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Guidance on sound insulation and noise reduction for buildings

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Contents

Annexes

List of figures

List of tables

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 78, an inside back cover and a back cover.

Foreword

Publishing information

This British Standard is published by BSI Standards Limited, under licence from The British Standards Institution, and came into effect on 28 February 2014. It was prepared by Technical Committee B/564, *Noise control on building sites*, and Subcommittee EH/1/6, *Building acoustics*. A list of organizations represented on these committees can be obtained on request to their secretaries.

Supersession

This British Standard supersedes BS 8233:1999, which is withdrawn.

Information about this document

This British Standard draws on the results of research and experience to provide information on the design of buildings that have internal acoustic environments appropriate to their functions. It deals with control of noise from outside the building, noise from plant and services within it, and room acoustics for non-critical situations. This document is intended for use by non-specialist designers and constructors of buildings and those concerned with building control, planning and environmental health.

This is a full revision of the standard. The principal changes have been made to reflect:

- changes to the legislative framework since publication of the 1999 edition;
- revisions to Building Regulations Approved Document E [1];
- the publication of specialist documents for specific sectors, such as healthcare and education;
- the publication in England of the National Planning Policy Framework [2] in March 2012, with the concurrent withdrawal of numerous individual planning guidance and policy statement documents, including those specifically relating to noise;
- a reappraisal of the tabular content with respect to setting targets for various classes of living space in the light of research findings; and
- the need to transfer some of the more detailed information from the main text to annexes.

BS 8233:1999 was, like its predecessor CP3 Chapter III:1972, published as a code of practice. However, it was decided to publish this edition as a guide because the text largely comprises guidance that does not support claims of compliance.

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Use of this document

As a guide, this British Standard takes the form of guidance and recommendations. It should not be quoted as if it were a specification or a code of practice and claims of compliance cannot be made to it.

Presentational conventions

The guidance in this standard is presented in roman (i.e. upright) type. Any recommendations are expressed in sentences in which the principal auxiliary verb is “should”.

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Contractual and legal considerations

0 Introduction

Noise control in and around buildings is discussed in this British Standard guide on an objective and quantifiable basis as far as is currently possible. For many common situations, this guide suggests criteria, such as suitable sleeping/resting conditions, and proposes noise levels that normally satisfy these criteria for most people. However, it is necessary to remember that people vary widely in their sensitivity to noise, and the levels suggested might need to be adjusted to suit local circumstances. Moreover, noise levels refer only to the physical characteristics of sound and cannot differentiate between pleasant and unpleasant sounds. Important though psychological factors are, it is not practicable to consider them in this guide.

NOTE The standard is intended to be used routinely where noise sources are brought to existing noise-sensitive buildings.

Attention is drawn to the fact that measures taken to control sound might also impinge on fire precautions and other health and safety requirements. All such requirements need to be considered together at an early stage of the design.

1 Scope

This British Standard provides guidance for the control of noise in and around buildings. It is applicable to the design of new buildings, or refurbished buildings undergoing a change of use, but does not provide guidance on assessing the effects of changes in the external noise levels to occupants of an existing building.

This British Standard does not cover:

a) specialist applications, such as auditoria and cinemas (for cinemas, see BS ISO 9568);

b) vibration control, except where it is evident in the form of radiated sound; or

c) noise that breaks out from the building that might affect external receptors.

NOTE Annex A describes some of the simpler types of noise calculation. A method of rating noise is described in Annex B. Methods of measurement of sound insulation are described in Annex C. Annex D outlines some special problems requiring expert advice. Annex E describes airborne and impact sound insulation. Annex F sets out the legislative framework applicable to noise producing developments. Annex G provides example calculations for resolving a typical design problem. Examples of design criteria adopted by various hotel groups are included for reference in Annex H.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS 4142, *Methods for rating and assessing industrial and commercial sound* [1]

BS 5502-32, *Buildings and structures for agriculture – Part 32: Guide to noise attenuation*

BS EN 20354, *Acoustics – Measurement of sound absorption in a reverberation room*

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[1] Revision in preparation.

BS EN 60942, *Electroacoustics – Sound calibrators*

BS EN 61672-1, *Electroacoustics – Sound level meters – Part 1: Specifications*

BS EN 61672-2, *Electroacoustics – Sound level meters – Part 2: Pattern evaluation tests*

BS EN ISO 140, *Acoustics – Measurement of sound insulation in buildings and of building elements*

BS EN ISO 140-4, *Acoustics – Measurement of sound insulation in buildings and of building elements – Part 4: Field measurements of airborne sound insulation between rooms*

BS EN ISO 140-7, *Acoustics – Measurement of sound insulation in buildings and of building elements – Part 7: Field measurements of impact sound insulation of floors*

BS EN ISO 10140-1, *Acoustics – Laboratory measurement of sound insulation of building elements – Part 1: Application rules for specific products*

BS EN ISO 10140-2, *Acoustics – Laboratory measurement of sound insulation of building elements – Part 2: Measurement of airborne sound insulation*

BS EN ISO 10140-3, *Acoustics – Laboratory measurement of sound insulation of building elements – Part 3: Measurement of impact sound insulation*

BS EN ISO 10140-4, *Acoustics – Laboratory measurement of sound insulation of building elements – Part 4: Measurement procedures and requirements*

BS EN ISO 10140-5, *Acoustics – Laboratory measurement of sound insulation of building elements – Part 5: Requirements for test facilities and equipment*

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this British Standard, the following terms and definitions apply.

3.1.1 A-weighted sound pressure

p_A

value of overall sound pressure, measured in pascals (Pa), after the electrical signal derived from a microphone has been passed through an A-weighting network

NOTE The A-weighting network modifies the electrical response of a sound level meter with frequency in approximately the same way as the sensitivity of the human hearing system.

3.1.2 A-weighted sound pressure level

L_{pA}

quantity of A-weighted sound pressure given by the following formula in decibels (dBA)

$$L_{pA} = 10 \log_{10} (p_A/p_0)^2$$

where:

p_A is the A-weighted sound pressure in pascals (Pa);

p_0 is the reference sound pressure (20 μPa)

NOTE Measurements of A-weighted sound pressure level can be made with a meter and correlate roughly with subjective assessments of loudness. They are usually made to assist in judging the effects of noise on people. The size of A-weighting, in 1/3 octave bands, is shown in Annex A (see ***A.5****). An increase or decrease in level of 10 dBA corresponds roughly to a doubling or halving of loudness.*

3.1.3 background sound

underlying level of sound over a period, *T*, which might in part be an indication of relative quietness at a given location

3.1.4 break-in

noise transmission into a structure from outside

3.1.5 break-out

noise transmission from inside a structure to the outside

3.1.6 cross-talk

noise transmission between one room and another room or space via a duct or other path

3.1.7 C_{tr}

correction term applied against the sound insulation single-number values (R_w, D_w, and $D_{nT,w}$) to provide a weighting against low frequency performance

NOTE The reference values used within the C_{tr} calculation are based on urban traffic noise.

3.1.8 equivalent continuous A-weighted sound pressure level

$L_{Aeq,T}$

value of the A-weighted sound pressure level in decibels (dB) of a continuous, steady sound that, within a specified time interval, *T*, has the same mean-squared sound pressure as the sound under consideration that varies with time

NOTE 1 This is given by the following formula.

$$L_{\mathrm{Aeq},T} = 10\log_{10}\left[\frac{1}{T}\int_0^T \frac{p_{\mathrm{A}}^2(\mathrm{t})}{p_0^2}\mathrm{d}t\right]$$

where:

$p_A(t)$ *is the instantaneous A-weighted sound pressure in pascals (Pa);*

p_0 *is the reference sound pressure (20 μPa).*

NOTE 2 Equivalent continuous A-weighted sound pressure level is mainly used for the assessment of environmental noise and occupational noise exposure.

3.1.9 equivalent sound absorption area of a room

A

hypothetical area of a totally absorbing surface without diffraction effects, expressed in square metres (m^2), which, if it were the only absorbing element in the room, would give the same reverberation time as the room under consideration

3.1.10 facade level

sound pressure level 1 m in front of the facade

NOTE Facade level measurements of L_{pA} are typically 1 dB to 2 dB higher than corresponding free-field measurements because of the reflection from the facade.

3.1.11 free-field level

sound pressure level away from reflecting surfaces

NOTE Measurements made 1.2 m to 1.5 m above the ground and at least 3.5 m away from other reflecting surfaces are usually regarded as free-field. To minimize the effect of reflections the measuring position has to be at least 3.5 m to the side of the reflecting surface (i.e. not 3.5 m from the reflecting surface in the direction of the source). Estimates of noise from aircraft overhead usually include a correction of 2 dB to allow for reflections from the ground.

3.1.12 impact sound pressure level

L_i

average sound pressure level in a specific frequency band in a room below a floor when it is excited by a standard tapping machine or equivalent

NOTE For additional information on impact sound pressure level and the standard tapping machine see Annex C and BS EN ISO 140-7.

3.1.13 indoor ambient noise

noise in a given situation at a given time, usually composed of noise from many sources, inside and outside the building, but excluding noise from activities of the occupants

NOTE The location(s) within the room at which the ambient indoor noise is to be measured or calculated ought to be considered.

3.1.14 noise criteria

numerical indices used to define design goals in a given space

3.1.15 noise rating

NR

graphical method for rating a noise by comparing the noise spectrum with a family of noise rating curves

NOTE Noise rating is described in Annex B.

3.1.16 normalized impact sound pressure level

L_n

impact sound pressure level normalized for a standard absorption area in the receiving room

NOTE Normalized impact sound pressure level is usually used to characterize the insulation of a floor in a laboratory against impact sound in a stated frequency band (see Annex C and BS EN ISO 140-7).

3.1.17 octave band

band of frequencies in which the upper limit of the band is twice the frequency of the lower limit

3.1.18 percentile level

$L_{AN,T}$

A-weighted sound pressure level obtained using time-weighting "F", which is exceeded for N% of a specified time interval

EXAMPLE

$L_{A90,1h}$ is the A-weighted level exceeded for 90% of 1 h.

NOTE Percentile levels determined over a certain time interval cannot accurately be extrapolated to other time intervals. Time-weighting "F" or "S" can be selected on most modern measuring instruments and used to determine the speed at which the instrument responds to changes in the amplitude of the signal. Time-weighting "F" is shorter than "S" and so its use can lead to different values when rapidly changing signals are measured.

3.1.19 rating level

$L_{Ar,Tr}$

equivalent continuous A-weighted sound pressure level of the noise, plus any adjustment for the characteristic features of the noise

NOTE This is used in BS 7445 and BS 4142 for rating industrial noise, where the noise is the specific noise from the source under investigation.

3.1.20 reverberation time

T

time that would be required for the sound pressure level to decrease by 60 dB after the sound source has stopped

NOTE Reverberation time is usually measured in octave or third octave bands. It is not necessary to measure the decay over the full 60 dB range. The decay measured over the range 5 dB to 35 dB below the initial level is denoted by T_{30}*, and over the range 5 dB to 25 dB below the initial level by* T_{20}*.*

3.1.21 sound exposure level

L_{AE}

level of a sound, of 1 s duration, that has the same sound energy as the actual noise event considered

NOTE 1 The L_{AE} *of a discrete noise event is given by the formula:*

$$L_{AE} = 10 \log_{10}\left[\frac{1}{t_0}\int_{t_1}^{t_2} \frac{p_A{}^2(t)}{p_0{}^2}\,dt\right]$$

where:

$p_A(t)$ *is the instantaneous A-weighted sound pressure in pascals (Pa);*

$t_2 - t_1$ *is a stated time interval in seconds (s) long enough to encompass all significant sound energy of the event;*

p_0 *is the reference sound pressure (20 µPa);*

t_0 *is the reference time interval (1 s).*

NOTE 2 L_{AE} *is also known as* L_{AX} *(single-event noise exposure level).*

3.1.22 sound level difference

D

difference between the sound pressure level in the source room and the sound pressure level in the receiving room

NOTE D is given by the following formula.

$$D = L1 - L2$$

where:

L1 is the average sound pressure level in the source room;

L2 is the average sound pressure level in the receiving room.

3.1.23 sound pressure

p

root-mean-square value of the variation in air pressure, measured in pascals (Pa) above and below atmospheric pressure, caused by the sound

3.1.24 sound pressure level

L_p

quantity of sound pressure, in decibels (dB), given by the formula:

$$L_\mathrm{p} = 10\log_{10}\left(p / p_0\right)^2$$

where:

p is the root-mean-square sound pressure in pascals (Pa);

p_0 is the reference sound pressure (20 µPa)

NOTE The range of sound pressures for ordinary sounds is very wide. The use of decibels gives a smaller, more convenient range of numbers. For example, sound pressure levels ranging from 40 dB to 94 dB correspond to sound pressures ranging from 0.002 Pa to 1 Pa. A doubling of sound energy corresponds to an increase in level of 3 dB.

3.1.25 sound reduction index

R

laboratory measure of the sound insulating properties of a material or building element in a stated frequency band

NOTE For further information, see Annex C and BS EN ISO 10140-2.

3.1.26 standardized impact sound pressure level

$L'_{\mathrm{n}T}$

impact sound pressure level normalized to a reverberation time in the receiving room of 0.5 s

NOTE Standardized impact sound pressure level is used to characterize the insulation of floors in buildings against impact sounds in a stated frequency band (see Annex C and BS EN ISO 140-7).

3.1.27 standardized level difference

$D_{\mathrm{n}T}$

difference in sound level between a pair of rooms, in a stated frequency band, normalized to a reference reverberation time of 0.5 s for dwellings

NOTE Standardized level difference takes account of all sound transmission paths between the rooms (see Annex C and BS EN ISO 140-4).

3.1.28 Groundborne and structure-borne noise

NOTE When elements of a structure vibrate they radiate noise and, if the vibration is high enough, this noise can be audible. Groundborne and structure-borne noise are rarely an issue outside buildings or structures.

3.1.28.1 groundborne noise

audible noise caused by the vibration of elements of a structure, for which the vibration propagation path from the source is partially or wholly through the ground

NOTE Common sources of groundborne noise include railways and heavy construction work on adjacent construction sites.

3.1.28.2 structure-borne noise

audible noise caused by the vibration of elements of a structure, the source of which is within a building or structure with common elements

NOTE Common sources of structure-borne noise include building services plant, manufacturing machinery and construction or demolition of the structure.

3.1.29 third octave band

band of frequencies in which the upper limit of the band is $2^{1/3}$ times the frequency of the lower limit

3.1.30 weighted level difference

D_{w}

single-number quantity that characterizes airborne sound insulation between rooms, but which is not adjusted to reference conditions

NOTE Weighted level difference is used to characterize the insulation between rooms in a building as they are. Values cannot normally be compared with measurements made under other conditions (see BS EN ISO 717-1).

3.1.31 weighted normalized impact sound pressure level

$L'_{\mathrm{n,w}}$

single-number quantity used to characterize the impact sound insulation of floors over a range of frequencies

NOTE Weighted normalized impact sound pressure level is usually used to characterize the insulation of floors tested in a laboratory (see Annex C and BS EN ISO 717-2).

3.1.32 weighted sound reduction index

R_{w}

single-number quantity which characterizes the airborne sound insulating properties of a material or building element over a range of frequencies

NOTE The weighted sound reduction index is used to characterize the insulation of a material or product that has been measured in a laboratory (see Annex C and BS EN ISO 717-1).

3.1.33 weighted standardized impact sound pressure level

$L'_{\mathrm{n}T,\mathrm{w}}$

single-number quantity used to characterize the impact sound insulation of floors over a range of frequencies

NOTE Weighted standardized impact sound pressure level is used to characterize the insulation of floors in buildings (see Annex C and BS EN ISO 717-2).

3.1.34 weighted standardized level difference

$D_{\mathrm{n}T,\mathrm{w}}$

single-number quantity that characterizes the airborne sound insulation between rooms

NOTE Weighted standardized level difference is used to characterize the insulation between rooms in a building (see Annex C and BS EN ISO 717-1).

3.2 Symbols

For the purposes of this British Standard the following symbols apply.

A	Equivalent sound absorption area (m^2)
D	Sound level difference (dB)
D_{w}	Weighted level difference (dB)

$D_{\mathrm{n}T}$	Standardized level difference (dB)
$D_{\mathrm{n}T,\mathrm{w}}$	Weighted standardized level difference (dB)
L_{Amax}	Maximum noise level (dB)
$L_{\mathrm{Ar},Tr}$	Rating level (dB)
L_{i}	Impact sound pressure level (dB)
L_{n}	Normalized impact sound pressure level (dB)
$L'_{\mathrm{n}T}$	Standardized impact sound pressure level (dB)
$L'_{\mathrm{n}T,\mathrm{w}}$	Weighted standardized impact sound pressure level (dB)
$L'_{\mathrm{n,w}}$	Weighted normalized impact sound pressure level (dB)
L_{p}	Sound pressure level (dB)
L_{pA}	A-weighted sound pressure level (dB)
$L_{\mathrm{AN},T}$	Percentile level (dB)
L_{AE}	Sound exposure level (dB)
$L_{\mathrm{Aeq},T}$	Equivalent continuous A-weighted sound pressure level (dB)
p	Sound pressure (Pa)
p_{A}	A-weighted sound pressure (dB)
$p_{\mathrm{A}}(t)$	Instantaneous A-weighted sound pressure (Pa)
p_0	Reference sound pressure (Pa)
R	Sound reduction index (dB)
R_{w}	Weighted sound reduction index (dB)
T	Time interval (also used for reverberation time) (s)
t_0	Reference time interval (s)

4 Measuring equipment and accuracy

The equipment to be used for measuring noise levels should:

a) conform to the accuracy requirements specified in BS EN ISO 140, BS EN ISO 10140 or BS 4142, as applicable; or

b) if not stated, meet Class 2 or better (see BS EN 61672-1, BS EN 61672-2 and BS EN 60942).

In critical situations, for example, where the measurements are to confirm that a specification has been met or for the resolution of a dispute, the appropriate guidelines for the building use should also be followed.

NOTE 1 Quantification of measurement uncertainty is generally described in the relevant British or International standard and specific guidance, such as that supporting the Building Regulations (see, for example, ***7.7.3.1****), healthcare design technical manuals and schools building bulletins (see, for example,* ***7.7.8****).*

NOTE 2 Where there are no specific measurement requirements for a building use, the guidelines published by the Association of Noise Consultants [3] or other professional bodies may be followed.

5 Planning and design

5.1 Sequence of stages

The recommended sequence of stages in the planning and early design stages of a development is as follows.

a) Assess the site, identify significant existing and potential noise sources, measure or estimate noise levels (see Clause **6**), and evaluate layout options (see **5.2**).

b) Determine design noise levels for spaces in and around the building(s) (see **5.3** and Clause **7**).

c) Determine sound insulation of the building envelope, including the ventilation strategy (see **5.4.5** and Clause **6**).

d) Identify internal sound insulation requirements (see **5.3** and Clause **8**).

e) Identify and design appropriate noise control measures (see **5.4**).

f) Establish quality control and ensure good quality workmanship (see **5.5**).

Although this British Standard does not cover the impacts on external receptors of noise that breaks out from the building, it might be necessary to address this within the overall design and planning process.

The same sequence [a) to f)] can be applied where a new noise-making development is to be introduced near an existing noise-sensitive development, such as housing.

5.2 Assessing the building or site

5.2.1 Need for noise assessment

When planning permission is sought for a new building or for a change of use to an existing building, the local planning authority may:

a) refuse permission if the site is too noisy for the proposed use and local or national noise policies will not be met; or

b) refuse permission if the proposed use is likely to cause noise disturbance to the occupants of existing buildings such that local or national noise policies will not be met; or

c) grant permission, with or without conditions regarding noise levels, so that local or national noise policies are met.

NOTE 1 The local planning authority needs to take account of the following government publications:

- *in England: the National Planning Policy Framework published by the Department for Communities and Local Government (March 2012) [2], relevant National Policy Statements and the Noise Policy Statement for England [4];*
- *in Wales: the Welsh Government publications "Planning Policy Wales" [5] and Technical Advice Note (TAN) 11: Noise [6];*
- *in Scotland: the Scottish Government's Planning Advice Note 1/2011: Planning and Noise [7] and the accompanying Technical Advice Note [8];*
- *in Northern Ireland: where appropriate, the relevant Planning Policy Statement [9] or relevant Development Control Advice Note [10]; and*
- *any noise action plans published under the relevant Environmental Noise Regulations [11, 12, 13, 14].*

It is therefore important that, even when a full environmental assessment is not mandatory, proposals for developments on noisy sites, or sites which generate noise, should take account of noise, and an assessment should be made of the possible effects of:

1) noise generated outside the site that might enter any building on site;
2) noise generated inside the site or a building on site that could affect people outside the site/building;

   NOTE 2 The noise in item 2) is outside the scope of this British Standard.

