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Introduction

Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international and European standards, comments will be reviewed by the relevant UK national committee before submitting the consensus UK vote and comments. If the draft standard is approved, it is usual for the resulting published standard to be adopted as a British Standard.

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BS 8233:2025

Sound insulation and noise reduction for buildings – Guide

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Foreword

Publishing information

This British Standard is published by BSI Standards Limited, under licence from The British Standards Institution, and came into effect on XX MONTH 2025. It was prepared by Technical Committee B/564, *Noise control on building sites*. A list of organizations represented on this committee can be obtained on request to the committee manager.

Supersession

This British Standard supersedes BS 8233:2014, which is withdrawn.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 to provide internal acoustic environments appropriate to their functions. It deals with the control of noise from outside the building, noise from plant and services within it, and room acoustics for non-critical situations.

This is a full revision of the document, and takes into account the following principal developments:

- changes to the legislative framework since publication of the 2014 edition;
- the passing of the Environment (Air Quality and Soundscapes) (Wales) Act 2024 [1], which requires local authorities in Wales, including local planning authorities, to have regard to the Welsh Ministers' national strategy on soundscapes when exercising any function of a public nature that could affect soundscapes in Wales; and
- the publication of the *Environmental noise guidelines for the European Region* [2] in 2018 by the World Health Organization.

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Use of this document

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

Presentational conventions

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

Additional commentary, explanation and general informative material is presented in smaller italic type.

Where words have alternative spellings, the preferred spelling of the *Shorter Oxford English Dictionary* is used (e.g. "organization" rather than "organisation").

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DRAFT

Introduction

Sound control in and around buildings is discussed in this British Standard on an objective and quantifiable basis as far as is currently possible. This British Standard suggests criteria, such as for suitable sleeping/resting conditions for dwellings, and proposes free field external sound levels that normally satisfy these criteria for environmental sound levels, predominantly from transportation. This British Standard recommends additional criteria for internal sound levels for domestic and non-domestic buildings, e.g. executive office. Criteria are also suggested for emerging uses such as the recording of podcasts.

The guidance provided is based on what is conventionally considered to be normal hearing ability and auditory experience. It is now increasingly recognized that there is a diverse range of differences in how individuals perceive and interact with sound, described as aural diversity. This can include people with impaired hearing or those with different sensitivity to frequencies and levels of sound. Some people are particularly sensitive to some types of sound and process sound in a different way, are more reliant on hearing to compensate for other sensory loss or have no hearing at all. The population includes groups with increased susceptibility to sound intrusion such as shift workers whose noise-sensitive times and places differ from the majority. Inclusive design takes into account the range of needs of a diverse population.

NOTE Guidance on inclusive design is provided in BS 8300-1 and BS 8300-2 and PAS 6463. Further information is available in the Aural Diversity infographic¹⁾ and toolkit²⁾.

Criteria are suggested that include single exposure scenarios and environmental sound sources in combination. For the reasons outlined above, the levels suggested might need to be adjusted to suit local circumstances or characteristics of the sound. Moreover, sound levels refer only to the physical characteristics of sound that can be measured using a sound level meter and cannot differentiate between pleasant and unpleasant sounds. Important though non-acoustic factors such as personal, situational and psychosocial are, they are not considered further in this British Standard.

There is a lack of research into the effects of noise on humans residing in dwellings arising from non-transportation sources (i.e. from neighbours or generated within the neighbourhood), which includes industrial and commercial sound (see *Environmental noise guidelines for the European Region* [2]). Non-transportation sources also include noise generated by people, music from entertainment venues, leisure activity, including motorsport etc., arising from specific premises where a source, process or operator can be identified as being responsible for elements of the prevailing acoustic environment.

Attention is drawn to the fact that measures taken to control sound might also impinge on energy efficiency, views and natural lighting, fire precautions, ventilation, overheating and other environmental and health and safety requirements. All such requirements need to be considered together at an early stage and throughout the design.

¹⁾ Available at <https://auraldiversity.org/infographic.html>.

²⁾ Available at www.arup.com/insights/aural-diversity-toolkit/.

1 Scope

This British Standard provides guidance for the control of sound in and around buildings. It is applicable to the design of new buildings, or redesign or refurbishment of existing buildings, including those undergoing a change of use. Guidance is given on levels of sound indoors and the type and character of the sound.

This British Standard does not cover:

- a) specialist applications, such as auditoria and cinemas;
NOTE 1 For information on cinemas see BS ISO 9568.
- b) vibration control, except where it is evident in the form of radiated sound;
- c) sound that breaks out from the building and affects external receptors;
- d) sound generated inside the site or a building on site that could affect people outside the site/building; or
- e) specific sources of external neighbour and neighbourhood sound arising from an identifiable source, process or operator.

NOTE 2 Annex A describes some of the simpler types of sound 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

There are no normative references in this document.³⁾

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this document, 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

3.1.2 A-weighted sound pressure level

L_{pA}

quantity of A-weighted sound pressure, in decibels (dB)

NOTE 1 This is given by the following formula.

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

where:

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

p_0 is the reference sound pressure (20 μ Pa).

NOTE 2 Measurements of A-weighted sound pressure level can be made with a meter and correlate roughly with the subjective impression of loudness. They are usually made to assist in judging the effects of sound on people. The magnitude of A-weighting, in 1/3 octave bands, is shown in Annex A (see A.5). An increase or decrease in level of 10 dB corresponds roughly to a doubling or halving of loudness.

³⁾ Documents that are referred to solely in an informative manner are listed in the Bibliography.

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

sound transmission into a structure from outside

3.1.5 break-out

sound transmission from inside a structure to the outside

3.1.6 cross-talk

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

3.1.7 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 time-varying sound under consideration

NOTE 1 This is given by the following formula.

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

where:

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

p_0 is the reference sound pressure (20 μ Pa).

