

Sound insulation and noise reduction for buildings — Code of practice

ICS 91.120.20

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- Aggregate Concrete Block Association
- Association of Building Engineers
- Association of Noise Consultants
- Autoclaved Aerated Concrete Products Association
- BAA plc
- British Precast Concrete Federation Ltd.
- Concrete Society
- Consumer Policy Committee of BSI
- Convention of Scottish Local Authorities
- Department of the Environment, Transport and the Regions
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- Gypsum Products Development Association
- Institute of Acoustics
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- Noise Abatement Society
- Royal Institute of British Architects
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- Society of Chief Architects of Local Authorities
- Wood Wool Slab Manufacturers Association

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Foreword

This British Standard code of practice has been prepared by Technical Committee B/209/18. It was first published as CP 3:Chapter III:1972, which was superseded by BS 8233:1987. This revision supersedes BS 8233:1987, which is withdrawn. It takes account of recent legislation and official guidance, and changes have been made to improve clarity and focus on essential information.

This code of practice 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 code of practice is intended for use by non-specialist designers and constructors of buildings and those concerned with building control, planning and environmental health.

The information in this code of practice follows the typical sequence of activities in building design. Clause 5 gives a general overview of the subject, and clauses 6, 7, and 8 cover specific aspects in more detail.

Clauses 5 to 8 are mainly applicable to new build, while clauses 7 and 8 will also be of use where rehabilitation or change of use of an existing building is being considered.

It has been assumed in the drafting of this code of practice that the execution of its provisions will be entrusted to people who, although not experts in acoustics, are appropriately qualified and experienced.

Annexes A, B, C, D and E are informative.

As a code of practice, this British Standard takes the form of guidance and recommendations. It should not be quoted as if it were a specification and particular care should be taken to ensure that claims of compliance are not misleading.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations. In particular, attention is drawn to the Town and Country Planning Act 1990 [1], the Building Regulations 1991 [2], the Building Standards (Scotland) 1990 [3] and the Building Regulations (Northern Ireland) 1994 [4].

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iii, a blank page, pages 1 to 49 and a back cover.

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Introduction

Noise control in and around buildings is treated in this code of practice on an objective and quantifiable basis as far as is currently possible. For many common situations, this code suggests criteria — such as reasonable sleeping/resting conditions — and proposes noise limits that will normally satisfy these criteria for most people. However, it should be borne in mind that people vary widely in their sensitivity to noise, and the limits suggested may have to be adjusted to suit local circumstances. Moreover, noise limits refer only to the physical characteristics of sound and cannot differentiate between pleasant and unpleasant sounds. Important though psychological factors may be, it is not practicable to consider them here.

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

1 Scope

This British Standard gives recommendations for the control of noise in and around buildings, and suggests appropriate criteria and limits for different situations. These criteria and limits are primarily intended to guide the design of new or refurbished buildings undergoing a change of use, rather than to assess the effect of changes in the external noise level. It covers room acoustics for simple situations, but not the design of buildings where the acoustics are critical, such as auditoria.

This code of practice does not cover vibration control, except where it is evident in the form of radiated sound.

2 Terms and definitions

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

2.1

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

2.2

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.

2.3

sound pressure level

L_p

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

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

where

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

p_o is the reference sound pressure (20 μ Pa)

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.

2.4

A-weighted sound pressure level

L_{pA}

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

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

where

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

p_o is the reference sound pressure (20 μ Pa)

NOTE Measurements of A-weighted sound pressure level can be made with a meter and correlate roughly with subjective assessments of loudness, and 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.

2.5

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. 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 faster than “S” and so its use can lead to higher values when rapidly changing signals are measured.

2.6

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, given by the 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 Equivalent continuous A-weighted sound pressure level is mainly used for the assessment of environmental noise and occupational noise exposure [5].

2.7

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 level (20 μ Pa);

t_0 is the reference time interval (1 s)

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

2.8

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 definition is used in BS 4142 for rating industrial noise, where the noise is the specific noise from the source under investigation.

2.9

free-field level

sound pressure level measured outside, far 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 being free-field measurements. To minimize the effect of reflections the measuring position should 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.