3) the effect of the proposed development on the existing ambient noise outside the site.

Some noise sources (e.g. airports) might not always be active, or might change their mode of operation under different weather conditions and/or at certain times of day or night. Furthermore, buildings might not necessarily be occupied when the outside environment is noisy. It is therefore essential to make a full assessment of the site before considering the need for, and extent of, noise control.

5.2.2 Noise generated inside or outside the building

5.2.2.1 Noise generated inside the building

For noise generated and heard within the building, the design guidance in Clause **8** for sound insulation within the building should be followed.

The existing and expected noise source(s) should first be identified and the designer should apply the following procedures.

a) Select metrics to use for measuring or predicting noise levels (e.g. $L_{\mathrm{Aeq},T}$, or L_{p} in octave or third octave bands).
b) Assess effects of topography and other features, such as noise screens or reflecting surfaces.
c) Measure or predict noise levels at strategic points. In some complex situations it might be worth drawing a contour map of external noise levels.
d) If appropriate, assess noise levels due to user activities around the buildings and site.

The levels of existing noise and noise expected in the foreseeable future should be based on measurement where practicable, or may be predicted if there is reliable information.

5.2.2.2 Noise generated outside the building

For noise sources outside the building, the initial appraisal should take account of the options for:

a) location of the site in relation to the noise source(s);
b) reduction of noise at source;
c) positioning of buildings on site;
d) orientation of buildings on site;
e) provision of barriers;
f) increasing the sound insulation of the building envelope; and
g) re-planning the interior layout of the building.

These options might also be applicable to protecting neighbouring buildings that are likely to be disturbed by noise generated within the building.

5.3 Design and noise criteria: noise levels

The designer should establish the intended use, including noise activity, noise sensitivity and privacy, of the proposed rooms and other spaces.

To achieve satisfactory sound insulation inside the building, it is necessary to know how each space is to be used so that appropriate noise criteria can be chosen. The designer can then decide which noise criteria are appropriate for the relevant parts of the proposed building, and select appropriate noise levels (see **7.2** and **7.3**).

*NOTE Advice on indoor ambient noise criteria for various building types is given in **7.3**.*

The designer should also:

a) compare external noise levels with internal design criteria;

b) calculate the noise reduction required between the exterior and interior;

c) if appropriate, assess internal noise sources;

d) calculate the noise reduction required between internal user areas and, if necessary, the noise reduction required to reduce noise from internal sources to the level required outside the building; and

e) identify which noise control measures would be appropriate to deliver this noise reduction (see **5.4**).

5.4 Noise control measures

5.4.1 General approach

All reasonable noise control measures should be designed and implemented to ensure that the noise levels are met, along with local or national noise management policies, as appropriate.

NOTE Effective design for noise control requires a good understanding of the behaviour of sound. While the general approach is explained in this subclause, practical information on the transmission of sound within buildings and propagation across the ground is given in the Building Research Establishment document BR 238/CIRIA report 127 [15]. Specialist advice is required for more complex situations, such as those listed in Annex D.

In determining the appropriate noise control measures, the designer should take the following steps, which may be iterative.

a) Check the feasibility of reducing noise levels and/or relocating noise sources.

b) Consider options for planning the site or building layout.

c) Consider the orientation of proposed building(s).

d) Select construction types and methods for meeting building performance requirements (see **5.4.4**).

e) Examine the effects of noise control measures on the requirements for ventilation, fire regulation, health and safety, cost, CDM (construction, design and management), etc.

f) Assess the viability of alternative solutions.

The designer should then decide which of the following options can be applied to reduce noise levels.

1) Quietening or removing the source of noise (**5.4.2**).

2) Attenuating the sound on its path to the receiver (**5.4.3**).

3) Obstructing the sound path between source and receiver (**5.4.4**).

4) Improving the sound insulation of the building envelope (**5.4.5**).
5) Using agreements to manage noise (**5.4.6**).

5.4.2 Quietening the source

Reducing the noise at source should always be considered because the number of people benefiting might be large and it can be the most cost-effective method.

5.4.3 Attenuating the noise

Noise is attenuated as it travels through the air because it:

a) spreads out;
b) is affected by nearby surfaces, such as grass-covered ground; and
c) is partly absorbed by the air itself.

These mechanisms for attenuating noise become more effective as the distance between the source and the receiver increases. Spreading is usually the most important effect. For small sources, the reduction is up to approximately 6 dB for each doubling of distance between source and receiver. For extended sources, there is a smaller reduction with distance. For example, the noise level from dense road traffic diminishes at approximately 3 dB for each doubling of distance.

In some circumstances, the noise might not attenuate at expected rates, with poor attenuation occurring with traffic in city streets with high buildings on both sides. In this situation, the noise level diminishes vertically very slowly as the storey height increases because of multiple reflections between the facades (canyon effect).

Ground attenuation is negligible for hard ground and water surfaces. For grassland and other types of ground considered “soft”, the attenuation varies with frequency.

5.4.4 Obstructing the sound

Complete enclosure of the noise source or receiver is the most effective form of barrier, provided it is impervious and sufficiently heavy. The walls and roof of a building usually perform this function (see Clause **8**). Their effectiveness as a sound insulator is reduced by weaknesses in the envelope (e.g. ventilation openings, thin glazing and doorways), especially when windows are opened. It is therefore important that the effectiveness of measures for obstructing sound is determined.

Barriers that are not complete enclosures (e.g. screens) are normally most effective when tall, long, sound-absorbent, and close to either the source or the receiver.

Solid fences, walls, earth bunds or buildings should extend to the ground.

Whilst neither of the national methods for calculating noise from road traffic or from railways provides for any reduction in noise due to the presence of vegetation, other available guidance suggests that appreciable attenuation can be expected under certain conditions. ISO 9613-2 includes procedures for estimating the attenuation from foliage (trees and shrubs) in each octave band as a function of the total propagation distance that the sound travels through the foliage.

In the context of promoting sustainable methods for reducing road traffic noise, the HOSANNA (Holistic and Sustainable Abatement of Noise by Optimised Combinations of Natural and Artificial Means) Research Project (see Note), funded by the European Union Seventh Framework Programme, was tasked with investigating the theoretical performance of different forms and configurations of vegetation-based noise mitigation, including trees (rows and belts), shrubs and bushes. The study reports that, through an optimized combination of scattering, dispersion, absorption and diffraction effects, appreciable reductions in traffic noise can be expected from compositions of vegetation elements (such as twigs, leaves, stems and trunks).

NOTE To calculate the attenuation for road and rail traffic noise and construction noise, see the references given in Clause ***6****. Attenuation values of approximately 10 dB are common, but a barrier can reduce the benefit of any ground absorption.*

5.4.5 Sound insulation of the building envelope

5.4.5.1 General

Where the designer proposes a form of construction that is intended to obstruct noise, and which might take into account cost and other constraints, the proposed design should be examined and calculations carried out to determine whether the target noise reduction is likely to be achieved. The results indicate whether a higher standard of noise reduction might be necessary or whether a lower standard is adequate. If the need for a change in the design is indicated, further calculations should be carried out and the process repeated until a satisfactory result is obtained. In a situation where a low standard suffices it might be prudent to consider future uses of the building.

When the sound insulation of the building envelope is not known, this may be calculated using one of the methods given in **5.4.5.2** (see also BS EN 12354).

5.4.5.2 Calculations

5.4.5.2.1 General

The required sound insulation should be determined on the basis of the assessment of:

a) the level and characteristics of the noise outside the building (see **5.2** and Clause **6**);

b) the design noise levels in the rooms and other spaces of the building (see **5.3** and Clause **7**).

The sound insulation required can then be determined.

5.4.5.2.2 Initial estimates

Initial estimates may be obtained using calculations based on single-figure data such as the following.

a) The level of the noise at a key position, such as the equivalent continuous A-weighted sound pressure level ($L_{\mathrm{Aeq},T}$) at the location of the nearest facade of the proposed building. The time period, T, should be chosen to cover the normal operation of the source, or particular occupational requirements of the building if more appropriate. If the source level varies, the maximum level having an appreciable duration should be chosen.

b) The sound reduction of appropriate parts of the building envelope, e.g. estimated from values of R_{w} (see Clause **8** and Annex E).

   NOTE Annex A contains a method for estimating the sound insulation of a non-uniform facade comprising windows, ventilation openings and cladding.

c) The design sound level at the receiver (e.g. $L_{\mathrm{Aeq},T}$). If the source operates at night, it might be appropriate to have separate design noise levels for day and night periods.

It is important to understand that there is no simple relationship connecting these single-figure data and that the results are approximate (see Clause **6**).

5.4.5.2.3 Detailed calculations

For detailed calculations, knowledge of the following is required.

a) Frequency characteristics of the noise source(s).

b) Frequency characteristics of the sound reducing elements.

c) Surface area of the common construction separating the two areas.

d) Reverberation time of the receiving space.

Generally, frequency data should be for contiguous octave bands.

5.4.6 Agreements

For certain types of building, it might be possible to assist the management of noise by express provisions in agreements. For example, a contract specification might set noise limits, a tenancy agreement can restrict the use of musical instruments, providing the restriction is sufficiently specific to be enforceable, or a noise management plan might require monitoring of noise levels and actions if limits are exceeded.

5.5 Quality control and workmanship

Quality control and workmanship should always be considered very carefully. Noise control measures can fail to perform adequately if they are not built as the designer intended. Such variations might appear to be unimportant, but often have serious implications for noise control, e.g. a slight warp in a window frame can reduce the effectiveness of the seals. To establish good quality control and workmanship the following aspects should be considered by the designer and discussed with the builder.

a) Detailed specifications.

b) The standards of materials and workmanship.

c) Performance specification in the contract documentation.

d) Checking and testing procedures that are to be used to demonstrate the standard of workmanship during construction.

e) Checking and testing procedures that are to be used to assess the building performance.

6 External noise sources

6.1 Introduction

Noise from common sources in the environment is dealt with in **6.2** to **6.7**. In each case, information is given on the characteristics of the noise and guidance is given as to how levels can be determined and controlled for each specific source. Example calculations for resolving a typical design problem are given in Annex G.

6.2 Noise from road traffic

6.2.1 General

Road traffic noise generation depends upon a number of factors, including:

a) traffic flow, which can vary considerably within and between days of the week;

b) type of vehicles, i.e. proportion of heavy or light;

c) mode of operation, i.e. on level or inclined road;

d) surface texture of the road; and

e) traffic speed and whether flow is continuous or interrupted.

NOTE Weather conditions, e.g. surface water on road, can also affect noise generation.

As with other types of noise the propagation depends upon meteorological conditions, topographical features and ground cover characteristics.

For a typical urban situation where road speed is below 60 km/h, sound energy is concentrated in the low frequency end of the spectrum because of high levels of exhaust noise, particularly from diesel commercial vehicles. At greater speeds (i.e. 80 km/h or higher), more energy is present at higher frequencies due to the road/tyre surface interaction and aerodynamic noise. This difference in spectral characteristics can affect the nature of the noise heard within a building, and should be considered when different noise control measures are being examined.

For initial design purposes, typical noise levels for three common situations are given in Table 1.

Table 1 **Typical traffic noise levels measured approximately 1 m from the facade**

Situation	**dB** $L_{\mathrm{Aeq,16h}}$
At 20 m from the edge of a busy motorway carrying many heavy vehicles; average traffic speed 100 km/h; intervening ground turfed	78
At 20 m from the edge of a busy main road through a residential area; average traffic speed 50 km/h; intervening ground paved	68
On a residential road parallel to a busy main road and screened by the houses from the main road traffic; free flowing traffic	58

NOTE Values are for dry road.

A typical noise spectrum for assessing sound reduction near roads is given in BS EN 1793-3. For more complex situations, detailed calculations or measurements should be undertaken.

6.2.2 Modelling traffic noise

The noise from road traffic can be calculated for a specified range of situations using the method in *Calculation of Road Traffic Noise* (CRTN) [16]. This method predicts the $L_{A10,18h}$ for the period 06:00 to 24:00 or the $L_{A10,1h}$ for roads carrying more than 1 000 vehicles per 18 h day or 50 vehicles per hour. It is the recognized national method for calculating road traffic noise levels, but has been augmented by additional guidance published by the Highways Agency (*Design Manual for Roads and Bridges*, Volume 11, Section 3, Part 7, HD 213/11 – Revision 1) [17]. This additional guidance includes updated advice on calculating night-time noise levels, determining the extent of the study area, vehicle classification, corrections for contemporary road surfaces, speed data, and other approaches to modelling certain specific situations. It is usual to make flow rate forecasts 15 years ahead.

The method takes the following factors into account.

a) Hourly or 18-hourly traffic flow rate.

b) Mean traffic speed.

c) Percentage of heavy vehicles.

Other information required for the calculation includes:

1) road surface and gradient;

2) ground type;

3) height of receiver;

4) shielding by barriers and cuttings;

5) reflections at facades and from nearby buildings; and

6) angle of view of the road.

The method can be used to draw noise contours on a site plan, and this is now usually implemented through a number of proprietary noise prediction models which implement the calculation procedure in CRTN [16]. However, where traffic conditions are complex or unusual it might be necessary to measure noise levels on site, and procedures for measurements are contained within CRTN [16].

A Defra-commissioned study, prepared by TRL and entitled "*Method for Converting the UK Road Traffic Noise Index $L_{A10,18h}$ to the EU Noise Indices for Road Noise Mapping*" [18], is the source of the method promulgated in Highways Agency document HD 213/11 [17] for estimating night-time noise levels from the calculated or measured $L_{A10,18h}$.

This study, however, also provides methods for the conversion of $L_{A10,18h}$ index to other indices, including various period $L_{Aeq,T}$ values. Whilst these conversions have been developed primarily for compliance with strategic EU noise mapping requirements, they provide one potential approach to estimating the range of noise indicators which are relevant to modelling traffic noise.

Otherwise, conversion of L_{A10} to L_{Aeq} can be achieved by the (approximate) relationship: $L_{Aeq,16h} = L_{A10,18h} - 2$ dB. This is generally correct with a 95% confidence interval of ±2 dB for moderate and heavy traffic flows.

6.3 Noise from aircraft

6.3.1 General

For most airports, the airport operator is responsible for the noise management, which has to be designed to align with Government policy. The exceptions are Heathrow, Gatwick and Stansted, for which the Department of Transport has noise management responsibility. Airports covered by Directive 2002/49/EC [19] have published Noise Action Plans which describe their noise management, including information about flight paths, hours of operation, the planning conditions under which they operate and other noise mitigation practices.

Aircraft noise can be controlled by voluntary noise abatement procedures, which can include:

a) the adoption of noise preferential routes; and

b) restrictions on the number of movements and/or classes of aircraft.

Aerodromes used for commercial air transport of passengers and for training in aircraft above certain total maximum total weights are licensed by the Civil Aviation Authority (CAA). Many aerodromes, including general aviation (private and recreational flying and aviation work), do not require a licence for their operation, but the CAA remains responsible for all matters affecting the safety of aircraft and provides guidance on noise consideration at general aviation aerodromes [20].

Planning conditions and legally binding agreements between local planning authorities and landowners can also impose restrictions on aircraft types and operating times, and number of movements, to control noise.

Military aircraft operate under the control of the Military Aviation Authority (MAA).

6.3.2 Prediction of noise from aircraft

Prediction of noise from aircraft or airports is complex, though aircraft noise modelling software packages are available. Many airports periodically produce contours showing the noise exposure around the airport. Care is needed in interpreting these contours as they tend to show average exposure, taking account of different modes of airport operation. This means that, on a particular day, the noise exposure at a particular location might be higher than implied by the contours, and consideration should be given to designing the building envelope for those operational days.

These contours show the noise of aircraft departing from and arriving at an airport without the presence of any shielding effects from buildings or topographical features. They also do not include the noise from ground operations such as taxiing, auxiliary or ground power units or engine testing. Where appropriate, these sources need to be considered separately.

Where it appears that sound insulation treatment is necessary, noise exposure data should be obtained by on-site noise measurements, taking account of wind direction and runway usage. The survey duration of on-site measurements should be sufficient to take account of the various permutations of runway use that can occur, as certain flight paths might only be used under certain wind direction conditions. Where treatment of the building envelope is required to achieve internal design standards then site-specific measurements should be recorded, including provision for the frequency content of the noise (predominantly low frequency noise). It should be noted that for a jet aircraft the frequency content of noise when landing is generally different from that when departing. Typically, landing jet aircraft produce relatively higher levels of high-frequency noise and departing jet aircraft produce relatively higher levels of low-frequency noise.

6.4 Noise from railways

6.4.1 General

Noise from passing trains is characterized in two ways.

a) The passage of trains over the day and night periods, which is dependent upon timetabling. Passenger trains follow strict daily timetables; freight train passage is less predictable and often occurs at night when passenger services have ceased.

b) The specific characteristic associated with the passage of each train type, but this is generally characterized by short periods of high noise levels dependent upon speed, locomotive type, power type (electric/diesel), etc.

6.4.2 Prediction of airborne noise from railways

The recognized national calculation method for airborne noise from railways is given in *Calculation of Railway Noise (CRN)* [21], with additional source terms given in *Additional railway noise source terms for "Calculation of Railway Noise 1995"* [22]. The method begins with the calculation of a reference sound exposure level (SEL or L_{AE}) for rolling noise at 25 m, which is speed-based. The calculated value is then corrected for vehicle type/description which takes into account number of axles and brake type. The procedure enables calculation of two $L_{Aeq,T}$ values:

a) day $L_{Aeq,16h}$ (07.00 to 23.00); and

b) night $L_{Aeq,8h}$ (23.00 to 07.00).

This method takes into consideration the following factors for each type of train.

1) SEL (or L_{AE}) of the train(s).
2) Number and times of train movements.
3) Distance from track.
4) Air absorption.
5) Ground type.
6) Track bed type.
7) Screening.
8) Angle of view.
9) Reflection and facade effects.

6.5 Noise from industry

6.5.1 General

Industrial noise can originate from specific processes, either internal or external to buildings, or from related transport operations, such as loading/unloading vehicles or activities involving other plant such as fork lift trucks.

NOTE Normal traffic movements on site may be assessed using the measures in ***6.2****.*

6.5.2 Assessment of industrial noise

Where industrial noise affects residential or mixed residential areas, the methods for rating the noise in BS 4142 should be applied. BS 4142 describes methods for determining, at the outside of a building:

a) noise levels from factories, industrial premises or fixed installations, or sources of an industrial nature in commercial premises; and

b) background noise level.

6.6 Noise from construction and open sites

6.6.1 General

Noise from construction and open sites can disturb occupants of nearby buildings, whether in residential or other uses. Noise at night can cause sleep disturbance. On this basis, it is commonly accepted that controls are necessary for many construction and open sites, unless they are sufficiently remote from occupied buildings. BS 5228-1 gives recommendations for basic methods of noise control for construction and open sites where work/activities/operations, including demolition, generate significant noise levels. Industry-specific guidance is also included. The legislative background to noise control is described and recommendations are given for establishing effective liaison between developers, site operators and local authorities. Guidance is also given on methods of predicting and measuring noise and assessing its impact on those exposed to it.

6.6.2 Noise effects and community reaction

The main factors that affect the acceptability of noise arising from construction sites are:

a) site location;

b) existing ambient noise levels;

c) duration of site operations;

d) hours of work;

e) attitude of the site operator, e.g. if the site operator communicates with affected residents on a regular basis as to when and for how long noisy events are planned to occur, the expected noise is perceived as less annoying than unexpected noise of an unknown duration;

f) noise characteristics; and

g) whether additional mitigation has been provided in the form of sound insulation or temporary or permanent rehousing.

BS 5228-1 describes methods for noise control and for determining the significance of noise effects. Several example assessment methods are provided from various significant projects. However, one of the key elements is the provision in BS 5228-1:2009, Annex F, of methods for estimating noise from sites, which is assisted by the inclusion of a large data set of source terms for plant and activities.

6.6.3 Prediction of construction site noise

Noise from construction sites arises from a wide range of plant and activities with many different characteristics. BS 5228-1:2009, Annex F, provides methods for estimating the $L_{\text{Aeq},T}$ levels, taking into account:

a) sound power outputs of processes and plant;

b) periods of operation of processes and plant;

c) distances from sources to receivers;

d) presence of screening by barriers;

e) reflection of sound; and

f) soft ground attenuation.

The levels from the range of equipment used are combined to give an overall $L_{\text{Aeq},T}$ level.

NOTE Slightly different procedures exist for stationary and mobile plant, and these are described in a flowchart in BS 5228-1:2009, Figure F.1.