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

3.1.8 equivalent sound absorption area (of a room)

A

hypothetical area of a totally absorbing surface without diffraction effects, which, if it were the only absorbing element in the room, would give the same reverberation time as the room under consideration

NOTE Equivalent sound absorption area of a room is expressed in m^2 .

3.1.9 façade level

sound pressure level 1 m in front of the façade

NOTE Façade level measurements of L_{pA} are typically 3 dB higher than corresponding free-field measurements because of the reflection from the façade.

3.1.10 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.

3.1.11 ground-borne and structure-borne sound

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

3.1.11.1 ground-borne sound

audible sound 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 ground-borne sound include railways and heavy construction work on adjacent construction sites.

3.1.11.2 structure-borne sound

audible sound 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 sound include building services plant, manufacturing machinery and construction or demolition of the structure.

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 16283-2.

3.1.13 indoor ambient sound

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

NOTE When deciding the location(s) within the room at which the ambient indoor sound is to be measured or calculated, variation in the sound levels across the room ought to be considered.

3.1.14 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.

3.1.15 normalized impact sound pressure level

L_n

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

NOTE A 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 16283-2).

3.1.16 octave band

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

3.1.17 percentile level

$L_{A,N,T}$

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

EXAMPLE

$L_{A10,1h}$ is the A-weighted level exceeded for 10% 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.

3.1.18 rating level

$L_{Ar,Tr}$

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

NOTE This is used in BS 7445-1 and BS 4142 for rating industrial sound, where the sound is the specific sound from the source under investigation.

3.1.19 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 60 dB decay derived from 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} .

3.1.20 sound criteria

numerical values and indices used to define design goals in a given space

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 sound event considered

NOTE 1 The L_{AE} of a discrete sound 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 μ Pa);

t_0 is the reference time interval (1 s).

NOTE 2 L_{AE} is also known as L_{AX} (single-event sound 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.

$$D = L_1 - L_2$$

where:

L_1 is the average sound pressure level in the source room;

L_2 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)

NOTE 1 This is given by the following formula.

$$L_p = 10 \log_{10} (p / p_0)^2$$

where:

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

p_0 is the reference sound pressure (20 μ Pa).

NOTE 2 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 spectrum adaptation term

C_{tr}

value, in decibels, to be added to the single-number rating (e.g. R_w) to take account of the characteristics of particular sound spectra

NOTE For further information, see BS EN ISO 717-1.

3.1.27 standardized impact sound pressure level

L'_{nT}

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 16283-2).

3.1.28 standardized level difference

D_{nT}

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 16283-1).

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

$L'_{n,w}$

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

$L'_{nT,w}$

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

$D_{nT,w}$

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 document, the following symbols apply.

A	equivalent sound absorption area (m ²)
D	sound level difference (dB)
D_w	weighted level difference (dB)
D_{nT}	standardized level difference (dB)
$D_{nT,w}$	weighted standardized level difference (dB)
L_{AE}	sound exposure level (dB)
$L_{Aeq,T}$	equivalent continuous A-weighted sound pressure level (dB)
L_{AFmax}	maximum sound level (dB) measured with a fast time constant
$L_{AN,T}$	percentile level (dB) (e.g. $L_{A10,T}$)
$L_{Ar,Tr}$	rating level (dB)
L_{ASmax}	maximum sound level (dB) measured with a slow time constant
L_{den}	noise indicator for overall annoyance (dB)
L_i	impact sound pressure level (dB)
L_n	normalized impact sound pressure level (dB)
L_{night}	noise indicator for sleep disturbance (dB)
L'_{nT}	standardized impact sound pressure level (dB)

$L'_{nT,w}$	weighted standardized impact sound pressure level (dB)
$L'_{n,w}$	weighted normalized impact sound pressure level (dB)
L_p	sound pressure level (dB)
L_{pA}	A-weighted sound pressure level (dB)
p	sound pressure (Pa)
p_A	A-weighted sound pressure (dB)
$p_A(t)$	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 Planning considerations

4.1 Policy

The planning system considers development at the societal level and seeks the promotion of sustainable development. It has an important contribution to make to prevent significant adverse effects from noise, by which we mean unwanted or harmful sound, and to minimize the adverse effects of noise by influencing the location, layout and design of new development.

When permission is sought for a new building or for a change of use to an existing building, noise is a material planning consideration. The role of the planning authority is to consider both the benefits and disbenefits of a scheme in the context of sustainable development. When considering an application for new development that could either be affected by a source or sources of sound, or generate sound that could affect noise-sensitive receptors, the planning authority might:

- refuse permission if the site is not suitable for the proposed use and local or national noise and/or soundscape policies are not met; or
- refuse permission if the proposed use is likely to be unsuitable to the occupants of buildings such that local or national noise and/or soundscape policies are not met; or
- grant permission, with or without noise-related planning conditions, so that local or national noise and/or soundscape policies are met.

NOTE 1 The following publications are relevant to noise:

- in England: the National planning policy framework [3], relevant National Policy Statements⁴⁾, the Noise policy statement for England [4] and associated technical guidance notes;
- in Wales, the current editions of the following Welsh Government documents: Planning policy Wales [5], associated Technical Advice Notes, and the national strategy on soundscapes, being at the time of writing the Noise and soundscape plan for Wales 2023-2028 [6];
- in Scotland: the Scottish Government's National planning framework 4 [7], Planning advice note 1/2011: Planning and noise [8] and the accompanying Technical advice note Assessment of noise [9];
- in Northern Ireland: where appropriate, the Noise policy statement for Northern Ireland [10] and the Strategic planning policy statement [11];

⁴⁾ Available at www.gov.uk/guidance/nationally-significant-infrastructure-projects-national-policy-statements.

- any noise action plans published under the relevant regional Environmental Noise Regulations ([12] to [15]); and
- any local development plan and/or supplementary planning guidance for the local authority area.

