sound reduction index*** R_w' can be determined in each applicable octave or third octave band for comparison with the respective laboratory indices R and R_w. For Agrément purposes, the ***standardised level difference*** D_{nT} in each applicable octave or third octave band and the ***weighted standardised level difference*** $D_{nT,w}$ calculated from these, are considered more appropriate. (For additional clarification of the differences between different indices, refer to SABS ISO 140.)

2.4 Selecting the appropriate test procedure

The sound leakage paths which are likely to exist in an actual building result in a lower degree of sound insulation between rooms than is measured with the test wall in the laboratory. Using a separating wall with a high weighted sound reduction index between adjacent rooms does not necessarily imply that a high degree of sound insulation will be achieved in practice, because there could be sound transmission due to erroneous design, poor workmanship, or as a result of flanking paths.

A laboratory test is therefore preferable where the sound insulating characteristics of a specific building element (wall, door, window, etc) have to be determined for comparison with other material and construction options for the same element. In cases where the acoustical performance of a building system using several components in practical, real life conditions have to be judged, field tests are more appropriate.

2.5 Applicable standardisation documentation

For both test options and for a variety of cases, **SANS/ISO 140** [1]provides the measurement prescriptions and **SANS/ISO 717** [2]the corresponding calculation procedures.

[1] SANS/ISO 140 *Acoustics – Measurement of sound insulation in buildings and of building elements*
[2] SANS/ISO 717 *Acoustics - Rating of sound insulation in buildings and building elements*

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3 Speech privacy

Typically the intelligibility of overheard speech in a room next-door to a space where someone is talking will depend on the sound insulation between the two rooms and the level of the steady component of the ambient noise in the receiving room. The higher each of these two dominant parameters will be, the lower the intelligibility of overheard speech and the better the speech privacy will be found. Several calculation procedures to cover this issue in various degrees of accuracy, can be found in the international acoustics literature. For general usage, the arithmetical sum of the D_{nT},w and L_{Aeq} values of the two dominant parameters can be used as shown in Table 2 to provide an indication (rather than a rigid criterion) of the expected quality of speech privacy. However, considerable variations in the basics can be expected, which may influence the subjective evaluation in a specific case:

- speech patterns differ amongst people
- the combined effect of hearing acuity and the individual's annoyance threshold level is not constant
- the standardised level differences D_{nT} from which D_{nT},w has been calculated may vary, although D_{nT},w is constant
- the spectral composition of the steady component of the ambient noise in the receiving room will vary from case to case.

The variations in spectral composition and listening level of all kinds of music, and the level at which intruding music will be considered as annoying, exceed those of speech to such an extent that music is not included in Table 2.

Table 2: Speech privacy in buildings with different ranges of D_{nT},w values between rooms

Speech as heard in adjacent receiving room	**Expected quality of speech privacy**	**Arithmetical total of DnT,w PLUS the dBA-value of the steady component of the ambient noise in the receiving room**	**In situ DnT,w values required in combination with specific values of the steady component of the ambient sound level as indicated**		
			L_{Aeq} = 25 dBA	L_{Aeq} = 35 dBA	L_{Aeq} = 45 dBA
Intelligible	Poor	< 73	$D_{nT,w}$ < 48 dB	$D_{nT,w}$ < 38 dB	$D_{nT,w}$ < 28 dB
Ranging between intelligible and unintelligible	Fair	73 to 83	$D_{nT,w}$ = 48 to 58 dB	$D_{nT,w}$ = 38 to 48 dB	$D_{nT,w}$ = 28 to 38 dB
Audible but not obtrusive (unintelligible)	Good	83 to 93	$D_{nT,w}$ = 58 to 68 dB	$D_{nT,w}$ = 48 to 58 dB	$D_{nT,w}$ = 38 to 48 dB
Inaudible	Excellent	> 93	$D_{nT,w}$ > 68 dB	$D_{nT,w}$ > 58 dB	$D_{nT,w}$ > 48 dB

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4 Requirements for airborne sound insulation

4.1 Minimum weighted standardised level difference $D_{nT,w}$

Agrément South Africa uses some essential requirements for D_{nT},w for specific adjoining rooms in various buildings which should be considered necessary to obtain modest acoustical performance. The minimum sound insulation values required (in terms of D_{nT},w) required for three categories of buildings are given in Table 3.

Table 3: Minimum weighted standardised level differences required

Type of building	Between	and	$D_{nT,w}$ (dB)
Dwelling units	dwelling unit	adjacent dwelling unit	45
	rooms within a dwelling unit	rooms in same dwelling unit	33
Non-residential school buildings	classrooms, offices, libraries	classrooms, offices, kitchens, utility rooms, toilets	42
Hotels and old age homes	suites	communal toilets	45
	bedrooms	other suites	45
	bedrooms	bedrooms not in same suite	45 (was 42)

4.2 Openings in walls and floors

Walls and floor slabs must, as far as possible, be kept free of openings and weak spots which will allow the passage of sound. For example, the required sound insulation will probably not be obtained if distribution boards, and electrical outlet boxes or recessed medicine cabinets are placed back-to-back in walls.

4.3 Ceilings

When buildings are not provided with ceilings, there will be a serious deterioration in the speech privacy unless the internal walls are taken up to the underside of and are sealed (airtight) to the roof covering material.

4.4 Suitable criteria for wider applications

Practical building applications may require a higher degree of acoustical comfort than associated with the minimum Agrément requirements, and/or recommendations for specific types of buildings and detailed

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applications not covered by the Agrément requirements. In such instances, reference should be made to the latest version of **SANS 218-1** [3]and/or similar sources from the international acoustics literature.

[3] SANS 218-1 *Acoustical properties of buildings: Part 1: Grading criteria for the airborne sound insulation properties of buildings*

References

SABS ISO 140-1: 1997. *Acoustics - Measurement of sound insulation in buildings and of building elements Part 1: Requirements for laboratory test facilities with suppressed flanking transmission*

SABS ISO 140-2: 1991. *Acoustics - Measurement of sound insulation in buildings and of building elements Part 2: Determination, verification and application of precision data*

SABS ISO 140-3: 1995. *Acoustics - Measurement of sound insulation in buildings and of building elements Part 3: Laboratory measurements of airborne sound insulation of building elements*

SABS ISO 140-4: 1998. *Acoustics - Measurement of sound insulation in buildings and of building elements Part 4: Field measurements of airborne sound insulation between rooms*

SABS ISO 140-5: 1998. *Acoustics - Measurement of sound insulation in buildings and of building elements Part 5: Field measurements of airborne sound insulation of facade elements and facades*

SABS ISO 140-7: 1998. *Acoustics - Measurement of sound insulation in buildings and of building elements Part 7: Field measurements of impact sound insulation of floors*

SABS ISO 140-8: 1997. *Acoustics - Measurement of sound insulation in buildings and of building elements Part 8: Laboratory measurements of the reduction of transmitted impact noise by floor coverings on a heavyweight standard floor*

SABS ISO 717-1: 1996. *Acoustics - Rating of sound insulation in buildings and building elements Part 1: Airborne sound insulation*

SABS ISO 717-2: 1996. *Acoustics - Rating of sound insulation in buildings and building elements Part 2: Impact sound insulation*

SABS 0218-1: 1999. *Acoustical properties of buildings Part 1: Grading criteria for the airborne sound insulation properties of buildings*

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