6.7 Noise from wind farms

6.7.1 General

Wind turbines vary in size and power output, from those just a few metres in diameter to large turbines of around 90 m in diameter. As the turbine blades rotate, aerodynamic noise is generated, which sounds like a swishing noise. Many modern pitch-regulated turbines achieve a maximum level of noise emission at or around the wind speed at which they reach their maximum power generation capacity, which then remains constant, or in some cases declines, as wind speed increases. Mechanical noise from the gearbox (when fitted) and, to a lesser extent, the generator is not usually significant, except in small or older turbine designs. The hub is isolated from the tower and the blade assembly to prevent significant structure-borne noise occurring, which in turn prevents any significant vibrations being transmitted to the ground.

6.7.2 Assessment of wind farm noise

The design, size and rotational speed of a turbine influences the character of the noise generated. The quantification of the noise emissions of medium to large wind turbines is set out in BS EN 61400-11. A particular feature of aerodynamic noise, which is often cited as an adverse feature of medium to large wind turbines, is that of amplitude modulation (AM), which is the modulation or rhythmic swish. Excess AM can sometimes occur. However, it cannot be predicted at the planning stage with the current state of the art. Within the UK, ETSU-R-97 [23] may be used to assess and rate the noise from wind farms. ETSU requires wind farms to achieve defined noise limits in order to preserve day time outdoor amenity and sleep quality at night.

In comparison, small turbines generally have a lower noise emission level, but generate higher frequencies since the blades rotate at greater speeds. Thus the noise impact from these turbines is relatively localized. Offshore turbines might only influence the design and construction of buildings when there is nearby onshore infrastructure, such as electrical substations and converter stations.

6.7.3 Prediction of wind turbine noise

Reliable estimates of wind turbine noise can be made using the procedures in the Institute of Acoustics' *A good practice guide to the application of ETSU-R-97 for the assessment and rating of wind turbine noise* [24], which provides accepted methods of noise prediction. Following these procedures permits calculation of reliable noise levels at varying distances and locations for a range of operational wind speeds (typically 4 m/s to12 m/s).

6.8 External noise sources: Meteorological effects

Whether noise levels are measured or predicted, wind gradients, temperature gradients and turbulence affect the level of received sound and audibility over short periods. The magnitude of these effects, i.e. variations in noise level and audibility, increases with increasing distance between source and receptor. The effects are asymmetrical and, for distances of 500 m to 1 000 m, typically range from increasing the level by typically 2 dB downwind to reducing it by typically 10 dB upwind. It is not usually practicable to use these factors in design, but the prevailing wind direction should be considered when planning building orientation.

Noise from wind and precipitation, including the wind-generated noise from trees, can also affect noise measurements.

6.9 Other sources of noise

Other noise sources exist, many of which originate from leisure activities, e.g. model aircraft, sports and entertainment.

Codes of practice give guidance on likely noise levels, assessment and frequency of occurrences for most of these noise sources [for example, 25, 26, 27]. Specialist advice might be required.

NOTE Codes produced by the Government can normally be obtained from The Stationery Office, and additional advice might be available from local authority environmental health departments.

Noise from natural sources, such as rivers, streams, waves, birdsong, wind in trees or rain, also contributes to the acoustic environment and could affect noise assessments.

7 Specific types of building

7.1 General

Guidance is given in **7.2** to **7.6** on acoustic criteria and noise levels appropriate for various types of space that have different functions. In addition, attention is drawn to special features requiring consideration. Where the acoustic performance of spaces or systems is critical [e.g. auditoria or complex heating, ventilating and air conditioning (HVAC) systems], specialist advice should be sought (see Annex D).

It is not practical to give detailed guidance on all types of building. Many types of building include spaces having different functions. For example, a factory may include workshops, offices and meeting rooms. Appropriate guidance is given in **7.7**.

7.2 Design considerations

To control internal ambient noise from sources such as traffic and mechanical services, the designer should, at the outset, decide which of the following are appropriate for all or different parts of the proposed building.

a) Industrial working conditions.

b) Speech and telephone communications.

c) Acoustic privacy.

d) Conditions for study and work requiring concentration.

e) Listening conditions.

f) Resting/sleeping conditions.

The designer should establish noise activity levels, noise sensitivity and privacy levels for the relevant spaces.

7.3 Indoor ambient noise criteria

For each space there might be a range of noise levels that are considered acceptable. The designer should select a level appropriate for the particular circumstances. In noise-making workshops, etc., the activity noise is dominant and so the internal ambient noise level is not critical. In most other situations internal ambient noise is important.

NOTE Guidance on indoor ambient noise levels is given in Table 2, Table 3, Table 4, Table 5 and Table 6 for various types of room.

Normally, only the maximum desirable noise level needs to be decided (see Table 4 and Table 5). In some cases, such as open-plan offices and restaurants, a moderate noise level might provide masking for acoustic privacy in shared spaces without causing disturbance, so upper and lower noise levels should be considered (see Table 2).

Table 2 **Indoor ambient noise levels in spaces when they are unoccupied and privacy is also important**

Objective	**Typical situations**	**Design range $L_{\mathrm{Aeq},T}$ dB**
Typical noise levels for acoustic privacy in shared spaces	Restaurant	40 – 55
	Open plan office	45 – 50
	Night club, public house	40 – 45
	Ballroom, banqueting hall	35 – 40
	Living room	35 – 40

NOTE See Noise control in building services [28] and BS EN ISO 3382.

Noise levels generally apply to steady sources, such as those due to road traffic, mechanical services or continuously running plant, and should be the noise level in the space during normal hours of occupation but excluding any noise produced by the occupants and their activities. The time period, T, should be appropriate for the activity involved (e.g. 23.00 to 07.00 for bedrooms, 30 min for schools). If the noise is fairly steady, it might not be necessary to measure for the whole of the relevant time period to establish the typical outdoor level.

*NOTE Guidelines for the measurement of noise in buildings can be obtained from The Association of Noise Consultants (http://www.association-of-noise-consultants.co.uk/index.php?*p=pubguide).*

7.4 Noise indices

The noise rating (NR) system, a graphical method described in Annex B, is in common use for rating noise from ventilation systems. Although there is no direct relationship between dBA and NR, the following approximate relation applies in the absence of strong low frequency noise.

$$\text{NR} \approx \text{dBA} - 6$$

Although the NR system is currently a widely used method for rating noise from mechanical ventilation systems in the UK, other methods are also available that are more sensitive to noise at low frequencies [29]. Low frequency noise can be disturbing or fatiguing to occupants, but might have little effect on the dBA or NR value.

7.5 Internal sound insulation

In addition to controlling exterior noise and internal services noise, sound from adjacent spaces can affect the intended use, depending on the noise activity, noise sensitivity and privacy requirement. A matrix may be used to determine the sound insulation requirement of separating partitions once the noise activity, noise sensitivity and privacy requirements for each room and space are established (see **7.2**). An example matrix, which can be adapted according to the specific building use, is given in Table 3. Each room may be both a source and a receiving room. Where adjacent rooms have different uses, the worst case sound insulation should be specified.

Table 3 **Example on-site sound insulation matrix (dB $D_{nT,w}$)**

Privacy requirement	**Activity noise of source room**	**Noise sensitivity of receiving rooms**		
		Low sensitivity	**Medium sensitivity**	**Sensitive**
Confidential	Very high	47	52	57 [A)]
	High	47	47	52
	Typical	47	47	47
	Low	42	42	47
Moderate	Very high	47	52	57 [A)]
	High	37	42	47
	Typical	37	37	42
	Low	No rating	No rating	37
Not private	Very high	47	52	57 [A)]
	High	37	42	47
	Typical	No rating	37	42
	Low	No rating	No rating	37

NOTE Background noise can also influence privacy. See also ***7.7.6.3****.*

[A)] $D_{nT,w}$ 55 dB or greater is difficult to obtain on site and room adjacencies requiring these levels should be avoided wherever practical.

7.6 Limits for reverberation time

As well as internal ambient noise level, the reverberation time, T, measured in seconds (s), should also be considered because it affects the noise level in the space, and also affects the clarity of speech and the warmth of music. Even where good speech conditions are not paramount, an excessively long reverberation time accentuates the background noise and can reduce the clarity of public address announcements.

General guidance on designing rooms for speech (e.g. meeting rooms) is given in **7.7.10**, although the acoustic design of auditoria is a specialized subject and is beyond the scope of this British Standard.

NOTE BS EN ISO 3382 covers the measurement of reverberation time in various room types.

7.7 Specific types of building

7.7.1 Dwelling houses, flats and rooms in residential use (when unoccupied)

This subclause applies to external noise as it affects the internal acoustic environment from sources without a specific character, previously termed “anonymous noise”. Occupants are usually more tolerant of noise without a specific character than, for example, that from neighbours which can trigger complex emotional reactions. For simplicity, only noise without character is considered in Table 4. For dwellings, the main considerations are:

a) for bedrooms, the acoustic effect on sleep; and

b) for other rooms, the acoustic effect on resting, listening and communicating.

NOTE Noise has a specific character if it contains features such as a distinguishable, discrete and continuous tone, is irregular enough to attract attention, or has strong low-frequency content, in which case lower noise limits might be appropriate.

7.7.2 Internal ambient noise levels for dwellings

In general, for steady external noise sources, it is desirable that the internal ambient noise level does not exceed the guideline values in Table 4.

Table 4 **Indoor ambient noise levels for dwellings**

Activity	**Location**	**07:00 to 23:00**	**23:00 to 07:00**
Resting	Living room	35 dB $L_{\text{Aeq,16hour}}$	—
Dining	Dining room/area	40 dB $L_{\text{Aeq,16hour}}$	—
Sleeping (daytime resting)	Bedroom	35 dB $L_{\text{Aeq,16hour}}$	30 dB $L_{\text{Aeq,8hour}}$

NOTE 1 Table 4 provides recommended levels for overall noise in the design of a building. These are the sum total of structure-borne and airborne noise sources. Groundborne noise is assessed separately and is not included as part of these targets, as human response to groundborne noise varies with many factors such as level, character, timing, occupant expectation and sensitivity.

NOTE 2 The levels shown in Table 4 are based on the existing guidelines issued by the WHO and assume normal diurnal fluctuations in external noise. In cases where local conditions do not follow a typical diurnal pattern, for example on a road serving a port with high levels of traffic at certain times of the night, an appropriate alternative period, e.g. 1 hour, may be used, but the level should be selected to ensure consistency with the levels recommended in Table 4.

NOTE 3 These levels are based on annual average data and do not have to be achieved in all circumstances. For example, it is normal to exclude occasional events, such as fireworks night or New Year’s Eve.

NOTE 4 Regular individual noise events (for example, scheduled aircraft or passing trains) can cause sleep disturbance. A guideline value may be set in terms of SEL or $L_{\text{Amax,F}}$*, depending on the character and number of events per night. Sporadic noise events could require separate values.*

NOTE 5 If relying on closed windows to meet the guide values, there needs to be an appropriate alternative ventilation that does not compromise the facade insulation or the resulting noise level.

If applicable, any room should have adequate ventilation (e.g. trickle ventilators should be open) during assessment.

NOTE 6 Attention is drawn to the Building Regulations [30, 31, 32].

NOTE 7 Where development is considered necessary or desirable, despite external noise levels above WHO guidelines, the internal target levels may be relaxed by up to 5 dB and reasonable internal conditions still achieved.

If there is noise from a mechanical ventilation system, the internal ambient noise levels should be reported separately with the system operating and with it switched off. If the room contains items such as fridges, freezers, cookers and water heaters, these should be turned off during measurement. Shorter measurement periods such as $L_{\mathrm{Aeq,\ 1\ hour}}$ may be used by agreement, provided the selected shorter measurement period is shown to be representative of the entire night or day period.

7.7.3 Living accommodation

7.7.3.1 Regulatory framework

The sound insulation between adjoining dwellings is controlled by the Building Regulations [30, 31, 32], which require reasonable standards of insulation for certain walls, floors, and stairs. As the Building Regulations have been devolved in Scotland, Wales and Northern Ireland, the appropriate national regulations should be consulted, together with their supporting documents:

- England: Approved Document E [1];
- Wales: Approved Document E [1];
- Scotland: Section 5 of the Technical Handbook [33];
- Northern Ireland: Technical Booklets G and G1 [34].

7.7.3.2 Design criteria for external noise

For traditional external areas that are used for amenity space, such as gardens and patios, it is desirable that the external noise level does not exceed 50 dB $L_{\mathrm{Aeq},T}$, with an upper guideline value of 55 dB $L_{\mathrm{Aeq},T}$ which would be acceptable in noisier environments. However, it is also recognized that these guideline values are not achievable in all circumstances where development might be desirable. In higher noise areas, such as city centres or urban areas adjoining the strategic transport network, a compromise between elevated noise levels and other factors, such as the convenience of living in these locations or making efficient use of land resources to ensure development needs can be met, might be warranted. In such a situation, development should be designed to achieve the lowest practicable levels in these external amenity spaces, but should not be prohibited.

Other locations, such as balconies, roof gardens and terraces, are also important in residential buildings where normal external amenity space might be limited or not available, i.e. in flats, apartment blocks, etc. In these locations, specification of noise limits is not necessarily appropriate. Small balconies may be included for uses such as drying washing or growing pot plants, and noise limits should not be necessary for these uses. However, the general guidance on noise in amenity space is still appropriate for larger balconies, roof gardens and terraces, which might be intended to be used for relaxation. In high-noise areas, consideration should be given to protecting these areas by screening or building design to achieve the lowest practicable levels. Achieving levels of 55 dB $L_{\mathrm{Aeq},T}$ or less might not be possible at the outer edge of these areas, but should be achievable in some areas of the space.

7.7.3.3 Internal planning

To minimize disturbance from internally generated noise:

a) services should be kept away from bedrooms;

b) special attention should be given when locating stairs next to noise-sensitive rooms, such as bedrooms, to prevent disturbance by footsteps;

c) special attention should be given when locating bedrooms near the lift and circulation areas, with less sensitive rooms being used as buffers.

NOTE Compatibility between rooms of adjacent dwellings can be assisted by handing and stacking identical dwelling plans.

Where it is necessary to locate bedrooms adjacent to stairs (other than stairs used for fire escape) or lifts, precautions should be taken where practical to minimize noise transfer.

7.7.3.4 Noise levels from lifts in living accommodation

7.7.3.4.1 General

The maximum recommended noise levels within the living accommodation due to lift operation should not exceed the values given in Table 5. These criteria relate to the highest noise levels during any part of the lift cycle and with any occupancy level between zero and the recommended maximum number of people in a car.

The values in Table 5 should be regarded as upper guideline values and every effort should be made in the design of the lift systems and components to minimize noise and vibration at source such that lower levels result in practice.

Table 5 **Noise levels from lifts in living accommodation**

Room	Maximum noise level (dB $L_{\mathrm{Amax,F}}$)
Bedroom	25
Living room	30
Other areas	35

NOTE These figures relate solely to lift noise levels and do not account for any other noise sources. These values include noise from the lifts irrespective of the transmission mechanism, i.e. they include both airborne and structure-borne noise.

The lift motor and associated equipment should be installed on suitable anti-vibration mountings to prevent the transmission of excessive vibration and/or structure-borne noise to any parts of the living accommodation.

Lifts should be positioned such as to minimize noise disturbance from the operation of the control gear. Lift doors should operate quietly, and acoustic signals to herald lift arrival should not be audible within dwellings.

7.7.3.4.2 Lift lobbies

Lift operation noise during any part of the lift cycle, including announcements, and with any occupancy level should not normally exceed 55 dB $L_{\mathrm{Amax,F}}$ when measured in the lift lobby.

7.7.3.5 Other precautions

Any partition separating a WC from a noise-sensitive room should have an airborne sound insulation of at least 40 dB R_w.

In an apartment building, sound-absorbing materials should be applied to the ceiling surfaces of communal corridors and stairwells to reduce propagation of noise through the building. Such materials need to be applied carefully, only where necessary and as agreed with building control.

Resilient floor coverings, such as carpet with underlay, can be used to minimize noise from footsteps on stair treads, corridors and landings. Noise is reduced at the same floor level and to rooms below the floor or stair. The quietest types of sanitary, heating and plumbing equipment (e.g. WCs, ball valves, refuse chutes) should be used, though their location is more important than their detailed design.

Structure-borne noise should be controlled by isolating the heating pipework from the building structure, at least near the pump. This may be achieved using flexible pipe connectors and resilient fixings on pipe runs. Where pipework penetrates walls and floors, air gaps should be sealed to reduce airborne noise transmission in such a way that structure-borne noise is not transmitted. This may be achieved by packing the gap with mineral wool, and sealing the faces with non-hardening mastic. Building Regulations guidance for fire safety [35, 36, 37] needs to be taken into account. Ventilation fans and similar equipment should be installed on resilient mountings where structure-borne noise would otherwise be a problem.

NOTE For additional guidance see [15].

7.7.4 Spaces in non-domestic buildings when they are unoccupied

The ambient noise levels in non-domestic buildings should not normally exceed the design ranges given in Table 6.

It is advisable to consult a specialist acoustician for guidance on the design of specialist spaces such as recording studios, cinemas, concert halls and opera houses.

NOTE For schools and hospitals, see ***7.7.8****.*

Table 6 **Typical noise levels in non-domestic buildings**

Activity	**Location**	**Design range** dB $L_{\text{Aeq}, T}$
Speech or telephone communications	Department store Cafeteria, canteen, kitchen	50 – 55
	Concourse Corridor, circulation space	45 – 55
Study and work requiring concentration	Library, gallery, museum	40 – 50
	Staff/meeting room, training room	35 – 45
	Executive office	35 – 40
Listening	Place of worship, counselling, meditation, relaxation	30 – 35

7.7.5 Hotels and rooms for residential purposes

7.7.5.1 Design criteria for intrusive external noise

7.7.5.1.1 General

The recommendations for ambient noise in hotel bedrooms are similar to those for living accommodation (see **7.7.2**).

NOTE 1 In addition to hotels, rooms for residential purposes include, among others, student halls of residence, school boarding houses, hostels, hospices and residential care homes. Approved Document E to the Building Regulations [1] might not be applicable to such premises as they are to dwellings. Occupants of rooms for residential purposes, although transitory rather than permanent, might typically reside for longer periods than hotel guests.

In hotels and other multi-occupancy premises containing rooms for residential purposes, it is desirable to avoid intrusive noise, both airborne and impact, in bedrooms, especially when occupants are sleeping (typically assumed to be at night-time).

Intrusive noise can arise from other rooms or uses within the building, from external sources through facades and from internal building services, including heating, ventilation and air conditioning plant.

Consideration should be given to adjacencies, both horizontal and vertical, between bedrooms, and between bedrooms and rooms used for other purposes. Particular attention should be paid to noise from corridors, door closers, adjoining bathrooms, stairwells, lifts and lift lobbies.

NOTE 2 Several large chains of hotels have developed their own criteria for insulating rooms against intrusive noise. Examples of design criteria adopted by various hotel groups are included for reference in Annex H. These examples reflect commercial judgements dependent on the nature of the accommodation provided, e.g. budget or luxury. They are included in this British Standard not as recommendations but as preliminary guidance and, where appropriate, specialist advice ought to be sought.

7.7.6 Offices

7.7.6.1 General

General acoustic guidance for offices is available from the British Council for Offices [38, 39] and the Association of Interior Specialists [40].

Complaints from office workers can arise from the intrusion of external noise, high internal noise levels from services, low background noise and excessive reflections from room surfaces. Inadequate sound insulation between offices is also a frequent source of complaint from those who require privacy for telephone conversations and interviews.

Privacy between offices and between an office and an occupied space requires effective insulation and moderate background noise to mask intruding speech. In order to achieve unintelligible speech from another office, the minimum sound insulation between two offices needs to be approximately D_w = 38 dB. Where privacy is important the minimum sound insulation should be D_w = 48 dB. It is possible that voices can be heard, but the conversation is not usually understood. Where the internal ambient noise level is low it might be necessary to design for higher insulation values (see Table 3 and **7.7.6.3**).

NOTE If a partition does not run from true slab to soffit, it is unlikely that a high level of privacy can be achieved, due to flanking transmission.

7.7.6.2 Controlling noise in open-plan offices

In open-plan offices, the maximum reduction that can be expected between screened workstations separated by 2.5 m to 3.0 m is 15 dB to 25 dB, but the cumulative noise of equipment and people might provide a masking background level which makes this adequate for general needs. The screening should be absorbent-faced and at least 1.5 m high. Low ceilings and absorbent ceilings can assist in reducing sound transmission between workstations. Where ceilings are higher than 3 m, it is more difficult to provide acceptable acoustic conditions in open-plan offices with absorption coverage lower than Class A. Where exposed soffits are used additional absorption might be required. Carpet having good sound-absorbent properties is a desirable floor finish. It should be noted that if the width of the room is small, reflections from the side walls might reduce the effectiveness of the arrangement.

NOTE BS EN ISO 3382-3 specifies methods for the measurement of room acoustic properties in open-plan offices with furnishing.