Proposals for developments should take account of the acoustic (i.e. sound) environment, and a proportionate assessment should be made of the effects of:

- 1) sound generated outside the site that might enter any building or be present within external areas; and
- 2) sound generated inside the site or a building on site that could affect people outside the site/building;

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

- 3) the proposed development on the ambient sound environment and how this might impact existing noise-sensitive uses.

The sound generated by some sources can vary according to the operational mode of the source, or change at certain times of day or night, during certain days or nights of the week or month or further vary due to seasonal circumstances. As buildings might not necessarily be occupied at all times, it is essential to understand the constraints and context of the site before considering the need for, and extent of, sound control under the planning system.

4.2 Sequence of planning stages

The assessment of sound in the planning and early stages of design of a development should:

- a) assess the site and identify significant existing and potential sound sources that might affect the development site;
- b) identify potential noise-sensitive receptors on and around the development site;
- c) measure existing or estimate predicted sound levels affecting the site and nearby receptors, characterize the sound environment and identify the noise risk;
- d) determine the design sound levels for spaces in and around the development according to their intended use and for noise-sensitive development, the dominant source of environmental sound;
- e) evaluate layout options for noise-sensitive and noise-generating elements of the development;
- f) determine the sound insulation requirements for the building envelope, including the ventilation strategy;
- g) determine internal sound insulation requirements;
- h) identify appropriate noise control measures or mitigation;
- i) optimize acoustic conditions according to the intended use for spaces in and around the development; and
- j) establish quality control and good workmanship to achieve the acoustic requirements.

NOTE Guidance on planning noise assessments is available in various publications including ProPG: Planning and noise [16], Technical advice note Assessment of noise [9]; Guidelines for environmental noise impact assessment [17].

4.3 Sound sources to consider at planning stage

4.3.1 Sound generated inside the building from internal sources

For sound generated and heard within the building, the design guidance in Clause 7 for sound insulation within the building should be followed.

The existing and expected sound source(s) should first be identified and the designer should then:

- a) select metrics to use for measuring or predicting sound levels (e.g. $L_{Aeq,T}$, or L_p in octave or third octave bands);
- b) assess sound levels due to user activities within the building that might affect other premises;
- c) assess effects of sound insulation between premises, including flanking transmission and sound emitted from one part of the building to outdoors and then breaking back into other parts of the same building;
- d) assess the risks of airborne and structure-borne sound caused by building services plant and equipment; and
- e) measure or predict sound levels at relevant receptor locations due to internal sources.

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

4.3.2 Sound generated outside the building from sources external to the building

For sound sources outside the building, the initial appraisal should take account of the:

- a) location of the site in relation to the sound source(s);
- b) reduction of sound at source;
- c) positioning of buildings;
- d) orientation of buildings;
- e) provision of acoustic barriers;
- f) use of car ports, garages or other structures to provide acoustic screening;
- g) removal or relocation of sound-sensitive uses and/or use of single aspect buildings; and
- h) sound insulation of the building envelope.

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

4.4 Design sound criteria

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

To achieve satisfactory sound insulation for the building, it is necessary to know how each space is to be used so that appropriate sound criteria can be chosen. The designer can then decide which sound criteria are appropriate for the relevant parts of the proposed building and select appropriate sound levels (see **6.2** and **6.3**).

NOTE Advice on indoor ambient sound criteria for various building types is given in 6.3.

The designer should also:

- a) compare external sound levels with internal design criteria;
- b) calculate the sound reduction required between the exterior and interior;
- c) if appropriate, assess internal sound sources;
- d) calculate the sound reduction required between internal user areas and, if necessary, the sound reduction required to reduce sound from internal sources to the level required outside the building; and

- e) identify which sound control measures would be appropriate to deliver this sound reduction (see **4.5**).

4.5 Sound control measures

4.5.1 General approach

Sound control measures should be designed and implemented such that the required sound levels are met, along with local or national noise and/or soundscape management policies, as appropriate.

NOTE 1 Effective design for sound 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 [18]. Specialist advice is required for more complex situations, such as those listed in Annex D.

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

- a) check the feasibility of reducing sound levels and/or relocating sound 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 **4.5.4**);
- e) examine the effects of sound control measures on the requirements for energy efficiency, ventilation, mitigating overheating, fire regulation, health and safety, cost, etc.; and

NOTE 2 Attention is drawn to the Construction (Design and Management) Regulations 2015 [19] and the Building Safety Act 2022 [20].

- f) assess the viability of alternative solutions.

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

- 1) quietening or removing the source of sound (see **4.5.2**);
- 2) attenuating the sound on its path to the receiver (see **4.5.3**);
- 3) obstructing the sound path between source and receiver (see **4.5.4**);
- 4) improving the sound insulation of the building envelope (see **4.5.5**); and
- 5) using agreements to manage sound (see **4.5.6**).

4.5.2 Quietening the source

Reducing the sound at source should be taken into account first because the number of people benefiting might be large and it can be the most cost-effective method.

4.5.3 Attenuating the sound

Sound is attenuated as it propagates over distance because it:

- a) reduces in energy via geometrical spreading;
- b) is affected by scattering, absorption and reflection by nearby surfaces, such as grass-covered ground; and
- c) is partly absorbed by the air itself.

These mechanisms for attenuating sound become more effective as the distance between the source and the receiver increases. Of those listed, geometrical spreading is usually the most dominant effect. For small (point) sources, the reduction is up to approximately 6 dB for

each doubling of distance between source and receiver. For extended (line or planar) sources, there is a smaller reduction with distance (e.g. the energy averaged sound level from free-flowing road traffic diminishes at approximately 3 dB for each doubling of distance).

In some circumstances, the sound might not attenuate at expected rates, for example with poor attenuation occurring with traffic in city streets with high buildings on both sides. In this situation, the sound 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 is more complex and varies with frequency.