As some office equipment (e.g. photocopying machines) is noisy, large installations should be contained in a well-screened area or separate room. This could also simplify control of ventilation noise in mechanically-ventilated buildings. Additional speech privacy can be gained by considering spatial planning and the internal ergonomics of the users.

7.7.6.3 Speech privacy in offices

The guidance in this subclause does not apply to amplified speech (e.g. two adjacent video conference rooms), which requires special consideration.

When considering the sound insulation of a partition between two areas, the following factors should be taken into account.

a) The required function of the two rooms. Is conversation required to be inaudible in one room or is some audible speech acceptable, not intrusive or intelligible?

b) The background sound level present in the critical area due to the air conditioning systems and other sources. The intelligibility of speech and the perception of extraneous noise are controlled by the masking created by this background sound level. The higher the background sound level, the more effective it is in masking unwanted sounds. However, the background noise should not become intrusive in itself, so a balance should be achieved between the background sound level and the partition sound reduction.

7.7.7 Industrial buildings

7.7.7.1 Selecting design criteria

The design criteria for inside the building should include provision of reasonable industrial working conditions and reasonable speech and telephone communications. Other acoustic requirements often include limiting the noise emitted from the building and controlling noise from activities outside the building (e.g. vehicle movements) to minimize disturbance to neighbours.

7.7.7.2 Noise inside workshops

As hearing damage is covered by the Control of Noise at Work Regulations [41], special precautions should be taken and management procedures implemented where it is known that noisy processes are taking place.

Table 7 contains maximum noise levels for reliable speech communication. Even where speech communication is not important, it is important that audible warnings and information announcements can be heard clearly (see, for example, BS 5839-8).

The noise control measures discussed in **7.7.6** should be applied to offices outside production areas.

Table 7 **Maximum steady noise levels for reliable speech communication**

Distances between talker and listener m	**Noise level** dBA	
	Normal voice	**Raised voice**
1	57	62
2	51	56
4	45	50
8	39	44

7.7.7.3 Noise emitted by factories

Where a proposed factory development is to be situated in the vicinity of noise-sensitive buildings, the local planning authority usually sets planning conditions that take account of any predicted increase in noise due to the factory (see Clause **5**). Extensive noise control measures might be required, especially if the noise is impulsive, has a strong tonal character, or is otherwise of a distinguishable nature.

On an industrial estate, the noisier factories should be sited furthest from houses, with warehouses and quieter production areas used as buffers between the noisier factories and dwellings outside the industrial estate. Careful site planning can give some protection to noise-sensitive activities on the estate.

Common causes of complaint, which should be taken into consideration, are noise from:

a) industrial processes;

b) external generators, etc.;

c) calling systems;

d) end-of-shift indicators;

e) vehicle movements; and

f) night-time working.

7.7.7.4 Controlling noise in production areas

A factory divided into a number of smaller workshops is likely to provide a better working environment than one that consists of a single uninterrupted area. As permanent and solid divisions to the full height of the workshop are often not possible, partial enclosures or screens in conjunction with absorbent treatments are useful, both between departments and around individual machines. However, these enclosures or screens should be located so as not to obstruct the flow of work or they could be removed.

Acoustically absorbent materials should be used to reduce the amount of reflected sound within a space. These reduce the noise exposure of people not exposed to the direct sound from a noisy machine or activity, although the absorbent material has little or no effect on the noise level in the immediate vicinity of the noisy machines, etc. These materials can be applied to wall and ceiling surfaces or hung freely in the space (functional absorbers).

NOTE The Health and Safety Executive has published practical examples of noise control measures [42].

7.7.8 Schools and hospitals

Detailed guidance on the design of schools is available from the Department for Education in England [43] and the corresponding departments in the devolved administrations, and detailed guidance on the design of hospitals is available from the Department for Health in England [44] and the corresponding departments in the devolved administrations.

7.7.9 Agricultural buildings

For buildings and structures for agricultural use noise attenuation should be in accordance with BS 5502-32.

7.7.10 Rooms for speech

7.7.10.1 General

Lecture theatres, classrooms and meeting/conference rooms require good acoustic conditions for speakers and listeners. This should be recognized at an early stage of the design as room size and shape influence the acoustic conditions, as much as the selection and distribution of finishes. Although room acoustics is a specialized subject beyond the scope of this British Standard, general guidance on common situations is given in **7.7.10.5** to **7.7.10.7**.

7.7.10.2 Design criteria for intrusive external noise

The design objective for internal ambient noise level is reasonable listening conditions (see Table 4). This requires a low level of background noise and a fairly short reverberation time (see Annex A). However, other requirements should also be fulfilled to ensure the acoustic conditions are good. The main parameters are discussed in **7.7.10.3** and **7.7.10.4**.

7.7.10.3 Design for good speech communication

The sound that arrives at the listener’s ears can be considered to have the following three components.

a) Direct sound. This is sound carried by waves that travel directly from the source (e.g. the speaker) to the listener. It should be the strongest component, and all listeners should have an unobstructed view of the source. The distance between the source and the most distant listener should be kept to a minimum. If this distance exceeds approximately 20 m an electro-acoustic sound reinforcement system might be required.

b) Early reflected sound. Shortly after the direct sound arrives, the listener hears a series of wave fronts, which have been reflected once or a small number of times from the walls, ceiling or other hard surfaces. As these have taken a longer path than the direct sound, they arrive later. Sound travels at approximately 340 m/s so, for the simpler paths, the delay can be estimated. Reflections that arrive within approximately 35 ms of the direct sound reinforce it, and so are beneficial. Longer delays generally reduce intelligibility, and delays greater than approximately 50 ms should be avoided. Longer delays can be perceived as echoes.

c) Reverberant sound. Sound waves emitted by a source in a room are repeatedly reflected by the room surfaces, and grow weaker because of absorption by the surfaces at each reflection. The reverberation time, T, is a measure of how long a sound takes to decay after the source has stopped. T affects the level of sound in a space and gives an indication of the clarity of speech and the warmth of music. It is proportional to the room volume, and inversely proportional to the total absorption, and so can be estimated if the absorption coefficients of the main surfaces and features in the room are known (see Annex A). The optimum T for a space depends on whether it is to be used mainly for speech or music, the type of music and the volume of the space.

The optimum values for reverberation time also vary with frequency (pitch) of the sound. Guide values of T for rooms of different volume can be found in standard texts, e.g. *Noise control in building services* [28]. Guidance on the calculation of reverberation time in enclosed spaces generally is given in BS EN 12354-6, while BS EN ISO 3382-2 gives guidance for calculation in ordinary rooms and BS EN ISO 3382-1 gives guidance for calculation in larger (performance) spaces.

7.7.10.4 Sound-absorbing materials

Sound-absorbing materials and devices dissipate sound energy as heat, instead of reflecting sound energy back into the source room. Most types of absorber do not provide high values of sound insulation. Porous materials provide absorption over a reasonably wide range of frequencies, depending mainly on their structure and thickness, and they usually perform better at middle and high frequencies. Tuned devices are available which absorb over a limited range of frequencies.

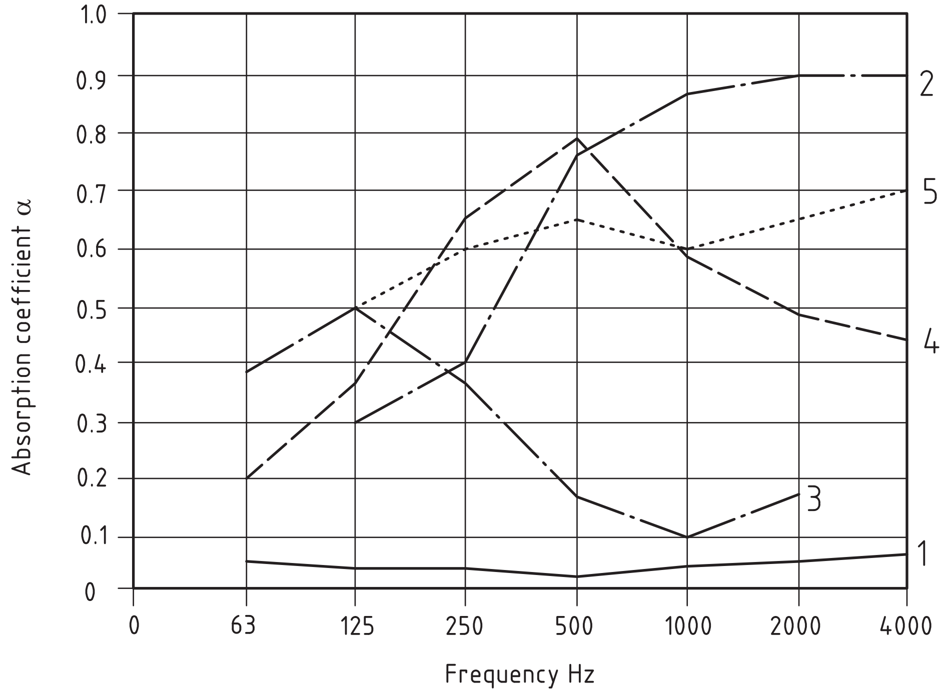
NOTE 1 Typical characteristics of different types of absorber are shown in Figure 1.

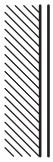
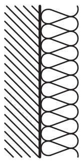
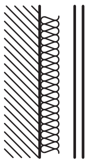
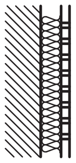
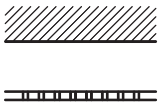
Sound absorbers are used to make acoustic corrections to rooms and spaces by changing the reverberation time (see Annex A). They are commonly used in rooms designed for music or speech, for general noise reduction in rooms (but with minimal benefit close to the source), and for preventing the spread of noise over large rooms or along corridors, ventilation ducts, etc. The type chosen should be influenced by a number of factors, such as acoustic characteristics, appearance, wearing qualities, maintenance, fire spread and other health and safety considerations.

The performance of a porous sound-absorbing material is given by the sound absorption coefficient α. The coefficient varies with the frequency of the sound and is commonly quoted for frequencies at the following octave intervals: 125 Hz, 250 Hz, 500 Hz, 1 000 Hz, 2 000 Hz and 4 000 Hz. Tests should be carried out in accordance with BS EN 20354 to obtain the coefficient in each frequency band.

NOTE 2 A method for assigning a single-number rating for porous absorbers is given in BS EN ISO 11654.

Figure 1 **Characteristics of sound-absorbing materials**



1		Hard finish: Plaster on solid backing
2		Porous absorber: 50 mm mineral fibre 50 kg/m^3 Performance is not significantly affected if protected by a perforated panel with at least 30% open area
3		Panel absorber: 9 mm ply, 50 mm cavity containing 25 mm mineral fibre
4		Perforated panel: 14% perforations, 25 mm cavity containing mineral fibre
5		Perforated gypsum ceiling tile/board: 13 mm gypsum tile/board, 16% perforations, suspended with 200 mm plenum

7.7.10.5 Committee/meeting rooms

Seats may be arranged in a circle or oval, rather than in parallel rows facing each other. The ceiling may be acoustically hard and low (not more than 3 m), at least over the table area, to reflect speech. A resilient floor covering minimizes noise from chair and foot movements, and reverberation should be controlled by absorbent materials on the walls. Noise from chair/table movement can also be controlled by rubber feet/castors. Appropriate wall treatments should be used to control the effects of flutter echo. Folding partitions can be provided in large rooms so the size is reduced when it is not fully occupied. The sound insulation of partitions is considered separately in **7.7.6.3**.

7.7.10.6 Lecture theatres

Human speakers project sound predominantly in the forward direction, so all listeners should have a reasonable view of the speaker's face. To facilitate this, the seating may be splayed in a fan shape around the lecturer's dais, extending approximately 70° either side of the centre line. The direct sound reaching the rear of the audience is weakened if the speaker-listener path passes over the heads of intervening listeners at a shallow angle. The effect can be minimized by raising the speaker on a podium or, better, by raking the audience seating at an angle of at least 20°. To reflect the speaker's voice the wall behind the speaker may be reflective. For the same reason, the ceiling may be reflective and horizontal for simplicity. Carpets should be used, and in large rooms the seats should be absorbent to control reverberation when unoccupied. Absorbent material on the rear wall and on the rear side walls should be considered if further measures to control reverberation are required.

Door lobbies can be used where it is necessary to minimize noise from people outside the theatre (see **8.4.4**).

7.7.10.7 Community halls

Although community halls are used for events that involve speech and music, they should normally be designed for speech. The reverberation time could be increased a little above 500 Hz if there are expected to be frequent unamplified musical events (see *Noise control in building services* [28]).

The need for a level floor means that direct sound from the stage is attenuated as it passes over rows of the audience. A reflective wall behind the stage and an angled reflector over it helps to project sound to the back of the room. Making the hall as wide as sight lines allow, rather than long and thin, also helps. In large halls, high-level loudspeakers by the stage might be required to reinforce the sound. The rear wall (i.e. behind the last row of the audience) and the rear side walls may be covered in sound-absorbing material, if necessary, to control reverberation and slap back. If the hall has to be long and thin, smooth, flat side walls should be avoided to prevent sound undergoing repeated reflections between them, giving rise to a flutter echo. Flutter can be controlled by having random indents and projections and/or patches of absorption on the side walls.

As musical events such as discos involve high noise levels, noise emanating from the building should be controlled to prevent this causing a nuisance to local residents, as well as to prevent external noise affecting events in the hall.

Although the designer has no control over the level at which music is played in the room, it would be prudent to inform the client that exposure to high noise levels can be harmful to hearing.

Electronic sound limiting equipment can be used to control the level of amplified music.

8 Sound insulation in a building

8.1 Factors affecting sound insulation

The main factors determining the sound insulation of a building element (wall, floor or facade) are mass, air-tightness and the isolation between elements (e.g. between the leaves of a cavity wall). Other factors which influence the sound transmission through a building are the characteristics of materials used for construction, the standard of workmanship, and the layout and detailing of the building. Sound transmission in buildings occurs through direct and flanking transmission paths, for which the resulting sound insulation can be predicted using theory, measurements or a combination of both [45].

NOTE Some of these factors are discussed in Annex E, which also lists typical sound insulation values of common constructions.

8.2 Flanking transmission

The sound insulation between rooms in a building is not only influenced by the sound insulation of the separating element, but also by transmission via adjoining elements and air paths through or round the element, known as flanking transmission (see Annex E). To control flanking transmission, careful design and high standards of site supervision and workmanship are essential. In addition to obvious air paths, hidden paths might be contained in materials themselves due to porosity and permeability: materials having a high permeability provide sound insulation considerably lower than an impervious material of similar mass per unit area. Applying a sealing finish, such as plaster or cementitious paint, can make a substantial improvement to the performance of a permeable material.

The degree of flanking transmission depends on the overall design of a building, and in some cases flanking transmission can exceed direct sound transmission. It is often a limiting factor where high performance is required. Some factors which should be considered are:

a) junction detail between the separating wall/floor and the flanking wall;

b) mass of flanking elements;

c) transmission through floor voids, loft spaces, service ducts, mullions and similar paths.

It is not practicable to consider the sound insulation of all possible combinations of the elements that might form a building. In the initial stages of a design, individual elements are often considered as though they behaved independently of each other, but later in the design process possible interactions between the elements should be considered and the design modified or refined as necessary.

*NOTE The characteristics of common types of building element are discussed in **8.4**.*

8.3 Sound insulation tests

Standard laboratory measurements of airborne sound insulation in accordance with BS EN ISO 10140-2 and impact sound insulation in accordance with BS EN ISO 10140-3 do not take account of flanking transmission, and so should only be regarded as a guide to the performance of an element in the field. The performance of the completed construction can be checked by tests carried out in accordance with BS EN ISO 140-4 and BS EN ISO 140-7. From these measurements, single-number ratings can be calculated according to BS EN ISO 717-1, for airborne insulation, and BS EN ISO 717-2, for impact insulation (see Annex C).

8.4 Sound insulation characteristics of common building elements

8.4.1 Masonry partitions

8.4.1.1 Single-leaf masonry walls

The main parameter which determines sound insulation is mass, and a rough guide to performance can be obtained from the mass law (see Annex E). Different materials sometimes have different empirical mass laws because the mass law approach does not account for stiffness, damping and airflow resistivity. However, all materials have a characteristic reduction in sound insulation due to the coincidence effect at their critical frequency (see Annex E), the position of which is mainly dependent on the mass and stiffness of the wall. The reduction in sound insulation in this frequency region depends on the amount of damping present, and for common materials the insulation at the critical frequency is often 5 dB to 10 dB below the trend at lower frequencies and remains low for an octave above the critical frequency. A typical 225 mm solid, dense masonry wall might show coincidence effects in the 125 Hz octave band, while 100 mm solid lightweight concrete might show the effects in the 500 Hz octave band.

8.4.1.2 Double-leaf masonry cavity walls

With masonry double-leaf walls, sound energy is transmitted from one leaf to the other through the air in the cavity which separates them, and in the form of mechanical vibrations through any ties or structural links between the two leaves. A wide cavity assists in providing good sound insulation. A high degree of structural isolation between the two leaves also assists in reducing structure-borne sound transmission. To this end, ties between the two leaves should be as few as possible and be flexible whilst maintaining structural stability. Butterfly pattern ties are better in this respect than most other types, which degrade acoustic performance. Type A ties need to have a measured dynamic stiffness of <4.8 MN/m^3 for the specified minimum cavity, at a standard density.

Because of unavoidable structural links, masonry cavity walls seldom attain their potential acoustic performance. Each leaf of double-leaf walls is subject to coincidence effects and, in addition, double-leaf constructions exhibit a mass-air-mass resonance (see Annex E) which reduces the insulation at low frequencies.

8.4.2 Lightweight partitions

8.4.2.1 Double-leaf stud walls

Single-frame and twin-frame lightweight partitions are often used to divide a large floor area into separate rooms, for example, in large office blocks. The effects described in **8.4.1.2** are particularly marked where sheet materials such as plasterboard are used. However, the reduction in insulation can be minimized if there is a high degree of mechanical discontinuity between the leaves.

The frames of the lightweight partitions can be made from timber or metal studs. For single-frame partitions the improvement in mechanical discontinuity can be made by use of resilient bar on one or both sides of either timber or metal frames. Mechanical discontinuity can also be improved by use of acoustic versions of the metal studs. Single-frame lightweight partitions can achieve R_w performances ranging from 30 dB to 65 dB.

A higher degree of mechanical discontinuity can be achieved with a twin-frame construction using separate support frames for each leaf, again made from metal or timber studs. Mechanical discontinuity of twin frames can also be improved by use of acoustic versions of studs or by increasing the cavity width. Twin-frame lightweight partitions can achieve R_w performances ranging from 55 dB to 75+ dB.

For both single-frame and twin-frame constructions, sound-absorbing infill such as mineral wool batts or quilt is beneficial. Well-designed, lightweight, double-leaf partitions can provide good performance with much lower mass than a masonry construction of comparable acoustic performance.

NOTE Low frequency performance can be different between lightweight and masonry partition walls.

Particular care should be taken to avoid any significant loss of sound insulation through indirect sound transmission routes. For example, where a partition wall is butted to a suspended ceiling, a continuous barrier should be provided in the space above it.

8.4.2.2 Pre-fabricated walls

To permit flexible room planning and quick installation there are numerous proprietary systems of prefabricated, lightweight, demountable partitions that are easily assembled using dry methods. These partitions seldom exceed approximately 40 kg/m^2 and employ room height units approximately 1 m wide, usually constructed with skins approximately 50 mm apart and with mineral wool or other lightweight cavity filling materials. Various methods are used to fix the panels to the structure and to fasten them together. However, for maximum sound insulation the partition should be fitted to the soffit of the structural slab and sealed around all edges.

Because of their lightness, and the inevitable small gaps around them, the insulation of prefabricated office partitions usually lies in the range 30 dB R_w to 40 dB R_w, occasionally extending up to 45 dB R_w.

8.4.2.3 Operable walls and moveable partitions

Folding and sliding partitions generally provide approximately 30 dB R_w, but better performance can be achieved with careful design and installation. Operable walls and moveable partitions can provide flexibility, for example, to allow meeting or training rooms to be separated or combined. However, where a high degree of acoustic privacy is required between separated spaces, the partitions can be expensive and require specialist maintenance to maintain the acoustic performance. Careful design is also required to avoid flanking paths and to provide structural support for the partition.