4.5.4 Obstructing the propagation path

Use of a full enclosure around the sound source or receiver provides the most effective form of barrier, provided it is acoustically impervious, and the construction materials are of sufficient surface density. The walls and roof of a building usually perform this function (see Clause 7). Their effectiveness as a sound insulator is reduced by weaknesses in the enclosure envelope (e.g. ventilation openings, glazing and doorways), especially when windows and doors are opened. It is therefore important that the acoustic performance of these elements is taken into account when determining the overall effectiveness of an enclosure.

Barriers that are not complete enclosures (e.g. walls, fences, purpose-built screens or earthwork bunds) are normally most effective when tall, long, acoustically impervious and close to either the source or the receiver.

Solid fences, walls and purpose-built screens should extend to the ground with no appreciable air gaps. It might also be necessary to line the inner face (facing the source) of the barrier with sound absorption treatments to control undesirable reflections. If left untreated, these reflections can reduce the expected overall acoustic performance of the screen, if the source itself is of an appreciable size.

Whilst not currently taken into account, or encouraged, as a noise control method in the current national calculation methods for road or rail noise, contemporary research focusing on the principles of sustainable control measures indicates that through an optimized combination of scattering, dispersion, absorption and diffraction effects, appreciable reductions in noise can be expected from compositions of soft ground and vegetation elements (such as tree belts and forest floors, wild meadows, shrubs, crops, hedges and vegetated berms).

Such measures are also considered to provide beneficial attributes and positive responses to the overall soundscape by promoting natural sound (birdsong, foliage psithurism and susurrantion), and the physical presence and associated appearance and smell of such measures has been shown to introduce improved non-acoustic moderators to human responses to the sound.

BS 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. Researchers consider that this provides only a conservative level of attenuation compared to empirical evidence from more contemporary and ongoing studies.

NOTE To calculate the attenuation for road and rail traffic sound and construction sound, see the references given in 5.2, 5.4 and 5.6.

4.5.5 Sound insulation of the building envelope

4.5.5.1 General

Where the acoustic benefits from other mitigation options have been exhausted it might be necessary to increase the sound insulation of the building. This depends on the circumstances of the specific development. For example, an executive office in a busy industrial estate might require alternative ventilation and an option to keep windows closed to provide internal sound levels sufficient to allow speech intelligibility, privacy and concentration. A process of good environmental acoustic design should be followed, particularly in relation to new residential development, where increases to the sound insulation of the building should be a last resort. Where the designer proposes a form of construction that is intended to obstruct sound, and which might take into account cost and other constraints, the proposed design should be examined, and calculations performed to determine whether the target sound reduction is likely to be achieved. The results indicate whether a higher standard of sound 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 done and the process repeated until a satisfactory result is obtained.

When the sound insulation of the building envelope is not known, this can be calculated using one of the methods given in **4.5.5.2** (see also the BS EN 12354 series).

4.5.5.2 Calculations

4.5.5.2.1 General

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

- a) the level and characteristics of the sound outside the building (see **4.3** and Clause **5**); and
- b) the design sound levels in the rooms and other spaces of the building (see **4.4** and **6.3**).

The sound insulation required can then be determined.

4.5.5.2.2 Initial estimates

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

- a) The sound level at a key position, such as the equivalent continuous A-weighted sound pressure level ($L_{Aeq,T}$) 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 **7** and Annex E).
- NOTE Annex A contains a method for estimating the sound insulation of a non-uniform façade comprising windows, ventilation openings and cladding.*
- c) The design sound level at the receiver (e.g. $L_{Aeq,T}$). If the source operates during the day and night, it might be appropriate to have separate design sound levels for day and night periods.

Where the estimate is within 5 dB of the target noise level, a more rigorous calculation should be carried out. It is important to understand that there is no simple relationship connecting these single-figure data and that the results are approximate (see Clause **5**).

4.5.5.2.3 Detailed calculations

For detailed calculations, knowledge of the following is necessary:

- a) frequency characteristics of the sound source(s);
- b) frequency characteristics of the sound reducing elements;
- c) surface area of the façade;
- d) reverberation time of the receiving space; and
- e) where appropriate, structure-borne transmission paths.

Generally, frequency data should be for contiguous octave bands.

4.5.6 Agreements

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

4.6 Quality control and workmanship

Quality control and workmanship should always be taken into account. Sound 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 sound 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 taken into account 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; and
- e) checking and testing procedures that are to be used to assess the building performance.

5 External sound sources

5.1 General

Sound from common sources in the environment is dealt with in **5.2** to **5.7**. In each case, information is given on the characteristics of the sound 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.

There are a number of well-established and widely used methods for calculating and mapping sound from many infrastructure sources, for example:

- a) *Calculation of road traffic noise* (CRTN) [21];
- b) *Additional railway noise source terms for “Calculation of Railway Noise 1995”* [22];

- c) Aviation Environmental Design Tool (AEDT)⁵; and
- d) *Common noise assessment methods in Europe* (CNOSSOS-EU) [23], which provides a common approach for road traffic, railway traffic, aircraft and industrial sources.

Assessment of road and rail sound levels for determining eligibility under the applicable noise insulation regulations currently requires the use of CRTN or CRN rather than measurement or CNOSSOS-EU calculations; however, they might not be appropriate in isolation for assessing the impacts on any particular building or site during design. Where other local sound sources are present, it is likely that a sound measurement survey would be needed. Furthermore, modelling methods might not calculate the appropriate assessment parameters such as the quantity and level of noise events during the night (measured using L_{AFmax}). In such instances, these can be identified by interrogating suitable measurement data.

The propagation of sound depends upon meteorological conditions, topographical features and ground cover characteristics. Sound from wind and precipitation, including the wind-generated sound from trees, can also affect sound measurements. More information is given in 4.5.3 and BS 7445-1.