8.4.3 Construction details

The following recommendations should be closely followed to maximize sound insulation. They are particularly applicable to masonry separating walls between dwellings.

a) Avoid forming recesses in the separating wall, but, if it is necessary to recess electrical sockets in the wall, they should not be placed back-to-back to avoid the risk of complete penetration.

b) Complete filling of mortar joints, particularly perpends, is important. In brick walls, if the bricks have frogs they should be laid frog up so that the frogs are filled with mortar.

c) In the case of walls formed from permeable materials, the wall surface should be sealed with cementitious paint or render unless it is to have a plaster finish. Ideally, this sealing should include the wall surface where it passes through a suspended timber floor.

d) The minimum number of connections between the leaves of masonry cavity separating walls consistent with structural stability should be used. Butterfly or similar low stiffness ties are recommended. Further information is given in the Building Regulations [30, 31, 32].

e) Care should be taken to ensure that mortar droppings or other foreign matter do not bridge cavities.

f) A cavity separating wall construction should continue right through the roof space.

g) Air paths through or round a separating wall, even in the loft space, should be kept to the minimum possible by careful sealing around any necessary penetration of the wall. Joists should preferably run parallel to a separating wall, but if they are perpendicular joist hangers should be used, or if they are built in all air paths should be filled.

h) The reveals of windows should be well sealed to prevent sound getting into the wall cavity. At the junction with the separating wall it is good practice to stop the external wall cavity with a flexible closer, such as mineral wool, to reduce sound transmission along the cavity. If the cavity is to be filled or partially filled for thermal insulation, additional stopping is not necessary.

i) Masonry separating walls should be rigidly bonded or tied to the inner leaf of a cavity wall or only leaf of a solid external masonry wall.

8.4.4 Doors

The main factors determining the sound insulation of a single door set are the mass of the door and the gaps around the edges; usually, the latter are critical. For good sound insulation, the door should form airtight joints with the frame when closed and the joints between frame and wall should be sealed. A threshold seal is essential, and even keyhole covers should be fitted in critical situations.

A nomogram is given in Annex A for estimating the insulation of elements comprising two components having different values of sound insulation, such as a partition containing a door.

Single door sets providing a sound insulation greater than 35 dB R_w are specialist products and are normally supplied as complete door sets. High performance seals might make the door hard to open and close. The most effective solution, where space is available, is to use two well-sealed doors separated by a lobby lined with absorbing material. Such sound lobbies are particularly useful where uninterrupted sound insulation is required (e.g. audiometric examination rooms) because one door can be closed before the other is opened. Well-constructed lobbies can be expected to provide sound insulation of 45 dB to 60 dB, although the higher figure can only be achieved if the whole construction is carefully designed.

Where infrequent access to a space is required, a removable panel may be installed in place of a door.

8.4.5 Windows

8.4.5.1 General

BS EN 12758 gives values for the sound insulation of windows.

NOTE Further information is given in BS 6262, [46] and [47]. Figure A.1 can be used to estimate the insulation of a wall containing a window.

The full sound insulation value of any window cannot be realized if there are air gaps. These commonly occur around frames due to insecure fixing, shrinkage of wood and poor maintenance, and between frames and opening lights.

Glass often shows a pronounced dip in insulation at its critical frequency (see Annex E). For 6 mm glass this is around 2 000 Hz. Laminated glass performs better because the increased damping reduces the effect.

When adjoining rooms have their windows open the sound reduction from one to the other is limited to approximately 30 dB if there are other buildings close to the windows to reflect the sound back. When the window is closed in one of the rooms, a reduction of over 50 dB between the rooms should be obtainable and, with both windows closed, this flanking path should not limit the insulation provided by normal separating elements.

8.4.5.2 Double-glazed units

A double-glazed unit is unlikely to perform better than a single pane of mass equivalent to the thicker pane of the sealed unit, and should be used in a frame with good seals to realize its full insulating potential.

8.4.5.3 Secondary windows

In addition to the need for good sealing, the following recommendations apply for double windows.

a) The air space should be at least 100 mm, although for good performance over the main frequency range of interest, a cavity of approximately 300 mm is desirable.

b) The sides and top of the reveal should be lined with sound-absorbing material (the bottom should be left clear to avoid staining due to condensation).

c) The best results are obtained if both windows are sealed, but this has obvious difficulties for cleaning (and means of escape where appropriate). When opening lights are used some loss of insulation occurs, but this can be minimized by good quality fittings and weather stripping.

d) The outer pane can be a double-glazed unit to improve thermal performance and reduce condensation.

8.4.5.4 Ventilation

The Building Regulations' supporting documents on ventilation [48, 49, 50] recommend that habitable rooms in dwellings have background ventilation. Where openable windows cannot be relied upon for this ventilation, trickle ventilators can be used and sound attenuating types are available. However, windows may remain openable for rapid or purge ventilation, or at the occupant's choice.

Alternatively, acoustic ventilation units (see **7.7.2**) are available for insertion in external walls. These can provide sound reduction comparable with double glazed windows. However, ducted systems with intakes on the quiet side of the building might be required in very noisy situations, or where appearance rules out through-the-wall fans.

8.4.6 Floors and ceilings

8.4.6.1 General

Airborne sound insulation is mainly considered for intermediate floors between spaces containing either noise sources or noise-sensitive occupants. For a ground or basement floor where there is neither an appreciable noise source nor a noise-sensitive occupant below the floor, the floor is only of interest if it could contribute to flanking transmission.

Separating floors suitable for use in dwellings, which are described in the technical documents that support the appropriate Building Regulations [1, 33, 34], fall into the following three broad categories for new buildings:

a) a concrete base with a soft covering;

b) a concrete base with a floating layer; and

c) a timber base with a floating layer.

Guidance on upgrading existing floors is also provided. The technical documents contain details of points to consider, and should be consulted for work in dwellings. As the gaps between precast units in beam and block floors are difficult to seal well, a bonded screed is strongly recommended.

Dwellings that adjoin other buildings with activities that generate noise levels greater than normal domestic activities might require constructions offering better performance than those described in the documents that support the appropriate Building Regulations [1, 33, 34].

8.4.6.2 Partitions on floating floors

It is generally better to build partitions on the structural base rather than on top of a floating floor. This is because a partition built on a floating floor might overload the resilient layer and reduce its isolation properties, and movement of the floating floor could cause cracking in the partitions. A partition built on a floating layer might also provide a flanking path between the floor and the walls. The isolation between the floating floor and the partition should be maintained. Specialist advice should be sought for floating floors.

8.4.6.3 Pipes and conduits in floating floors

It is often necessary for services, such as electrical conduits and gas and water pipes, to run across a concrete floor. Whenever possible these pipes should be accommodated within the thickness of the floor slab or levelling screed, but sometimes they have to be laid on top of the slab and contained within the depth of the floating layer. Pipes or conduits are less likely to damage floating floors, providing they do not extend more than approximately 25 mm above the base, are properly fixed so as not to move while the floating floor is being laid, and are haunched up with mortar on each side to give continuous support to the resilient quilt. When two pipes cross, one of them should be sunk into the base slab. The resilient quilt should be carried right over the pipes.

NOTE Although channel systems have been devised to allow access to pipes in concrete and timber floors, the acoustic performance of these is not well documented.

8.4.6.4 Squeaking floor boards

Floating floors of timber or similar materials might squeak when walked on. To minimize the risk for boarding or panels, deep battens and long nails or screws may be used. For softwood tongued and grooved boards, latex adhesive between boards and on joists may be used, while for tongued and grooved chipboard sheets, a polyvinyl acetate emulsion adhesive is more suitable.

NOTE Further information is given in [51].

Timber joists made from reconstituted wood are available and can also be used to help minimize squeaking.

8.4.7 Roofs and mansards

Roofs and mansards generally have lower sound insulation than masonry facade walls, but in many cases they are required to reduce noise from external sources such as aircraft or road traffic. The performance of various roof types is indicated in Table 8. As rainfall noise can be a problem with lightweight roofs and skylights, these should be avoided in critical situations. Laminated glass is likely to transmit slightly less noise than an equivalent solid pane, but the manufacturer's advice should be sought.

Table 8 **The sound insulation of roofs**

Roof type	**Weighted sound reduction index R_w** dB
Tiles on felt, pitched roof with 100 mm mineral wool on plasterboard ceiling	43
100 mm flat concrete roof (230 kg/m^2)	52
Flat timber joist roof, asphalt on boarding, 12 mm plasterboard ceiling, thermal insulation	45
Single-skin galvanized steel cladding	22
50 mm sandwich panel, galvanized steel panels with thermal foam infill	26
Double-skin galvanized steel cladding with mineral fibre infill	38

9 Noise from building services

9.1 General

Detailed building services design advice is beyond the scope of this British Standard and it might be necessary to seek advice from an acoustic consultant. Several useful texts are available, which provide guidance on noise from mechanical services [28] and [52].

The general principles are discussed in **9.2** to **9.6**.

9.2 Main components

The components of a heating, ventilating and air conditioning (HVAC) system move air, water or refrigerant, as appropriate, around the system. The following contain advice on control of noise from the components of a typical air conditioning system, from intake to outlet.

a) *Intakes*. There should be sufficient ducting distance between intake grilles and fans to enable fan noise travelling back to the opening to be reduced. Common methods of attenuation are splitter attenuators and sound-absorbing lined ducts. However, fibrous absorbent materials should be used with caution as these can damage health.

b) *Fans*. The type and size of fans are influenced by noise control needs. In general, larger and slower fans are quieter, for a given volume and pressure duty. The casing, fan and drive motors commonly require vibration isolating mountings to reduce structural vibration. It is often essential that the fan casing is isolated from ducting using flexible connectors, and the ducting may need to be supported from resilient hangers.

c) *Chillers*. Chillers create high levels of noise and vibration and so should be located in an enclosure if situated near sensitive areas. Careful attention should be paid to air gaps allowing noise to escape. Resilient mountings are usually necessary. It is essential that all pipework leading to and from the chillers is held by isolating clips or hangers (or is fixed to joists that can be isolated), and passes through the enclosure in sleeves lined with a resilient material.

d) *Ducts*. Ducts might have fan noise propagating inside them, or turbulence noise generated in them by fast-moving air or by drumming of the duct walls. Noise generated in one room can be transmitted to a neighbouring room by a common duct, resulting in poor sound insulation (cross-talk). Noise can escape from inside a duct to the outside (break-out). Consequently, ducts that pass close to sensitive areas might need to be lagged with noise insulating material. Conversely, if a duct passes through a noisy area, noise can break in and be transmitted down the duct. This is most likely to occur in a plant room where, for example, a silencer has been located close to a fan and the silenced duct runs through the plant room. The silencer should be located at the position where the duct penetrates the plant room wall.

e) *Outlets*. Air movement through diffuser grilles can be the source of significant levels of noise (known as regenerated noise). Reduction of the velocity of the air or removal of any obstructions can significantly reduce the regenerated noise from the grilles. In some cases where background noise is needed, noisier grilles can be useful, but to achieve a steady noise level the velocity of the air from the grille should be constant.

9.3 Frequency characteristics of noise

The frequency ranges of noise from the components can be generalized as follows.

a) Fan instability, air turbulence, structure-borne noise: 10 Hz to 80 Hz perceived as throb and rumble.

b) Fan and pump noise: 50 Hz to 500 Hz perceived as rumble and roar.

c) Variable air volume (VAV) unit noise: 125 Hz to 2 500 Hz, perceived as roar and whistle or whirr.

d) Chiller noise: 250 Hz to 1 000 Hz, perceived as roar and whistle or whirr.

e) Outlet (or diffuser) noise: 800 Hz to 4 000 Hz, perceived as whistle or whirr and hiss.

Many types of silencer are available, which can work over a wide frequency range (broad band) or be tuned to a particular frequency band.

NOTE For more information about silencers see BS EN ISO 14163.

9.4 Rating noise from services

Continuous ventilation noise is commonly rated in the UK using either dBA levels or noise rating (NR) curves based on an octave band analysis of the noise (see Annex B). Noise criteria curves are also used and are broadly similar to NR curves (see Annex B). CIBSE Guide B5 [52] provides further rating systems and information.

9.5 Sound-absorbing treatment

The reduction in noise within a room where the source is outside the room is limited to approximately 3 dB for each doubling of total sound absorption within the room. Increasing absorption is therefore not usually an alternative to improving sound insulation. This approach is most effective in factory buildings. Sound-absorbing materials are also used to control noise in ducts, taking into account health and safety considerations.

9.6 Quality control and workmanship

Experience has shown that effective sound insulation and noise control require careful detailing on the part of the designer and a high standard of workmanship on the part of the contractor. Correct execution of the detailing should be checked on site, and the completed building should be fully commissioned before handover.

Noise control is only one aspect of environmental design and designers should be aware that the solution to a noise problem can cause difficulties elsewhere, e.g. thermal insulation, cold bridging, solar gain, ventilation and condensation. Much information on the environment in and around buildings is available and should be considered at an early stage of the design process.

Annex A (informative) Noise calculations

A.1 General

Some of the simpler types of noise calculation are described in this annex. For methods of predicting noise from road and rail traffic, see Clause **6**.

A.2 Addition of two noise levels

To determine the combined sound pressure level (L_c) resulting from the sound pressure levels of two or more noise sources (L_1, L_2, etc.), it is necessary to calculate and add the mean-square values of their individual sound pressures and convert this back to a sound pressure level. This can be achieved using the following formula.

$$L_\mathrm{c} = 10\lg\left(10^{\frac{L_1}{10}} + 10^{\frac{L_2}{10}}\right)$$

As the individual sound pressure levels are logarithms of the mean-square sound pressures, they cannot simply be added arithmetically.

A.3 Subtraction of two noise levels

When measuring noise from a source, the true noise level of the source alone is less than that shown by the meter if the level of background sound is less than approximately 10 dB below the total noise level. This is given by the following equation.

$$L_\mathrm{s} = 10\lg\left(10^{\frac{L_\mathrm{m}}{10}} - 10^{\frac{L_\mathrm{b}}{10}}\right)$$

where:

L_s is the source sound level;

L_m is the measured sound level;

L_b is the background sound level.

A.4 Non-uniform facades comprising windows and cladding

Figure A.1 shows how to calculate the overall sound insulation of a non-uniform facade comprising a window and cladding. It may also be used to give an indication of the effect of gaps or holes in a partition by assigning a sound insulation value of 0 dB to the aperture.

A.5 A-weighting calculations

The equivalent A-weighted level is often required when data on a noise source are available as a set of octave band or one-third octave band levels. The conversion can be performed manually, using the standard A-weighting values (see Table A.1). For all but the simplest situations it is more convenient to use a computer spreadsheet to do the conversion.

A.6 Reverberation time calculation

An estimate of the reverberation time, *T*, of a room can be obtained using the model in BS EN 12354-6.

Figure A.1 **Sound insulation of non-uniform facades comprising windows and cladding**

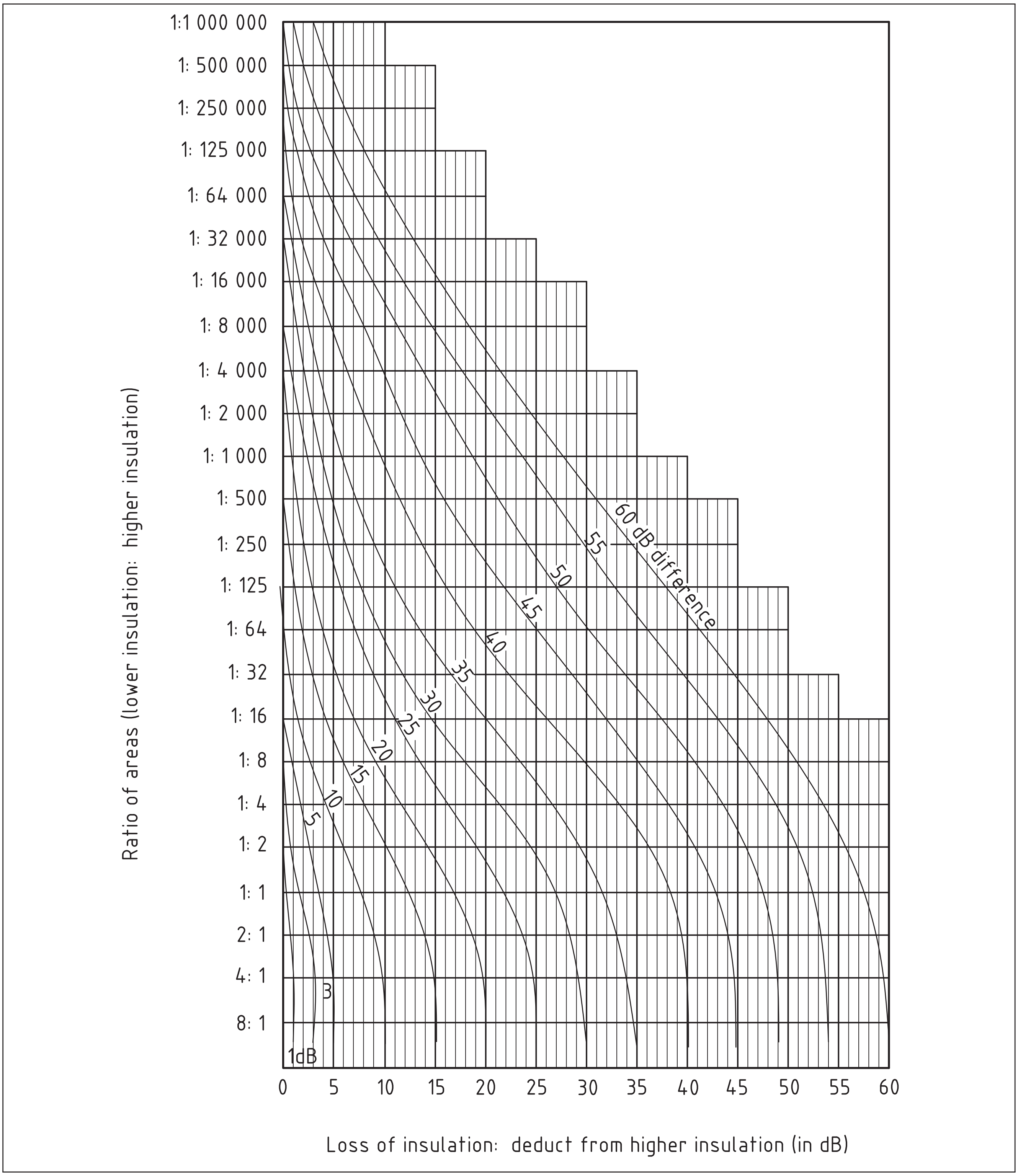


Table A.1 **Standard A-weighting values (dB)**

Third octave band centre frequency Hz	Octave band centre frequency Hz	A-weighting dB	Third octave band centre frequency Hz	Octave band centre frequency Hz	A-weighting dB
10		–70.4	500	500	–3.2
12.5		–63.4	630		–1.9
16	16	–56.7	800		–0.8
20		–50.5	1 000	1 000	0
25		–44.7	1 250		0.6
31.5	31.5	–39.4	1 600		1.0
40		–34.6	2 000	2 000	1.2
50		–30.2	2 500		1.3
63	63	–26.2	3 150		1.2
80		–22.5	4 000	4 000	1.0
100		–19.1	5 000		0.6
125	125	–16.1	6 300		–0.1
160		–13.4	8 000	8 000	–1.1
200		–10.9	10 000		–2.5
250	250	–8.6	12 500		–4.3
315		–6.6	16 000	16 000	–6.6
400		–4.8	20 000		–9.3

Annex B (informative)

Noise rating

Noise rating (NR) is a graphical method for assigning a single-number rating to a noise spectrum. It can be used to specify the maximum acceptable level in each octave band of a frequency spectrum, or to assess the acceptability of a noise spectrum for a particular application. The method was originally proposed for use in assessing environmental noise, but it is now used in the UK mainly for describing noise from mechanical ventilation systems in buildings. To obtain a rating, the noise spectrum is superposed on a family of NR contours. The NR of the spectrum corresponds to the value of the first NR contour that is entirely above the spectrum. The values at intervals of NR 5 (from NR 0 to NR 75) are shown in Table B.1 for the frequency range 31.5 Hz to 8 kHz.

Measured or calculated noise levels should be determined to not more than one decimal place.

NR values may be determined in each octave band by the following equation, rounded to the nearest single decimal place.

$$L = \mathrm{a} + \mathrm{bN}$$

where:

L is the octave band sound pressure level corresponding to NR level N;

a and b are constants for each frequency band, as given in Table B.2.

NOTE NR values cannot be converted directly to dBA values, but the following approximate relationship applies.

$$\mathrm{NR} \approx \mathrm{dBA} - 6.$$

The NR level is that entirely above the spectral levels calculated.

For example, if a spectrum contains a noise level of 48.6 dB at 500 Hz, the NR level would be at least NR 46.

Although the NR system is currently a widely-used method for rating noise from mechanical ventilation systems in the UK, other methods which are more sensitive to noise at low frequencies are available [28], but they are not yet widely accepted in the UK. Low-frequency noise can be disturbing or fatiguing to occupants, but might have little effect on the dBA or NR value.

Table B.1 **Noise rating values**

Noise rating	**Octave band centre frequency** Hz								
	31.5	**63**	**125**	**250**	**500**	**1 000**	**2 000**	**4 000**	**8 000**
NR75	106.5	94.7	87.2	81.7	77.9	75	72.6	70.8	69.2
NR70	103.1	90.8	82.9	77.1	73.0	70	67.5	65.7	64.1
NR65	99.7	86.8	78.5	72.4	68.1	65	62.5	60.5	58.9
NR60	96.3	82.9	74.2	67.8	63.2	60	57.4	55.4	53.8
NR55	92.9	78.99	69.8	63.1	58.4	55	52.3	50.3	48.6
NR50	89.4	75.0	65.5	58.5	53.5	50	47.2	45.2	43.5
NR45	86.0	71.0	61.1	53.6	48.6	45	42.2	40.0	38.3
NR40	82.6	67.1	56.8	49.2	43.8	40	37.1	34.9	33.2
NR35	79.2	63.1	52.4	44.5	38.9	35	32.0	29.8	28.0
NR30	75.8	59.2	48.1	39.9	34.0	30	26.9	24.7	22.9
NR25	72.4	55.2	43.7	35.2	29.2	25	21.9	19.5	17.7
NR20	69.0	51.3	39.4	30.6	24.3	20	16.8	14.4	12.6
NR15	65.6	47.3	35.0	25.9	19.4	15	11.7	9.3	7.4
NR10	62.2	43.4	30.7	21.3	14.5	10	6.6	4.2	2.3
NR5	58.8	39.4	26.3	16.6	9.7	5	1.6	–1	–2.8
NR0	55.4	35.5	22.0	12.0	4.8	0	–3.5	–6.1	–8

Table B.2 **Values of a and b**

Octave band centre frequency Hz	a	b
31.5	55.4	0.681
63	35.4	0.790
125	22.0	0.870
250	12.0	0.930
500	4.2	0.980
1 000	0.0	1.000
2 000	–3.5	1.015
4 000	–6.1	1.025
8 000	–8.0	1.030

Annex C (informative) Specification of sound insulation

C.1 General

Sound insulating elements work mainly by reflecting sound energy back into the source room, not by absorbing it. The methods of measurement and the terms used are described in **C.2** to **C.4**.

C.2 Insulation against airborne sound

In the tests specified in BS EN ISO 10140-2 and BS EN ISO 140-4 the insulation between a pair of rooms is measured, either:

a) in third octave bands having centre frequencies which cover at least the range 100 Hz to 3 150 Hz; or

b) in octave bands which cover at least the range 125 Hz to 2 000 Hz.

The noise is produced by a loudspeaker in one of the rooms (called the source room) and at each frequency the average noise levels are measured in the source room (L_S) and in the adjacent receiving room (L_R). The difference between these two levels (D) is a measure of the sound insulation between the rooms, regardless of the transmission path(s) the sound energy followed to travel between the rooms. The equation is as follows.

$$D = L_S - L_R$$

The actual level in the receiving room depends on:

- the sound insulation of the separating wall or floor;
- the area of the separating wall or floor;
- the volume of the receiving room;
- the flanking transmission, i.e. the importance of transmission paths other than the separating wall or floor; and
- the amount of absorbing material (e.g. furniture) in the receiving room.

For field measurements, apart from the amount of absorption, these factors are a property of the building and need to be taken into account by the measurement procedure. As the amount of absorbing material (e.g. soft furniture) in the room at the time of measurement is arbitrary, it has to be allowed for separately. This is achieved by measuring the reverberation time, T, of the room in seconds (s), which is a measure of how long it takes a sound to die away after the source has been switched off. As the sound energy is dissipated as heat in the absorbing material, T is related to the total amount of absorption in the room. The receiving room level can be corrected to the level it would be if the room has a standard reverberation time, T_o, which is typical of bedrooms, and is taken to be 0.5 s. The corrected level difference is known as the standardized level difference, D_{nT}, and is calculated using the following equation.

$$D_{nT} = L_S - L_R + 10 \log_{10} (T/T_o)$$

For laboratory measurements the insulation of the separating wall or floor being tested is assessed in a way that is independent of the actual measuring laboratory. For this reason, laboratories are designed to have minimal flanking transmission and a different correction is applied to account for the other factors.

This correction is $10 \log_{10} (S/A)$, where:

S is the common area of the separating wall or floor in square metres (m^2);

A is the equivalent absorption area in the receiving room in square metres (m^2).

The laboratory corrected level difference at each frequency is known as the sound reduction index, R, and is calculated using the following equation.

$$R = L_S - L_R + 10 \log_{10} (S/A)$$

If the test wall or floor is mounted in a realistic way in the laboratory and flanking transmission is low in the field, the sound reduction index may be used to predict its performance in the field. The relationship between D_{nT} and R is:

$$D_{nT} = R - 10 \log_{10} (3S/V)$$

where:

S is the area of the separating wall or floor in the field in square metres (m^2);

V is the volume of the receiving room in the field in cubic metres (m^3).

This equation shows that, if the source and receiving rooms have different volumes, D_{nT} depends on which is used as the source room. Using the larger room as the source room gives the lower value.

C.3 Insulation against impact sound

The procedure for measuring the impact insulation of floors is rather different (see BS EN ISO 10140-3 and BS EN ISO 140-7). Instead of a loudspeaker, a machine containing five small hammers is placed on the floor. While the hammers strike the floor at a rate of ten blows a second, the resulting noise level, L_i, is measured in the receiving room below at each of the same frequency bands used for airborne insulation. In the field, the receiving room levels are again “corrected” to a standard reverberation time, T_o, of 0.5 s to give the standardized impact sound pressure level, L'_{nT}, which is calculated as follows.

$$L'_{nT} = L_i - 10 \log_{10} (T/T_o)$$

In the laboratory, the noise level depends mainly on the characteristics of the floor being tested and the amount of absorption, A (m^2), in the laboratory. It is therefore appropriate to correct the noise level to a standard area of absorption. The area used is 10 m^2. The resulting normalized impact sound pressure level, L_n, is calculated as follows.

$$L_n = L_i + 10 \log_{10} (A/10)$$

C.4 Rating sound insulation

Measurements of insulation against both airborne and impact sounds yield values in a number of frequency bands. To make this information more manageable, rating methods such as those in BS EN ISO 717-1 and BS EN ISO 717-2 are used to reduce the frequency band values to single-figure ratings. These single-figure ratings are generally good predictors of subjective assessments of insulation of similar constructions. However, this is not always the case for different constructions, for example the low-frequency performance of a lightweight partition might be significantly different from that of a masonry partition with the same single-number rating, so it is prudent to examine the full measurement data in critical situations.

The more common indices used to describe sound insulation are summarized in Table C.1 and Table C.2.

NOTE 1 Further guidance on rating sound insulation is given in BS EN ISO 717-1 and BS EN ISO 717-2. The terminology shown in Table C.1 is used, but with additional spectrum adaptation terms (C).

EXAMPLE

R_w (C; C_{tr}) = 41(0; –5) dB.

Here, C (value 0) is the correction needed to convert R_w to a dB insulation value against a pink noise spectrum; C_{tr} (–5) is the correction needed to convert R_w to a dB insulation value against a standardized road traffic noise spectrum. In this case the dB insulation is 41 – 5 = 36 dB.

NOTE 2 Pink noise has the same sound pressure level in adjacent frequency bands, and is used to represent general activity noise.

It is essential that the difference between the sound insulation value obtained for a single building element in the laboratory and the value for a completed construction in the field environment is understood. A common mistake is to expect to obtain values of a weighted sound reduction index, R_w, from a completed building. To clarify this, different indices are used to indicate sound insulation performance in the different environments. Table C.1 and Table C.2 show the different indices that apply to the laboratory or field environment respectively.

Due to the flanking transmission paths and a difference in the calculation method, a laboratory test value for sound insulation might not be obtained in the field, even if all elements of the construction have been specified and built correctly.

Table C.1 **Common indices used to describe laboratory airborne and impact sound insulation**

Airborne (*A*) or impact (*I*)	**Measured values**		**Single number quantity**	
	Name	Symbol	Name	Symbol
A	Sound reduction index	R	Weighted sound reduction index	R_w
A	Spectrum adaptation term	C	Spectrum adaptation term	C
A	Spectrum adaptation term	C_{tr}	Spectrum adaptation term	C_{tr}
I	Normalized impact sound pressure level	L'_n	Weighted normalized impact sound pressure level	$L'_{n,w}$

Table C.2 **Common indices used to describe field airborne and impact sound insulation**

Airborne (*A*) or impact (*I*)	**Measured values**		**Single number quantity**	
	Name	Symbol	Name	Symbol
A	Standardized level difference	D_{nT}	Weighted standardized level difference	$D_{nT,w}$
A	Spectrum adaptation term	C	Spectrum adaptation term	C
A	Spectrum adaptation term	C_{tr}	Spectrum adaptation term	C_{tr}
I	Standardized impact sound pressure level	L'_{nT}	Weighted standardized impact sound pressure level	$L'_{nT,w}$
A	Apparent sound reduction index	R	Weighted sound reduction index (dB)	R'_w

Annex D (informative) Special problems requiring expert advice: Guidance for specific applications

D.1 General

Certain design problems require reliable advice of a kind that is not easy to find in published material. The advice of an expert is necessary for these kinds of problems, some examples of which are given in **D.2** to **D.9**.

D.2 Acoustic test rooms

The design of rooms in which acoustic measurements are carried out, such as reverberation chambers, free-field rooms and audiometric test rooms, might need to conform to national or international standards and usually requires the advice of an expert.

D.3 Performing spaces

The design of theatres, opera houses, concert halls and similar performing spaces usually requires expertise in room acoustics and noise control. The intrusion of relatively low levels of noise can seriously interfere with the enjoyment of the performance and distract the performers. The requirements for low noise levels often mean that more room has to be allocated for low velocity ventilation ductwork and the impact on the design of the ventilation system is often substantial.

D.4 Broadcasting and recording studios

Broadcasting and recording studios have requirements similar to those of performing spaces (see **D.3**). For some infrequent intrusive noises, the requirements are sometimes relaxed on the grounds that a retake is possible, but this can result in higher operating costs.

D.5 Aircraft noise

As there are many variables affecting the level of aircraft noise heard on the ground, expert advice is almost always required. Contours of daytime $L_{\mathrm{Aeq},T}$ levels are available from most major airports and helipads. Where measurements of facade insulation are necessary a test method is described in BS EN ISO 140-5.

D.6 Groundborne noise

Projects involving groundborne noise from underground trains, plant or industrial sources usually require expert advice.

D.7 Low-frequency noise

Projects involving low-frequency noise usually require expert advice as accurate measurement is difficult and there is a shortage of reliable data below 100 Hz.

D.8 Active noise control

Active noise control is the reduction of noise by cancellation with a similar noise (anti-noise) generated by electro-acoustic means. Commercial systems are available which successfully reduce low frequency noise from mechanical ventilation systems.

D.9 Noise surveys

Noise surveys are carried out for a variety of reasons, for example:

a) before construction, to establish the existing noise climate at the site of a proposed development where reliable prediction is impracticable, as an aid to the design of the building envelope, either to protect against external noise or contain internally produced noise;

b) during construction, to monitor noise from building activity, either to assess the likely nuisance to the local community or the risk of hearing damage to the workforce;

c) at the end of a building contract to check the insulation of the building envelope or the noise levels produced by the services;

d) as part of a planning requirement;

e) to provide objective evidence to support or defend a legal action.

Surveys ought to be carried out by competent persons and the interpretation of survey results might require expert advice.

Annex E (informative) Airborne and impact sound insulation

E.1 General

Airborne sound refers to noise produced by sources that directly set the air around them into vibration. Impact sound refers to noise caused by sources which produce impulsive mechanical excitation of part of a building (e.g. footsteps, electric light switches, slamming doors). Many sources of impact sound also produce significant levels of airborne sound. The term structure-borne sound has no very precise meaning as the structure can be excited by both airborne and impact sources; it is often used to refer to sound that travels for long distances via the structure, especially in connection with vibrating machinery linked directly to the structure.

E.2 Direct and indirect transmission

Figure E.1 shows diagrammatically a pair of rooms in a house where the construction consists of solid walls, etc., bonded together. Sound travelling from Room 1 to Room 2 can travel via the direct path a-a and by the many indirect, or flanking, paths shown. The term flanking transmission is usually used to mean transmission paths involving the structure, while the term indirect transmission includes flanking paths and airborne paths through gaps and ducts, etc. The indirect paths can limit the sound insulation attainable no matter how much the direct sound is reduced by the separating wall or floor. The indirect transmission can be reduced by measures such as the following.

- Increasing the mass of the flanking walls.
- Increasing the mass of the partition.
- Introducing discontinuities in the indirect paths.
- Erecting independent wall linings adjacent to the flanking walls to prevent energy entering the flanking construction.
- Sealing any air gaps and paths through ducts.

Figure E.2 shows a number of indirect paths that have been found in offices.

It is important to remember that standard test laboratories are designed to minimize transmission by all paths other than the direct path. This makes it difficult to relate the results of laboratory measurements to those likely to be obtained in the field.

E.3 Airborne sound insulation

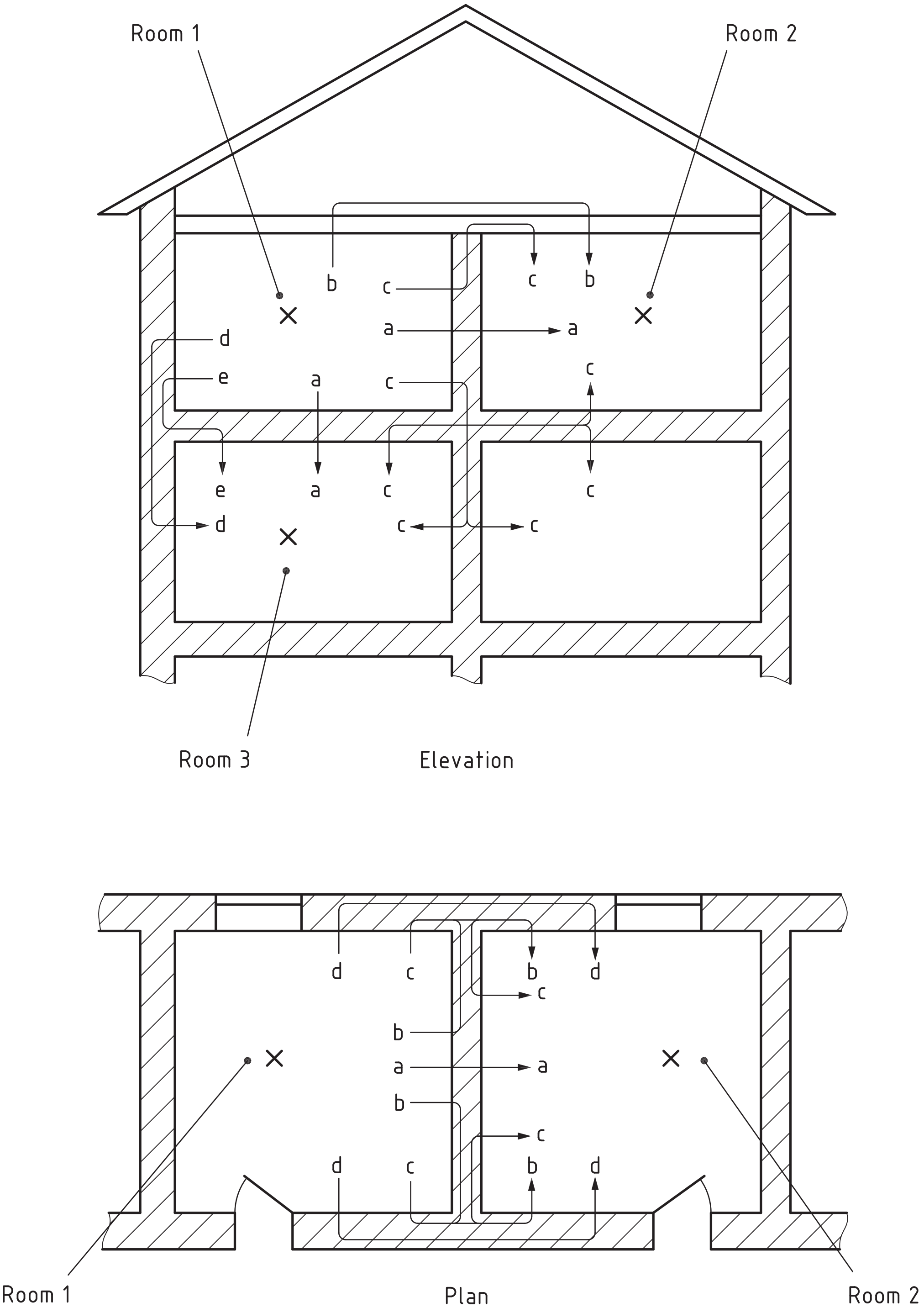
E.3.1 General

The sound insulation of structural elements, such as walls and floors, always varies with frequency, the insulation rising in general as the frequency rises.

E.3.2 Mass law

An approximate empirical relationship has been established between sound insulation and mass for single-leaf constructions, as shown in Figure E.3. This so-called “mass law” gives a useful first approximation to the behaviour of a single sheet or plate. In practice, the sound insulation predicted by the mass law might not be attained because of factors such as the coincidence effect, which is outlined in **E.3.3**. Results for specific materials vary around the value given by the mass law relationship, and so measured data are to be used when available. Table E.1 gives a list of materials and indicates the sound insulation of a single, imperforate sheet when fixed to a suitable wood or metal framework. These values are useful, for example, when assessing existing structures.

Figure E.1 **Transmission paths (via the structure) of noise originating in Room 1 (diagrammatic)**



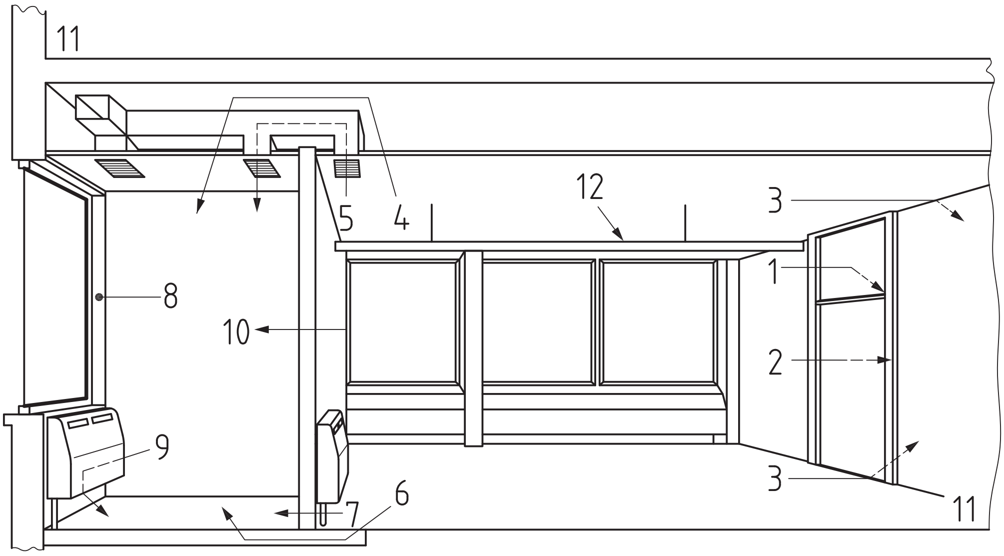
Room 1: Source room

Room 2: Horizontal receiver

Room 3: Vertical receiver

NOTE The arrows indicate the direction of transmission of sound from letter X *in the source room to the same letter* X *in the receiving room.*

Figure E.2 **Indirect sound leakage paths**



Key

1	Lightweight panels above doors
2	Doors
3	Air leaks through gaps, cracks or holes
4	Sound transmission via suspended ceilings/partitions
5	Common ventilation system without silencers
6	Common floor duct
7	Electrical outlets and service pipes
8	Lightweight mullions or mullion/partition closers
9	Continuous sill line heating
10	Partition performance
11	Appliances
12	Continuous lighting fittings

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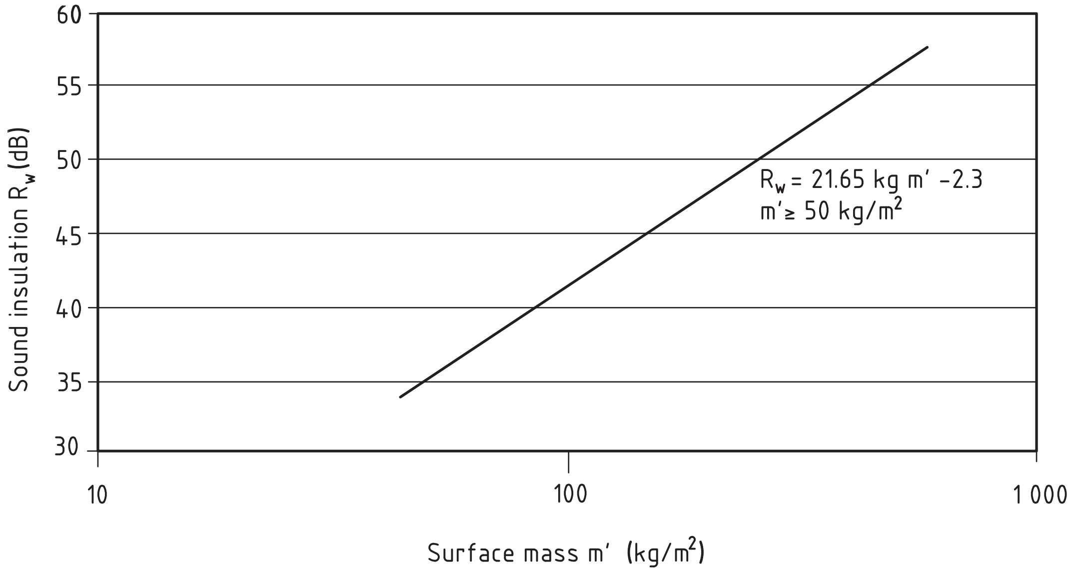
Figure E.3 **Mass law curve**



E.3.3 The coincidence effect

The coincidence effect occurs when the wavelength of the wave impressed on the panel by the incident sound wave is close to the wavelength of free bending waves in the panel. The effect of coincidence is to lower the sound insulation of a construction by as much as 10 dB below the level expected from its mass per unit area over a limited frequency range. The coincidence effect can be pronounced with thin lightweight partitions, resulting in loss of insulation at middle and high frequencies. Reducing the stiffness without a corresponding reduction of mass can raise the critical frequency above 3 150 Hz, and so improve the insulation over the important 100 Hz to 3 150 Hz range. An increase of stiffness has the reverse effect.