Whether sound levels are measured or predicted, wind gradients, temperature gradients and turbulence affect the level of received sound and audibility over short periods. Variations in sound level and audibility increase 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 2 dB downwind to reducing it by 10 dB upwind. The prevailing wind direction should be determined when planning building orientation and downwind assumed for sound propagation.

5.2 Sound from road traffic

5.2.1 General

Road traffic sound generation depends on several factors, including:

- a) traffic flow, which can vary considerably within and between days of the week and with school terms;
- b) type of vehicles, i.e. proportion of heavy or light;
- c) mode of operation, i.e. on level or inclined road;
- d) surface of the road;
- e) traffic speed and whether flow is continuous or interrupted; and
- f) propulsion type (electric or combustion) especially for vehicle speeds less than 30 km/h.

NOTE Weather conditions, e.g. surface water on road, can also affect sound generation directly and indirectly through driver behaviour (driving more slowly).

For a typical urban situation where road speed is below 50 km/h, sound energy is concentrated in the low frequency end of the spectrum because of high levels of exhaust sound, particularly from diesel commercial vehicles; however, this might not have a great effect on the A-weighted sound pressure level. At greater speeds, more energy is present at higher frequencies due to the road/tyre surface interaction. This difference in spectral characteristics can affect the nature of the sound heard within a building and should be assessed when sound control options are being examined.

Aerodynamic sound contributes little to the overall sound at speeds below about 150 km/h.

A typical sound spectrum for road traffic is given in BS EN 1793-3.

⁵) See <https://aedt.faa.gov/>.

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

Table 1 – Typical traffic sound levels (façade levels)

Situation	Traffic flow (18h)	%HGV	Speed (km/h)	BNL (dB $L_{A10, 18h}$) ^{A)}	$L_{Aeq, 16h}$ (dB)	L_{Aeq} conversion method
At 10 m from the edge of a busy motorway	70 000	15	100	82.5	80.5	Subtract 2 (WebTAG ^{B)})
At 10 m from the edge of a busy main road through a residential area	8 000	5	50	67.1	65.1	Subtract 2 (WebTAG ^{B)})
At 10 m from a quieter residential road	1 000	1	50	54.6	53.3	Method 3 L_{day} formula (TRL report PR/SE/451/02 [25])

^{A)} The CRTN method (see 5.2.2) of predicting noise from a road consists of five main stages: one of these is the calculation of the basic noise level (BNL), at a reference distance of 10 m away from the nearside carriageway edge, for each road segment. Traffic flow, speed and HGV percentage are required to calculate a reference noise emission (the BNL) as defined in CRTN [21], Appendix A. The final column relates to the conversion method from $L_{A10, 18h}$ to $L_{Aeq, 16h}$.

^{B)} See www.gov.uk/guidance/transport-analysis-guidance-tag for further guidance.

In practice, detailed location-specific calculations or measurements should be undertaken.

5.2.2 Calculating traffic sound

When calculating the sound from road traffic, the recognized national methodology should be used. This is currently the method in *Calculation of Road Traffic Noise* (CRTN) [21]. CRTN 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. The National Highways *Design manual for roads and bridges* [24], LA 111 Noise and vibration provides additional advice concerning the implementation of CRTN.

The method is usually implemented through proprietary sound prediction models, which take into account associated traffic data and other road characteristics. Where traffic conditions are complex or unusual it might be necessary to measure roadside traffic sound levels on site. Procedures for the measurements are contained within CRTN [21].

Predictions calculated from traffic data using CRTN [21] (and CNOSSOS-EU [23]) are typically related to new road schemes, strategic mapping and situations where a new or altered building development is proposed in the vicinity of existing roads. Such calculations can be considered valid as long as reliable traffic data is available, and road traffic noise is considered to be the dominant sound source in the development. If reliable traffic data is not available or there are other sources which provide a significant contribution, measurements are likely to be required to inform assessments in accordance with this British Standard.⁶⁾

The Defra-commissioned study *Converting the UK traffic noise index $L_{A10, 18h}$ to EU noise indices for noise mapping* [25] is the source of the method promulgated in the National Highways *Design manual for roads and bridges* [24] for estimating night-time sound levels from the calculated or measured $L_{A10, 18h}$. This study also provides methods for the conversion of $L_{A10, 18h}$ index to other indices, including L_{den} and various period $L_{Aeq, T}$ values.

⁶⁾ This was correct at the time of publication. Work is underway to publish a revised methodology with increased flexibility in the calculations that can be performed.

Whilst these conversions were developed primarily for compliance with strategic noise mapping requirements, they provide one potential approach to estimating the range of noise indicators which are relevant to modelling traffic sound.

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.

5.3 Sound from aircraft

5.3.1 General

For most civilian airports, the airport operator is responsible for sound management, which has to align with government policy. The exceptions are Heathrow, Gatwick and Stansted, for which the Department for Transport (DfT) has sound management responsibility.

The Environmental Noise Regulations 2006 ([12] to [15]) require major airports (those with more than 50 000 movements per year) to publish strategic noise maps and implement a noise action plan every 5 years. Noise action plans describe noise management, including information about flight paths, hours of operation, the planning conditions under which the airports operate and other noise mitigation practices.

Aerodromes used for commercial air transport of passengers and for training in civilian aircraft above certain total maximum total weights are licensed by the Civil Aviation Authority (CAA). Many aerodromes, including general aviation (private, business and recreational flying and aviation work including helicopters) 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 (see *Noise considerations at general aviation aerodromes* [26]).

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).

5.3.2 Prediction of sound from aircraft

Prediction of sound from aircraft or airports is complex, though aircraft sound modelling software packages are available. Strategic noise map contours 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 it might be necessary to design the building envelope for those operational days.

These contours show the sound 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 sound 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, sound exposure data should be obtained by on-site sound 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. It might also be necessary to consider any changes in sound levels that could be expected due to any airspace change proposals.