It is possible to design lightweight stud partitions so that they perform to their maximum effect in the speech frequency region between 250 Hz and 2 000 Hz, i.e. between the mass-spring-mass and coincidence regions respectively. The worst coincidence dips occur in materials such as plate glass and rigid metal sheets. Heavily damped materials such as lead sheets are least affected.

E.3.4 Mass-spring-mass frequency

A double-leaf wall can perform better than a single-leaf wall of similar mass because the sound has to pass through two barriers. If the two leaves are not connected to each other, the insulation values of the two leaves can be added together. However, in practice, the leaves are often connected by ties or studs, and the full insulation cannot be achieved. Even where the two leaves are isolated from each other, the full benefit can only be obtained above a certain frequency that depends on the cavity width. This is because the air in the cavity behaves like a spring connecting the leaves together, and causes a resonance at the mass-spring-mass frequency. Below this frequency, the two leaves behave more like an equivalent single leaf.

Making the cavity wide can reduce the mass-spring-mass frequency, as in the case of sound insulating secondary glazing. The mass-spring-mass frequency (F_0) can be estimated from the following equation.

$$F_0 = 59.6\sqrt{\frac{1}{d}\left(\frac{1}{m_1}+\frac{1}{m_2}\right)}$$

where:

m_1 and m_2 are the surface masses of the two leaves in kilograms per square metre (kg/m^2);

d is the cavity width in metres (m).

E.3.5 Impact sound control

A structure that receives an impact or has a vibrating source in contact with it behaves more like an extension of the source rather than an intervening element between source and listener. For this reason, a relatively small amount of impact energy can produce a loud sound and, if the structure is continuous, the sound can travel a long distance. Control is usually obtained by inserting a resilient surface at the point of contact with the source (e.g. laying a carpet) or by introducing a structural discontinuity.

Floating floors, which are an example of the latter approach, are a common method of controlling impact sound from footsteps. However, an effective floating floor might result in increased sound from impacts on the source side of the floor. The conventional forms of floating floor might be unsatisfactory if protection against the low-frequency content of impact noise is required (e.g. a dance floor over a restaurant).

E.4 Airborne insulation values of walls and airborne and impact insulation values of floors

Table E.1 and Table E.2 give examples of common types of wall and floor construction with sound insulation in the ranges shown. The insulation indices are for laboratory and field measurements assessed in accordance with BS EN ISO 717-1 and BS EN ISO 717-2. The insulation values given are necessarily approximate since examples of nominally identical constructions might show variations of several decibels. Variation in the amount of indirect transmission can affect significantly the insulation between two rooms separated by a given barrier. For example, the sound insulation of some types of floor could be reduced by indirect transmission along the walls supporting them, particularly if these walls are of lightweight masonry and carried past the floor.

In many cases, simple solid partitions give insulation values according to their mass (see **E.3.2**). Moreover, with partitions of this type there is usually little variation between field and laboratory test results unless the laboratory insulation exceeds 45 dB. Exceptions can occur in buildings that have not been specially designed to minimize common cavities and strongly coupled elements in lightweight panelling. The examples given are not exhaustive. Flanking structures are not listed since these can vary widely and are often dependent upon other factors, such as thermal insulation, which are outside the scope of this British Standard.

Table E.1 and Table E.2 give general, non-exhaustive guidance on the potential sound insulation performance of generic constructions. Manufacturers’ products and systems are continually being developed. Additional information on the most up-to-date specifications available ought to be obtained directly from the manufacturers. When considering separating partitions above 50 R_w or $D_{nT,w} + C_{tr}$, expert advice might be required.

Table E.1A **Laboratory airborne sound insulation of walls and partitions**

Sound insulation R_w dB	Type of wall or partition
26 to 33	a) 1 mm steel sheet panels fixed to steel frame members to form demountable partition units 50 mm overall thickness. Mineral wool cavity insulation.
	b) Plywood or wood fibre board 12 mm thick nailed both sides of (50 × 50) mm timber framing members spaced at 400 mm centres.
	c) Paper faced strawboard or wood wool 50 mm thick panels plastered both sides.
	d) Chipboard hollow panels 50 mm thick tongued and grooved edges, hardboard faced. Joints covered with wood trim.
33 to 37	a) Lightweight masonry blockwork. Plaster or drylining on at least one side. Overall mass per unit area not less than 50 kg/m².
	b) Timber stud partitions any size timbers greater than (50 × 350) mm, 400 mm centres, cross noggins, 9.5 mm plasterboard lining on both sides, any suitable finish.
	c) Metal stud partition, 50 mm studs 600 mm centres, clad both sides with 12.5 mm plasterboard, joints filled and perimeters sealed. Approximate mass per unit area 18 kg/m².
	d) 50 mm lightweight masonry blockwork, plastered both sides to 12 mm thickness or drylined with 9.5 mm plasterboard.
37 to 43	a) Lightweight masonry blockwork, plaster or dry lining on at least one side. Overall mass per unit area not less than 75 kg/m².
	b) Either 75 mm or (100 × 50) mm timber studs (no noggins) spaced 600 mm apart, 50 mm mineral fibre quilt in stud cavity. Frame-lined on both sides with one layer 12.5 mm plasterboard. Approximate mass per unit area 19 kg/m².
	c) Metal stud partition, 50 mm studs 600 mm centres, clad both sides with 15 mm plasterboard, joints filled and perimeters sealed. Approximate mass per unit area 26 kg/m².
43 to 50	a) Masonry wall, joints well filled. Either plaster or dry lining on both sides. Overall mass per unit area not less than 150 kg/m².
	b) 100 mm metal stud partition, "C" section studs not greater than 600 mm spacing, not less than nominal 50 mm web depth. Clad on both sides with two layers of plasterboard of not less than 22 mm combined thickness. Mineral fibre quilt hung between studs. Approximate mass per unit area 35 kg/m².
	c) (75 × 50) mm timber framing using stagged studs at 300 mm spacing with 25 mm stagger forward and back. Frame clad with two layers of 12.5 mm of plasterboard on both sides. Mineral fibre quilt hung between studs. Approximate mass per unit area 36 kg/m².
	d) (50 × 25) mm timber stud partition to form a 25 mm cavity, clad on both sides with minimum 38 mm wood wool slabs having their outer faces screeded or plastered.
	e) Solid autoclaved aerated concrete blocks, 215 mm thick plaster or dry-lined finish on both sides, blockwork joints well filled. Overall mass per unit area not less than 160 kg/m².
50 to 54	a) Two separate frames of timber studs not less than (89 × 38) mm, or boxed metal studwork with 50 mm minimum web depth. Studs at 600 mm maximum centres. A 25 mm mineral wool quilt suspended between frames. Frames spaced to give a minimum 200 mm overall cavity. Clad on outside of each frame with a minimum of 30 mm plasterboard layers (e.g. 19 mm plus 12.5 thickness). Approximate mass per unit area 54 kg/m².
	b) Either in situ or precast concrete wall panel not less than 175 mm thick and not less than 415 kg/m². All joints well filled.

Table E.1A **Laboratory airborne sound insulation of walls and partitions**

Sound insulation R_w dB	**Type of wall or partition**
	c) Brick laid frogs up, wall nominal 200 mm thickness, weight (including plaster) not less than 380 kg/m^2. Plaster or dry-lined finish both sides. Brickwork joints well filled.
	d) “No fines” concrete 225 mm thickness, weight (including plaster) not less than 415 kg/m^2. Plaster or dry-lined finish both sides.
	e) Cavity lightweight aggregate block (maximum density of block 1 600 kg/m^3) with 75 mm cavity and wall ties of the butterfly wire type. Dry-lined finish on both sides. Joints in blockwork well filled. Overall mass per unit area not less than 300 kg/m^2.
	f) Dense aggregate concrete block cavity wall with 50 mm cavity and wall ties of the butterfly wire type. Dry-lined finish on both sides. Joints in blockwork well filled. Overall mass per unit area not less than 415 kg/m^2.
	g) Autoclaved aerated concrete block cavity wall consisting of two leaves, 100 mm blocks not less than 75 mm apart, with wall ties of the butterfly type. Plaster or dry-line finish on both sides. Joints in blockwork well filled. Overall mass per unit area not less than 150 kg/m^2.
	h) Metal stud partition, 70 mm acoustic studs 600 mm centres, clad both sides with 15 mm plasterboard, joints filled and perimeters sealed. Mineral fibre within cavity. Approximate mass per unit area 26 kg/m^2.
54 to 60	a) Two separate frames of timber studs not less than (100 × 50) mm, spaced at 600 mm maximum centres. A 50 mm mineral wool quilt in each frame between studs. Frames spaced to give a minimum 300 mm overall cavity. Each frame clad on outside with three layers of 12.5 mm plasterboard nailed to framing. Approximate mass per unit area: 51 kg/m^2.
	b) Metal stud partition, 146 mm acoustic studs 600 mm centres, clad both sides with a double layer 15 mm plasterboard, joints filled and perimeters sealed. Approximate mass per unit area: 51 kg/m^2.
	c) Solid masonry with an overall mass per unit area of not less than 700 kg/m^2, fully sealed both sides.
	d) Dense aggregate concrete block solid wall 215 mm thick plaster finish to both surfaces. Overall mass per unit area not less than 415 kg/m^2.
	e) Cavity lightweight aggregate block (maximum density of block 1 600 kg/m^3) with 75 mm cavity and wall ties of the butterfly wire type. Plaster finish on both sides. Joints in blockwork well filled. Overall mass per unit area not less than 300 kg/m^2.
	f) Dense aggregate concrete block cavity wall with 50 mm cavity and wall ties of the butterfly wire type. Plaster finish on both sides. Joints in blockwork well filled. Overall mass per unit area not less than 415 kg/m^2.
	g) Metal stud partition, 146 mm acoustic studs 600 mm centres, clad both sides with a double layer 15 mm plasterboard, joints filled and perimeters sealed. Mineral fibre within cavity. Approximate mass per unit area 52 kg/m^2.
60+	a) Two separate frames of metal 48 mm “C” studs 600 mm centres, clad both sides with a double layer 15 mm plasterboard, joints filled and perimeters sealed. Minimum overall width of 200 mm. Mineral fibre within cavity. Approximate mass per unit area 55 kg/m^2.

NOTE 1 Construction details and workmanship are important if the levels of sound insulation indicated are to be achieved.

NOTE 2 Constructions might not achieve these laboratory performances in the field, even if correctly specified and correctly built, due to flanking transmission paths.

Table E.1B **Field airborne sound insulation of walls and partitions**

Sound insulation $D_{nT,w} + C_{tr}$ dB	**Type of wall or partition capable of achieving required performance**
40 - 44	a) Metal stud partition of overall nominal width of 208 mm. 146 mm metal "C" studs at 600 mm centres, 50 mm mineral wool insulation in the cavity, double layer of 15 mm plasterboard each side (minimum plasterboard density 25 kg/m^2 each side).
	b) Metal stud partition of overall nominal width of 138 mm. 70 mm metal "C" studs at 600 mm centres with resilient bars at 600 mm centres fixed to one side of the stud framework, 50 mm mineral wool insulation positioned in the cavity, double layer of 15 mm plasterboard each side (minimum plasterboard density 22 kg/m^2 each side).
45 - 49	a) Metal stud partition of overall nominal width of 208 mm. 146 mm metal acoustic studs at 600 mm centres, 50 mm insulation in the cavity, double layer of 15 mm plasterboard each side (minimum plasterboard density 25 kg/m^2 each side).
	b) Metal stud partition of overall nominal width of 200 mm. Two frames of 48 mm metal "C" studs at 600 mm centres, cross-braced at 1 200 mm centres. Cavity width of 140 mm. 50 mm mineral wool insulation positioned between the frames. Double layer of 15 mm plasterboard each side (minimum plasterboard density 25 kg/m^2 each side).
50 - 52	a) Aggregate block cavity wall, minimum 100 mm blocks (minimum density 1 350 kg/m^3), minimum 75 mm cavity between leaves, finished with 13 mm plaster.
	b) Aggregate block cavity wall, minimum 100 mm blocks (minimum density 1 350 kg/m^3), minimum 75 mm cavity between leaves, finished with nominal 8 mm (minimum 6 mm) gypsum parge coat, 12.5 mm plasterboard (minimum plasterboard density 8 kg/m^2).
	c) Metal stud partition of overall nominal width of 250 mm. Two frames of minimum 60 mm metal "I" studs at 600 mm centres (no bracing between leaves). Minimum cavity width of 190 mm. 100 mm mineral wool insulation positioned between the frames. Double layer of 15 mm plasterboard each side (minimum plasterboard density 25 kg/m^2 each side).
	d) Timber stud partition of overall nominal width of 300 mm. Two frames of timber studs at 600 mm centres (no bracing between leaves). Minimum cavity width of 240 mm. 90 mm mineral wool insulation positioned between the studs in each timber frame. Double layer of 15 mm plasterboard each side (minimum plasterboard density 25 kg/m^2 each side).
53+	a) Aggregate block cavity wall, minimum 100 mm blocks (minimum density 1 350 kg/m^3), minimum 100 mm cavity between leaves, 100 mm mineral wool insulation in the cavity, finished with plasterboard (minimum plasterboard density 10 kg/m^2).
	b) Metal stud partition of overall nominal width of 300 mm. Two frames of minimum 60 mm metal "I" studs at 600 mm centres (no bracing between leaves). Minimum cavity width of 240 mm. 100 mm mineral wool insulation positioned between the frames. Double layer of 15 mm plasterboard each side (minimum plasterboard density 25 kg/m^2 each side).

NOTE 1 Construction details and workmanship are important if the levels of sound insulation indicated are to be achieved.

NOTE 2 These constructions might perform better than the field values given above if tested in a laboratory where flanking paths are idealized.

Table E.1C **Typical performance measured in the field of walls built to Robust Details generic systems**

dB $D_{nT,w}$ Mean	**dB $D_{nT,w}+C_{tr}$ Mean**	**Type of wall** [A)]
59	53	E-WM-1 - cavity masonry – dense aggregate blockwork (wet plaster)
59	53	E-WM-2 - cavity masonry – lightweight aggregate blockwork (wet plaster)
60	54	E-WM-3 - cavity masonry – dense aggregate blockwork (render and gypsum-based board)
59	53	E-WM-4 - cavity masonry – lightweight aggregate blockwork (render and gypsum-based board)
58	52	E-WM-6 - cavity masonry – aircrete blockwork (render and gypsum-based board)
55	50	E-WM-9 - solid masonry – solid dense aggregate blockwork (render and gypsum-based board)
62	55	E-WM-11 - cavity masonry – lightweight aggregate blockwork (render and gypsum-based board) with 100 mm minimum cavity [For Scotland: V-WM-11]
62	55	E-WM-16 - cavity masonry – dense aggregate blockwork (render and gypsum-based board) with 100 mm minimum cavity
60	53	E-WM-18 - cavity masonry – dense aggregate blockwork (wet plaster) with 100 mm minimum cavity
62	56	E-WM-21 - cavity masonry – lightweight aggregate blockwork (wet plaster) with 100 mm minimum cavity [For Scotland: V-WM-11]
63	55	E-WT-1 – twin-leaf timber frame – without sheathing board [For Scotland: V-WT-1]
63	54	E-WT-2 – twin-leaf timber frame – with sheathing board [For Scotland: V-WT-2]
58	51	E-WS-1 - steel frame – twin metal frame

A) See the Robust Details (RD) Handbook [53] or, for Scotland, [54] for full specification details, including flanking requirements.

Table E.2A **Laboratory airborne sound insulation of floor constructions**

Sound insulation R_w dB	**Type of floor construction**
Below 43	Timber joist floor consisting of 22 mm tongued and grooved floor boarding or equivalent fixed directly to floor joists. Ceiling of 12.5 mm plasterboard and skim with no floor covering.
Above 43	a) A concrete floor having mass per unit area not less than 365 kg/m², including any screed or ceiling finish directly bonded to the floor slab, together with a floating floor or resilient floor covering equivalent to rubber or sponge rubber underlay or thick cork tile (e.g. carpet and underlay or sponge rubber backed vinyl flooring).
	b) A solid floor consisting of: • a solid slab; or • concrete beams and infilling blocks; or • hollow concrete planks, together with a floating floor. A ceiling finish is required for a beam and block floor. In each case the slab is to have a mass per unit area of at least 300 kg/m², including any screed or ceiling finish directly bonded to it. Where a floating floor is laid over a floor of beams and hollow infill blocks or hollow beams along the top of the structural floor, the latter is to be sealed and levelled before the resilient layer is put down. It is also essential to have due regard for conduits and pipework to be be laid and covered so as to prevent any short circuit of the floor’s isolating properties. If precast units are used as a structural floor it is essential that the joints are filled to ensure that the sound insulation performance is maintained. The resilient material is laid to cover completely the structural floor and turned up against the surrounding wall along all edges. The resilient layer is usually of mineral fibre, or a special grade of expanded polystyrene. When the screed is laid, it is important that none of the mix finds its way through the resilient layer to the structural floor, as this short-circuits the isolation between the two decks and significantly reduces the sound insulation.
	c) A floor consisting of boarding nailed to battens laid to float upon an isolating layer of mineral fibre capable of retaining its resilience under imposed loading. With battens running along the joists, a dense fibre layer can be used in strips. The ceiling below to be of metal lath and plaster not less than 29 mm thick, with pugging on the ceiling such that the combined mass per unit area of the floor, ceiling and pugging is not less than 120 kg/m².
	d) A floor consisting of 18 mm tongued and grooved chipboard on 19 mm plasterboard, laid on battens running parallel to the joists and supported on 25 mm thick mineral wool of approximately 90 kg/m³ to 140 kg/m³ density; 100 mm of fibre absorbent (as used for insulation in roof spaces) laid between the joists on top of the plasterboard ceiling. The ceiling can be 19 mm plus 12.5 mm plasterboard. It is imperative that the resilient layer is not punctured by nails.
	e) A floor consisting of 18 mm tongued and grooved chipboard on 19 mm plasterboard floating on a 25 mm thick mineral wool layer of approximately 60 kg/m³ to 80 kg/m³ density; this on a 12.5 mm plywood platform; 100 mm of fibre absorbent laid between the joists on top of the plasterboard ceiling. The ceiling can be 19 mm plus 12.5 mm plasterboard. It is imperative that the resilient layer is not punctured by nails.

NOTE 1 Construction details and workmanship are important if the levels of sound insulation indicated are to be achieved.

NOTE 2 Constructions might not achieve these laboratory performances in the field, even if correctly specified and correctly built, due to flanking transmission paths.