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 sound (predominantly low frequency sound). For a jet aircraft the frequency content of sound when landing is generally different from that when departing. Typically, landing jet aircraft produce relatively higher levels of high-frequency sound while departing jet aircraft produce relatively higher levels of low-frequency sound.

5.3.3 Sound from drones and other novel aircraft

Autonomous and electrified aircraft are beginning to come into use and are being rapidly developed. These introduce a new source of either environmental or neighbourhood sound that requires consideration in future planning and building design. A particular consideration is that the sound character can be very different from other sources of environmental sound and potentially more likely to cause annoyance than other transportation sources. Human response to drone sound can also be modified by non-acoustic factors such as the use of the drone and fear of surveillance or invasion of privacy, which is not associated to such a degree with conventional aircraft. Currently there are no standards or guidelines in the UK for assessing these sound impacts.

5.4 Sound from railways

5.4.1 General

Sound 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 while 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 – this is generally characterized by short periods of high sound levels dependent upon speed, locomotive type, power type (electric/diesel), etc.

Ground-borne sound can also be generated by railway systems and might be audible in buildings above rail tunnels. Ground-borne sound might also be audible in spaces within a building that are screened from airborne transmission paths.

5.4.2 Prediction of airborne sound from railways

The currently recognized national calculation method for airborne sound from railways is given in *Calculation of railway noise (CRN)*, with additional source terms given in *Additional railway noise source terms for "Calculation of railway noise 1995"* [22]. 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).

5.4.3 Prediction of ground-borne sound from railways

Ground-borne sound from railways has different characteristics from airborne sound, typically being perceived as a low frequency rumbling sound. Quantification and assessment of impacts, therefore, require a different approach and are generally assessed in terms of the L_{Amax} with a slow time weighting. Guidance on the measurement and assessment of ground-borne sound is given in the Association of Noise Consultants document [27] and in the BS ISO 14837 series.

5.5 Sound from industrial and commercial premises

5.5.1 General

Industrial and commercial sound can originate from specific processes, either internal or external to buildings, or from related transport operations at the premises, such as loading/unloading vehicles or activities involving other vehicles and plant such as forklift trucks or ancillary activities, e.g. air handling plant, ventilation or cooling equipment.

5.5.2 Assessment of industrial and commercial sound

BS 4142 provides methods for assessing external sound of an industrial and/or commercial nature that could affect people inside or outside a dwelling or premises used for residential purposes. BS 4142 describes methods for determining, outside a building, sound from:

- a) industrial and manufacturing processes;
- b) fixed mechanical and electrical plant and equipment;
- c) loading and unloading of goods and materials; and
- d) mobile plant and vehicles that are an intrinsic part of the overall emissions from the premises or process.

BS 4142 describes a method for determining a typical background sound level and a rating level for the specific sound source that has an industrial or commercial character, adding penalties for acoustic features associated with the source being assessed. It then gives guidance on the significance of the rating level relative to the typical background sound level. Numerically, the greater the positive difference between the rating level and typical background sound level, the greater the likelihood of adverse or significant adverse impact due to the specific sound source, depending on the context.

The method is applied for the purpose of investigating complaints, assessing sound of an industrial and/or commercial nature from existing, proposed, new, modified or additional sources and assessing sound at proposed new dwellings or premises used for residential purposes. The BS 4142 methodology allows an adjustment to the numerically derived “initial estimate of impact” due to the context and circumstances of the assessment.

5.6 Sound and vibration from construction and open sites

Sound and vibration from construction and open sites can disturb occupants of nearby buildings, whether in residential or other uses. Sound and vibration 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 sound control for construction and open sites where work/activities/operations, including demolition, generate significant sound levels. Industry-specific guidance is also included. The legislative background to sound 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 sound and assessing its impact on those exposed to it. BS 5228-2 gives equivalent guidance on vibration.

5.7 Sound from wind farms

5.7.1 General

Wind turbines vary in size and power output, from those just a few metres in diameter to large turbines well over 100 m in diameter. As the turbine blades rotate, aerodynamic sound is generated, which sounds like a swishing sound. Many pitch-regulated turbines achieve a maximum level of sound 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 sound 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 sound occurring, which in turn reduces the vibrations transmitted to the ground.

5.7.2 Assessment of wind farm sound

The design, size and rotational speed of a turbine influences the character of the sound generated. The quantification of the sound emissions of medium to large wind turbines is set out in BS EN 61400-11. A particular feature of aerodynamic sound, 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 but cannot be predicted when applying existing standards. Within the UK, ETSU-R-97 [28] can be used to

assess and rate the sound from wind farms. ETSU-R-97 [28] requires wind farms to achieve defined sound limits in order to preserve daytime outdoor amenity and sleep quality at night.

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

5.7.3 Prediction of wind turbine sound

Predictions of wind turbine sound can be made using the procedures given 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* [29], which provides accepted methods of noise prediction.

A recent review of ETSU-R-97 by BEIS [30] identified limitations in the prediction method and gaps in the state of knowledge that need to be addressed to enable a comprehensive update of the prediction methods.

Non-acoustic factors can play a major role in the human response to wind turbine sound, particularly annoyance.

5.8 Other sources of sound

Other anthropogenic sound sources exist, many of which originate from leisure activities, e.g. model aircraft, clay target shooting, outdoor sports, recreation and entertainment, etc.

There is guidance on likely sound levels, assessment and frequency of occurrences for most of these sound sources. Specialist advice might also be required. Relevant publications include the following:

- a) *Code of practice on noise from organised off-road motorcycle sport* [31];
- b) *Clay target shooting: Guidance on the control of noise* [32]; and
- c) *Code of practice on environmental noise control at concerts* [33].

NOTE Codes of practice are also produced by the government. Additional advice might be available from local authority environmental health departments.

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

6 Building design objectives

6.1 General

Guidance is given in **6.2** to **6.6** on acoustic criteria and sound levels appropriate for various types of space that have different functions, as well as areas requiring particular 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 possible to give detailed guidance on all types of building. Many types of building include spaces having different functions; for example, a factory might include workshops, offices and meeting rooms.

6.2 Design considerations

To control internal ambient sound from external sources such as traffic and mechanical services within the building, the designer should, at the outset, establish the intended use for each part of the proposed building and the acoustic conditions required for that use, for example:

- a) industrial working conditions;
- b) speech and telephone communications;
- c) acoustic privacy;
- d) conditions for study and work requiring concentration;
- e) listening conditions; and
- f) resting/sleeping conditions.

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

6.3 Criteria for indoor ambient sound levels or façade sound insulation

Control of external sound ingress into buildings can be expressed in terms of internal level criteria for external sources, or façade sound insulation. For each space there might be a range of internal sound levels that are considered acceptable. The designer should select a level appropriate for the particular circumstances. Sector specific guidance (such as BB 93 [34] for schools, HTM 08-01 [35] for healthcare facilities, BCO *Guide to specification* [36] for offices, for example) contains guidelines internal ambient noise levels.

NOTE 1 Guidance on indoor ambient sound levels is given in Table 2 where privacy is also important (i.e. a minimum level of sound is also desirable to provide a masking effect); façade sound insulation and internal level criteria for dwellings are presented in Table 9 and Table 10 respectively.

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

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

Objective	Typical situations	Design range $L_{Aeq,T}$ dB
Typical sound levels for acoustic privacy in shared spaces	Restaurant	40 – 45
	Cafeteria	45 – 50
	Open plan office	35 – 45
	Public house	40 – 55
	Ballroom, banqueting hall	35 – 40

NOTE See Noise control in building services [37] and the BS EN ISO 3382 series.

The indoor ambient sound criteria for non-domestic buildings generally apply to steady external sources (such as road traffic) and internal sources (such as mechanical services or continuously running plant). Criteria are for the sound level in the space during normal hours of occupation but excluding any sound produced by the occupants and their activities. For all building types, the time period, T , should be appropriate for the activity involved.

NOTE 2 Guidance can be found in the ANC publication, Measurement of sound levels in buildings [38].

6.4 Noise indices

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

$$NR \approx L_{pA} - 5 \quad (1)$$

Although the NR system is currently a widely used method for rating noise from mechanical services in the UK, other methods are also available, including some that are more sensitive to sound at low frequencies (see “Noise control for providing a quality environment” [39]). Low frequency sound can be disturbing or fatiguing to occupants but might have little effect on the L_{pA} or NR value.

Noise criteria (NC) curves are also used and are broadly similar to NR curves; CIBSE Guide B5 [40] provides further rating systems and information. CIBSE Guide A provides criteria for mechanical services noise in a wide range of settings, in terms of NR, dBA and dBC.

6.5 Internal sound insulation

6.5.1 General

In addition to controlling exterior sound and internal services sound, sound from adjacent spaces can affect the intended use, depending on the sound activity, sound sensitivity and privacy requirement. When repurposing buildings, it can be difficult to achieve high levels of sound insulation.

6.5.2 Residential

Minimum requirements for sound insulation for residential buildings in England can be found in Approved Document E of the Building Regulations [41] and in the corresponding documents of the devolved nations.

With the rise of home working, consideration can also be given to sound insulation within dwellings; this is not currently addressed in regulations for the purposes of confidentiality and privacy for home working.

6.5.3 Healthcare

Sound insulation requirements for healthcare premises can be found in HTM 08-01 [35] and in the corresponding documents of the devolved nations.

6.5.4 Education

Minimum sound insulation requirements for schools can be found in BB 93 [34]. These criteria might also be appropriate to other education establishments.

NOTE BB 93 [34] contains guidance on sound insulation between offices. Those criteria do not always achieve sufficient privacy.

6.5.5 Offices and meeting rooms

The key consideration in cellular offices and meeting rooms is speech privacy. Example sound insulation standards derived from speech privacy considerations are set out in Table 3. The minimum level differences are based on a steady state background sound level of approximately NR 30 or 35 dB L_{Aeq} . Where the background level is likely to be lower than NR 30, the minimum $D_{nT,w}$ should be increased accordingly.

The criteria in Table 3 are based on the privacy factor as described in Equation (2), assuming that reverberation time is approximately 0.5 s. If the reverberation time is significantly different, a different reference reverberation time can be used in the calculation and measurement of $D_{nT,w}$ to achieve the appropriate privacy factor, PF .

$$PF = D_{nT,w} + NR \quad (2)$$

where:

$D_{nT,w}$ is the standardized level difference between rooms

NR is the prevailing sound level in the receiving room (i.e. not the mechanical services sound level upper limit) due to mechanical services and occupant activity that might be relied upon and is always present. The equivalent privacy factors are noted in Table 3.

Modern building services systems adjust the operational duty due to occupancy, heat loads or other monitorable parameters, and in some circumstances, might not be relied upon to provide the minimum steady state background sound. In this instance, the sound reduction of the separating partitions might require enhancing, or a sound masking system might be installed.

Table 3 – Example office and meeting room speech privacy and associated sound insulation standards

Speech privacy category	Speech privacy description	Minimum standardized sound level difference (dB $D_{nT,w}$)	Comments	Assumed privacy factor (PF)
A	Highly confidential	50	Loud speech typically barely audible	80
B	Confidential	45	Loud speech typically audible but not intelligible Raised speech typically barely audible	75
C	Moderate privacy	40	Raised speech typically audible but not intelligible Normal speech typically barely audible	70
D	Low privacy	35	Raised speech potentially intelligible Normal speech typically audible but not intelligible	65
N/C	None	<35	Normal speech typically intelligible	—

6.5.6 Furniture elements

BS ISO 23351-1 provides a test methodology for determining the speech sound level reduction of a standalone furniture item. This includes classifications derived from the speech level reduction and the steady state background sound levels. BS ISO 23351-1 indicates that suitable speech privacy can be achieved when the $D_{S,A}$ added to the ambient L_{Aeq} achieves at least 60 dB. However, where rooms are occupied for long-term use, it is recommended to increase this. Recommended privacy classes for phone booths and meeting pods are based on an ambient level of 35 dB L_{Aeq} . On this assumption, the following performance is required:

- enclosed phone booths should achieve a minimum speech level reduction of 25 dB $D_{S,A}$ (speech privacy Class B); and
- enclosed meeting room pods should achieve a minimum speech level reduction of 30 dB $D_{S,A}$ (speech privacy Class A).