Table E.2B **Typical performance measured in the field of floors built to Robust Details generic systems**

dB $D_{nT,w}$ Mean	dB $D_{nT,w}+C_{tr}$ Mean	dB $L'_{nT,w}$ Mean	Type of floor [A)]
54	50	51	E-FC-1 - precast concrete plank with directly applied screed and floating floor treatment
62	56	44	E-FC-2 – in situ concrete slab and floating floor treatment
60	52	52	E-FT-1 - timber I-joists and floating floor treatment [For Scotland, V-FT-1]
60	52	52	E-FT-2 - timber solid joists and floating floor treatment [For Scotland, V-FT-2]
64	56	37	E-FS-1 - steel deck and in situ concrete and floating floor treatment [For Scotland, V-FS-1]

[A)] See the Robust Details (RD) Handbook [53] or, for Scotland, [54] for full specification details, including flanking requirements.

Annex F (informative) Legislative framework and guidance

NOTE Much of the advice already given in ***5.1*** *to* ***5.5*** *can also be applied to a new noise producing development. As the local planning authority might require noise control measures, and failure to implement these properly could result in widespread annoyance and legal action, it is necessary to consider the legislative framework.*

F.1 Legislative framework

For many projects involving buildings, there is usually a need to carry out some form of noise impact assessment in order to satisfy local and national noise management and planning policies. The scope of the assessment needs to include all phases of the proposed development including construction and operation.

Certain types of project that meet specific criteria require either a full environmental impact assessment (EIA) [55] to be carried out, an important part of which is often noise, or a more specific noise assessment process to be followed. In all cases, it is prudent to consult, at an early stage, with:

a) the relevant local planning authority;

b) the relevant local authority environmental health department;

c) the relevant building control authority.

F.2 Construction noise

Sections 60 and 61 of the Control of Pollution Act 1974, as amended [56], provide the legislative basis for controlling construction noise, including local authority powers. Useful advice on controlling construction noise is given in BS 5228-1.

F.3 Noise from other sources

A local authority can take legal action to prevent or stop a noise from fixed premises, including land, which it considers prejudicial to health or a nuisance. Any new noise source of that nature has the potential to be a statutory nuisance. Furthermore, an existing noise source can become susceptible to nuisance legislation if residential premises are introduced into its vicinity. Useful advice on the assessment of sources of an industrial nature can be found in BS 4142.

In England, Wales and Scotland, a local authority's power is primarily to be found in section 80 of the Environmental Protection Act 1990 [57] and, in Northern Ireland, Article 70 The Clean Neighbourhoods and Environmental Act (Northern Ireland) 2011 [58]. These Acts also make provision for private individuals to take complaints directly to a magistrate's court (or Sheriff's court in Scotland).

The main principles established under these Acts are as follows.

a) There is no prescribed level above which a noise automatically becomes a statutory nuisance. Each case is considered on its merits taking account of a range of factors, including the likely reaction of a typical person.

b) Where the noisemaker is operating from industrial, trade or business premises, it is a defence to show that the best practicable means to control noise have been used.

F.4 Civil action

Civil action can be taken against the perpetrator of noise that is felt to be a nuisance and, again, each case is assessed on its merits. The criterion for a civil action is how the noise affects the individual, compared with the ordinary inconvenience suffered by the public at large, or how it affects land in which the individual has an interest. The defence of best practicable means is not available.

Annex G (informative) Typical design problem

G.1 Typical design problem: Simple calculation

A small housing development is to be situated 55 m from the edge of an existing road. The average traffic speed is 50 km/h, and the intervening ground is paved.

To establish the noise exposure of the site, the $L_{A10,18h}$ could be calculated or measured for a typical unit near the road. This has been calculated from CRTN [16] to be 65 dB free-field. This is approximately 63 dB $L_{Aeq,16h}$. The local planning authority has requested noise control measures; in this case to reduce the noise level inside the bedrooms to 35 dB $L_{Aeq,16h}$ during the day and 30 dB $L_{Aeq,8h}$ at night.

To reduce the noise exposure inside the houses, attention needs to be given to the sound insulation of both the roof and facade. A traditional pitched roof with concrete tiles and a 9 mm plasterboard ceiling, covered in thermal insulating material, has an insulation of approximately 43 dB R_w (see Clause **8**).

The windows, and any trickle ventilators, are normally the weakest part of a brick and block facade. Insulating glass units have an insulation of approximately 33 dB R_w and, assuming suitable sound attenuating trickle ventilators [2] are used, the resulting internal noise level, roughly 30 dB, ought to be determined by the windows. This level is acceptable with the windows closed and attenuated background ventilation, even with the correction for first floor level. If partially open windows were relied upon for background ventilation, the insulation would be reduced to approximately 15 dB [3], resulting in the target levels being exceeded. However, windows may still be openable for rapid or purge ventilation, or occupant's choice.

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[2] Note that, where more than one ventilator is used to meet the ventilation requirement, the overall ventilator attenuation needs to be suitable (see **G.2.1**, Note 5). Where the glazing exceeds the required attenuation, the ventilation is usually the weakest part of the facade.

[3] Note that the level difference through a window partially open for ventilation can

This calculation ought to be repeated for night-time traffic conditions, and the design needs to satisfy both sets of requirements. Strictly, the insulation values used here relate to a pink noise spectrum, and actual values achieved are lower for traffic noise. Furthermore, the method does not take account of the absorption (e.g. furnishings) in the room. However, the R_w values suffice for a rough calculation, although it is likely to underestimate the level in the room by up to 5 dBA. Where the estimate is within 5 dBA of the target noise level, a more rigorous calculation needs to be carried out using octave bands, as explained in **G.2**.

G.2 Typical design problem: More rigorous calculation

G.2.1 Calculation method

This calculation method is based on that given in BS EN 12354-3.

NOTE 1 This method is applicable for simple facades without balconies. The calculation is different for external noise intrusion from a point source, e.g. an item of construction plant, and that for a line source. The external noise is assumed to irradiate the external facade at random incidence, whereas for a point source there is irradiation from a single direction of incidence, with a cosθ factor being applied to account for various incident angles. BS EN 12354-3, which in any case is more difficult to follow than the example given here, does not distinguish between point and line source cases.

NOTE 2 Measurement methods for the insulation of facade elements are given in BS EN ISO 10140-2.

The following equation, which gives the equivalent sound pressure level in a room, $L_{\text{eq},2}$, needs to be evaluated for each frequency band of interest.

$$L_{\text{eq},2} = L_{\text{eq,ff}} + 10\log_{10}\left(\frac{A_0}{S}10^{\frac{-D_{\text{n,e}}}{10}} + \frac{S_{\text{wi}}}{S}10^{\frac{-R_{\text{wi}}}{10}} + \frac{S_{\text{ew}}}{S}10^{\frac{-R_{\text{ew}}}{10}} + \frac{S_{\text{rr}}}{S}10^{\frac{-R_{\text{rr}}}{10}}\right) + 10\log_{10}\left(\frac{S}{A}\right) + 3 \qquad \text{(G.1)}$$

where:

$L_{\text{eq,ff}}$	is the equivalent continuous sound pressure level outside the room elements under consideration; *NOTE 3 It is the free-field sound level (i.e. in the absence of the facade), measured or estimated at the intended position of the element under consideration. It is related to the level $L_{eq,1}$ measured within a few millimetres of the actual facade by the relation $L_{eq,ff} \approx L_{eq,1} - 6$, and to the level $L_{eq,2m}$ measured 2 m away from the facade by the relation $L_{eq,ff} \approx L_{eq,2m} - 3$.* *NOTE 4 The calculation method assumes the source is traffic noise and a facade shape correction factor is not required. BS EN 12354-3 provides a more detailed calculation method where these assumptions are not valid.*
A_0	is a reference absorption area of 10 m² and is independent of frequency;
S_f	is the total facade area in square metres (m²) of the room in question;
S_{wi}	is the area in square metres (m²) of the windows of the room;

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vary significantly depending on the window type and the frequency content of the external noise. If the specific details of the window and external noise are known the value for insulation may be adjusted accordingly.

S_{ew}	is the area in square metres (m²) of the external wall of the room;
S_{rr}	is the area in square metres (m²) of the ceiling of the room;
S	is the total area in square metres (m²) of elements through which sound enters the room, i.e. $S_f + S_{rr}$;
$D_{n,e}$	is the insulation of the trickle ventilator measured according to BS EN ISO 10140;
	NOTE 5 Where more than one ventilation unit is required to achieve the background ventilation, the $D_{n,e}$ of the combined ventilators should be used in the calculation.
R_{wi}	is the sound reduction index (octave band value) of the window (see Annex C);
R_{ew}	is the sound reduction index (octave band value) of the external wall (see Annex C);
R_{rr}	is the sound reduction index (octave band values) of the roof/ceiling (see Annex C);
A	is the equivalent absorption area of the receiving room being considered (see Annex C);
3	is a correction factor.

Values of L_{eq}, $D_{n,e}$, R and A are frequency dependent, and the calculation of $L_{eq,2}$ has to be repeated using values for each octave band of interest. If the dBA level in the room ($L_{Aeq,2}$) is to be estimated, the resulting values of $L_{eq,2}$ ought to be A-weighted (to give $L_{Aeq,125}$ in the 125 Hz octave band, etc.) and summed logarithmically (see Annex A). The equation for summing the levels in each frequency is as follows.

$$L_{Aeq,2} = 10\log_{10}\left(10\frac{L_{Aeq,125}}{10} + 10\frac{L_{Aeq,250}}{10} + \ldots +\right) \tag{G.2}$$

G.2.2 The calculation of the noise level inside a room

The calculation for this example is conducted most easily on a spreadsheet, using the data in Table G.1. Each term in the equation is evaluated for each frequency band, as shown in Table G.2.

In this example the exposure of the roof and all facade elements is the same. Where this is not the case the calculation has to be undertaken on an element-by-element basis and the resulting internal levels summed using equation (G.2).

The calculated noise level is above the target of 35 dBA, and Table G.2 shows that the main contribution comes from the window (row C), although the roof (row E) dominates at low frequencies. A better product ought to be selected and the procedure repeated until it has no significant effect on the insulation. The revised value may be compared with the rough estimate of 34 dBA. This procedure needs to be repeated for night-time conditions and the design has to satisfy both sets of requirements. The rapid ventilation problem still needs to be tackled.

In this calculation the trickle ventilators were not an important transmission path, but this might not always be the case.

Although this calculation is more rigorous than the simple example, the method still makes assumptions, and it is likely that the estimated levels differ from measured values. It does, however, indicate the relative performance of each element in each octave band and allows iterative changes. Facade calculations are also covered in [15].

Table G.1 **Data used in the calculation of the noise level inside a room**

Terms that are frequency dependent

Term	**Description**	**Single-figure rating**	**Octave band centre frequency** Hz					**A-weighted level**
			125	**250**	**500**	**1 000**	**2 000**	
$L_{eq,ff}$	—	—	70	66	63	61	61	67
$D_{n,e}$	Sound attenuated trickle ventilator	—	37	36	35	36	34	—
R_{wi}	6-12-6 insulated glass unit	33	26	29	33	28	24	—
R_{ew}	Brick and block external wall	50	40	44	45	51	56	—
R_{rr}	See Table G.2	43	28	34	40	45	49	—
A	—	—	11	14	16	16	15	—

Terms that are not frequency dependent

Term	**Derivation**	**Value** m^2
S_f	Facade area (including window)	10
S_r	Roof area (exposed side)	40
S_{wi}	Window area	1.5
S_{ew}	$S_f - S_{wi}$	8.5
S_{rr}	Area of ceiling	15
S	$S_f + S_{rr}$	25
A_0	Reference absorption area given in BS EN ISO 10140-2	10

NOTE The expected precision of this calculation is ±2 dB.

Table G.2 **The calculation of the noise level inside a room**

Term from equation (G.1)	Reference letter of result	Octave band centre frequency Hz				
		125	**250**	**500**	**1 000**	**2 000**
$L_{eq,ff}$	A	70	66	63	61	61
$D_{n,e}$		37	36	35	36	34
$\frac{A_0}{S}10^{\frac{-D_{n,e}}{10}}$	B	0.000 08	0.000 10	0.000 13	0.000 10	0.000 16
R_{wi}		26	29	33	28	24
$\frac{S_{wi}}{S_f}10^{\frac{-R_{wi}}{10}}$	C	0.000 15	0.000 08	0.000 03	0.000 10	0.000 24
R_{ew}		40	44	45	51	56
$\frac{S_{ew}}{S_f}10^{\frac{-R_{ew}}{10}}$	D	0.000 03	0.000 01	0.000 01	0.000 00	0.000 00
R_{rr}		28	34	40	45	49
$\frac{S_{rr}}{S_f}10^{\frac{-R_{rr}}{10}}$	E	0.000 95	0.000 24	0.000 06	0.000 02	0.000 01
$10\log_{10}(B+C+D+E)$	F	–29.2	–33.7	–36.4	–36.6	–33.9
A (furnished)		11	14	16	16	15
$10\log\frac{S}{A}$	G	3.6	2.5	1.9	1.9	2.2
$L_{eq,2}$	A + F + G + 3	47.4	37.8	31.5	29.3	32.3
A-weighting dB		–16	–9	–3	0	1
$L_{eq,2}$ + A-weighting	$L_{Aeq,125}$ etc.	31.4	28.8	28.5	29.3	33.3

$L_{Aeq,2}$ is obtained by combining these values using equation (G.2).
A-weighted level in the room $L_{Aeq,2}$ is 37.7 dB

Annex H (informative) Examples of design criteria adopted by hotel groups

H.1 General

Airborne sound insulation between spaces is not to be less than the values given in Table H.1, when measured in accordance with BS EN ISO 140-4 and rated in accordance with BS EN ISO 717-1.

Table H.1 **Airborne sound insulation**

Room areas	Performance
Bedroom – Bedroom Bedroom – Bathroom (different rooms) Bathroom – Bathroom	Walls: 43 dB $D_{nT,w} + C_{tr}$ Floors: 45 dB $D_{nT,w} + C_{tr}$
Bedroom – Restaurant/bar	60 dB $D_{nT,w}$
Bedroom – Kitchen	60 dB $D_{nT,w}$
Bedroom – Other tenancies	65 dB $D_{nT,w}$
Bedroom – Corridor	Walls: 43 dB $D_{nT,w} + C_{tr}$
Bathroom – Corridor	45 dB $D_{nT,w}$
Bedroom – Laundry	43 dB $D_{nT,w} + C_{tr}$
Bedroom – Plant room	60 dB $D_{nT,w}$

NOTE It might be important to take account of the purpose of the room.

Internal wall constructions within bedrooms (but not to en suite bathrooms) are to have a sound insulation performance of not less than 40 dB R_w. Doors to bedrooms are to have a sound insulation performance of not less than 29 dB R_w, when measured in accordance with BS EN ISO 10140-2 and rated in accordance with BS EN ISO 717-1. Interconnecting doors should maintain the required room-to-room sound insulation performance of the total wall as identified in accordance with **H.2**.

Where moveable walls are to be installed between meeting rooms and between function rooms, the entire wall, including cupboards for parking the wall panels and the wall above and beneath the ceiling or floor, is, in its entirety, to achieve a minimum installed performance of 48 dB $D_{nT,w}$.

H.2 Impact sound insulation

Impact sound insulation between spaces is not to exceed the values given in Table H.2, when measured in accordance with BS EN ISO 140-7 and rated in accordance with BS EN ISO 717-2.

Table H.2 **Impact sound insulation for hotels**

Room areas	Performance
Bedroom – Bedroom	62 dB $L'_{nT,w}$
Bathroom – Bedroom	62 dB $L'_{nT,w}$
Corridor – Bedroom	62 dB $L'_{nT,w}$

NOTE The applicable Building Regulations [30, 31, 32] might require more stringent standards than those given in this table.

All separating floor systems need to be free from "squeaks" and "creaks" from footsteps (see **8.4.6.4**). All doorsets should include seals on the sides, head and threshold in order to meet the necessary acoustic requirements. Smooth-closing doors are to be installed in order to minimize noise disturbance from occupant movement.

H.3 Sound absorption in common parts

Sound absorption is to be provided for corridors, staircases and hallways in accordance with Clause **8**. The applicable Building Regulations [30, 31, 32] contain provisions for sound absorption that is necessary in corridors, staircases and hallways.

H.4 Internal noise levels from external sources

The noise level in any hotel bedroom, with windows closed, from all external sources, including road, rail and air traffic and noise from activities outside the hotel and any adjacent premises, are to be within the range of average noise levels in Table H.3.

Table H.3 **Indoor ambient noise level ranges for hotel bedrooms**

Period	Noise level
Daytime (07:00 – 23:00 hrs)	30 – 40 dB $L_{Aeq,1hour}$
Night-time (23:00 – 07:00 hrs)	25 – 35 dB $L_{Aeq,1hour}$
Night-time (23.00 – 07.00 hrs)	45 – 55 dB L_{Amax}

NOTE Some hotels may set lower noise levels, depending on location.

Music and patron noise intrusion from inside any adjacent, neighbouring or connected bar/restaurant or nightclub into the guest bedrooms is to be controlled such that it is unlikely to cause disturbance.

In hotels, other commercial factors could influence the criteria adopted for the break-in to bedrooms of building services noise from adjacent rooms or spaces.

External facade constructions and components, such as brise soleil, grilles, ventilators, curtain walling systems or other architectural features, are not to give rise to intrusive whistling, creaking, rattling or other noises as a result of wind or other climatic effects.

H.5 Background noise levels: Internal sources

The background noise level in any hotel bedroom arising from comfort cooling room units serving the bedroom is not to exceed NR25 L_{eq} when the units are operating at their design duty. Comfort cooling systems installed in bedrooms are to have the facility to be operated at quieter duties and to be switched off by room occupants.

The background noise level in any hotel bedroom as a result of constant minimum fresh air ventilation systems serving the bedroom or other parts of the development is not to exceed NR20 L_{eq} when the systems are operating at their design duty.

The background noise level in any hotel bedroom arising from any other building services systems serving the bedroom or any other parts of the development is not to exceed NR20 L_{eq} within the bedroom.

The building services noise in other areas of the hotel is not to exceed the levels given in Table H.4.

Table H.4 **Building services noise in hotels**

Area	Noise level
En suite bathrooms	NR35 to NR 45 $L_{eq,\ 1hr}$
Corridors/lobbies	NR40 $L_{eq,\ 1hr}$
Restaurants	NR35 to NR 45 $L_{eq,\ 1hr}$
Public toilets	NR40 $L_{eq,\ 1hr}$
Staff rooms	NR40 $L_{eq,\ 1hr}$

Noise emission from hydraulic systems, including domestic hot and cold water services, refrigerant pipework, and soil and waste pipes serving other bedrooms, is not to cause disturbance in normal use.

Noise from the operation of lifts is not to cause disturbance in hotel bedrooms (see **7.7.3.4**).

H.6 Noise control measures for bedrooms, corridors and stairwells

The air conditioning system is to be designed to conform to Table H.4, and to avoid compromising sound insulation between rooms. Bedrooms are not to be located next to lift shafts, plant rooms or other areas where there are high noise levels. Effective protection against indoor noise is necessary, and partitions and floors between rooms are required to meet the appropriate Building Regulations [30, 31, 32].

To avoid unnecessary transmission of airborne noise between adjoining rooms by way of open windows, windows are not to open in such a way as to direct sound immediately from one room into the next. Where possible, bedrooms are not to overlook courtyards, or to be over kitchens or service vehicle areas that are frequently noisy in the early morning.

Door openings on opposite sides of corridors may be staggered and fitted with acoustic seals on all four edges to reduce noise transmission (but without making it necessary to slam the doors closed). Doors may have quiet-action latches. Corridors can be fitted with carpeted floors. Sound-absorbing ceilings are beneficial, though not always essential if a carpet is fitted in the corridor. Staircases and lift halls may be separated from the corridors by means of doors that can open and close quietly (such as swing doors) and, where possible, isolated from bedrooms by linen stores and similar rooms. If bedroom doors have to be located close to lift doors, acoustic lift signals are not to be audible in the bedrooms. Except within the same suite, bathrooms are not be planned next to bedrooms. In all cases, the types of sanitary fittings chosen ought ideally to be quiet in operation and the plumbing system designed to minimize noise by avoiding sharp bends and restrictions of flow.

H.7 Function rooms

Large hotels often have ballrooms, banqueting rooms and meeting rooms, which are hired out separately for public and private functions. Proceedings might go on well into the night and it is essential, therefore, that these rooms can be effectively isolated from bedrooms, with all noise paths suitably insulated. For example, a ballroom in an internal court does not sufficiently insulate from bedrooms in higher storeys if it has windows opening into the well of the court, or a lightweight roof construction. To minimize disturbance the roof is to be of concrete or other solid construction, and any top lights or windows are to be double-glazed and sealed, with a separate air conditioning system if necessary.

The insulation between the public rooms themselves also needs to be considered. In rooms in which dancing could take place on one side of a division wall and speech-making on the other, a wall of less than 60 dB R_w insulation might not provide adequate protection. Folding partitions are not normally sufficient to separate rooms where disparate activities take place.

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