Where pods or phone booths are located directly adjacent to each other or in a cluster, speech privacy between enclosed spaces should be put in place.

6.5.7 Video conference/Podcast rooms

A common addition to modern offices is a video conference or podcast room. Where podcast rooms are located within occupied areas, the minimum standards set out in Table 4 are recommended. The potential for noise ingress from adjacent occupied areas during recording should be determined; the sound insulation of the room might need to be enhanced, particularly to the room front providing access.

Table 4 – Example podcast and video conference room sound insulation standards

Adjacency	Minimum standardized sound level difference, range (dB $D_{nT,w}$)
Podcast room front into a corridor	35 – 40
Podcast room front into open plan office	45 – 50
Podcast to adjacent cellular space	50 – 55
Podcast to control room/editing suite directly associated with podcast room containing glazed element	45 – 50

6.5.8 Other spaces

Where there is no specific sound reduction standard available, levels due to activity sounds should not exceed the ambient noise limits in adjacent spaces. Where sound is impulsive, higher levels of sound insulation should be installed.

Low frequency sound from bars, clubs or gyms should be specifically considered with the aim that disturbance to adjacent sensitive spaces is reduced to an acceptable level. A typical scenario is the location of gyms on the ground floor beneath offices. Sound levels in gym spin rooms can be as high as 100 dB L_{Aeq} with strong low frequency content and is likely to require specialist isolation.

A matrix can be used to determine the sound insulation requirement of separating partitions once the sound activity, sound sensitivity for each room and space are established (see 6.2). An example matrix, which can be adapted according to the specific building use, is given in Table 5. Each room can be both a source and a receiving room. Where adjacent rooms have different uses, the higher sound insulation should be specified.

Table 5 – Example on-site sound insulation matrix (dB $D_{nT,w}$)

Activity sound of source room	Noise sensitivity of receiving rooms		
	Low sensitivity	Medium sensitivity	Sensitive
Very high	45	50	55 ^{A)}
High	35	40	45
Typical	30	35	40
Low	No rating	30	35

^{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.

6.6 Control of reverberant sound

6.6.1 Limits for reverberation time

As well as internal ambient sound level, the reverberation time, T , measured in seconds (s), should also be taken into account because it affects the sound level in the space. It therefore also affects the sound insulation requirements between spaces and degree of privacy in multi-occupancy spaces. Additionally, an excessively long reverberation time accentuates the background sound and can reduce the clarity of natural and amplified speech, including public address and emergency voice alarm systems announcements. Short reverberation

times can assist clarity of speech, especially for microphones used for videoconferencing, etc., but might require additional vocal effort where a speaker is addressing a number of listeners (training, briefing, lecture rooms, etc.).

General guidance on designing rooms for speech (e.g. meeting rooms) is given in **9.8**.

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

6.6.2 Control of reverberant sound from occupant activity

Buildings and facilities should be designed to suit a wide range of people and age groups, with a specific and measurable focus on reducing health inequalities by creating the conditions for everyone to access them as far as practicable; see, for example, NHS England's *Putting health into place* [42] and *Planning policy Wales* [5], sections 3.5 to 3.6. While minimum standards for sound absorption or reverberation times exist in a range of sector-specific guidance (e.g. Approved Document E [41], BB 93 [34], HTM 08-01 [35], to enable PAVA systems to operate, etc.), what might constitute "good" or "better" acoustic conditions is rarely described elsewhere.

There should be sufficient sound absorption to control the build-up of reverberant sound within spaces from the activities of the occupants. This is achieved by specifying minimum amounts of sound absorbing material to reduce the overall sound level and limit excessive reverberation that could impair speech intelligibility or cause discomfort.

The distribution of sound absorption can be significant for the room acoustic response. Sound absorption is normally most effective when applied at the same level as speakers and listeners and evenly distributed around the space.

Guidance is given in Annex I for the ratio of the room's total equivalent sound absorption area, A , to the room volume V (A/V ratio) over the frequency range of 250 Hz to 2 000 Hz. The criteria refer to the normal state of furnishing.

NOTE 1 The purpose of these recommendations is to control the build-up of sound from the occupants and other sources of sound internal to the building, not to address external noise ingress.

A range of categories, from A to F, describe different levels of provision of sound absorption in Table 6. These categories indicate the minimum values for the ratio A/V (m^2/m^3) to be achieved in each octave band from 250 Hz to 2 000 Hz. The absorption of occupants themselves should be excluded from the calculated provision, but the normal furnishings intrinsic to the room types are usually included. The calculation of the total equivalent absorption area, A , is described in BS EN 12354-6.

The target values vary based on the room's clear height, h , to allow for the greater volume of reverberant sound build-up in taller spaces. For multi-story or mixed height spaces, h is the average room height, but distributing absorption on a per-floor basis is beneficial for reducing reverberant noise build-up. The average height, h , can be calculated by dividing the total room volume by its net floor area.

NOTE 2 The absorption of objects can be determined by assigning a volume to the objects as described in BS EN 12354-6. It is found that lightly furnished classrooms have objects to around 2% of the room volume, whereas in densely furnished classrooms the objects can amount to 5% of the room volume.