2.10

façade level

sound pressure level measured 1 m to 2 m in front of the façade

NOTE Façade level measurements of L_{pA} are usually 2 dB to 3 dB higher than corresponding free-field measurements.

2.11

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.

2.12

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 BS EN ISO 140-3 and annex C.

2.13

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 BS EN ISO 717-1 and annex C).

2.14

standardized level difference

D_{nT}

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

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

2.15**weighted standardized level difference** $D_{nT,w}$

single-number quantity, which characterizes the airborne sound insulation between rooms

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

2.16**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).

2.17**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

NOTE For additional information on impact sound pressure level and the standard tapping machine see BS EN ISO 140-6 and annex C.

2.18**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 BS EN ISO 140-7 and annex C).

2.19**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 BS EN ISO 140-6, BS EN ISO 140-7 and annex C).

2.20**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 BS EN ISO 717-2 and annex C).

2.21**weighted normalized impact sound pressure level**

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 BS EN ISO 717-2 and annex C).

2.22**cross-talk**

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

2.23**break-out**

unwanted sound transmission from inside a duct to the outside

2.24**break-in**

unwanted sound transmission into a duct from outside

2.25**indoor ambient noise**

pervasive 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

2.26**octave band**

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

2.27**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

2.28**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} .

2.29**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 in question

3 Symbols

The main symbols used in this code, together with relevant symbols used in standards referred to in this code, are given in Table 1.

4 Measuring equipment and accuracy

Measuring equipment should normally conform to the accuracy requirements given in the appropriate standard (BS EN ISO 140, BS 4142, BS EN 20354) or, if not stated, to type 2 or better (see BS EN 60804, BS EN 60651, 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 guidance given in the appropriate guidelines published by the Association of Noise Consultants should also be followed [6].

Table 1 — Symbols

Quantity	Symbol	Unit	Relevant standard
Sound pressure level	L_p	dB	
A-weighted sound pressure level	L_{pA}	dB	
Root mean square sound pressure	p	Pa	
Instantaneous A-weighted sound pressure	$p_A(t)$	Pa	
Reference sound pressure	p_o	Pa	
Percentile level	$L_{AN,T}$	dB	
Sound exposure level	L_{AE}	dB	
Equivalent continuous A-weighted sound pressure level	$L_{Aeq,T}$	dB	
Time interval (also used for reverberation time)	T	s	
Reference time interval	t_o	s	
Rating level	$L_{Ar,Tr}$	dB	BS 4142
Impact sound pressure level	L_i	dB	BS EN ISO 140-6
Normalized impact sound pressure level	L_n	dB	BS EN ISO 140-6, BS EN ISO 140-7
Standardized impact sound pressure level	L'_{nT}	dB	BS EN ISO 140-7
Weighted standardized impact sound pressure level	$L'_{nT,w}$	dB	BS EN ISO 717-1
Sound level difference	D	dB	
Weighted level difference	D_w	dB	BS EN ISO 717-1
Weighted standardized level difference	$D_{nT,w}$	dB	BS EN ISO 717-1
Sound reduction index	R	dB	BS EN ISO 140-3
Weighted sound reduction index	R_w	dB	BS EN ISO 717-1
Equivalent sound absorption area	A	m ²	BS EN 20354
Standardized level difference	D_{nT}	dB	BS EN ISO 140-4
Weighted normalized impact sound pressure level	$L'_{n,w}$	DB	BS EN ISO 717-2

5 Planning and design

5.1 Suggested sequence to be followed

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

- a) Assess the site and identify significant noise sources (see 5.3), measure or estimate noise levels (see clause 6).
- b) Evaluate layout options (see 5.2).
- c) Decide noise criteria and limits for spaces in and around the building(s) (see 5.4 and clause 7).
- d) Consider internal sound insulation requirements.
- e) Consider sound insulation of building envelope.

Much of the advice given here can be applied in the reverse situation where a new noisy development is to be introduced near an existing noise sensitive development, such as housing. This is discussed in 5.7, where the legal position is also outlined.

5.2 Assessing the site

5.2.1 Planning requirements

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

- a) refuse permission if the site is too noisy for the proposed use;
- b) refuse permission if the proposed use is likely to cause a noise nuisance to the occupants of existing buildings;
- c) impose conditions regarding noise levels.

The local planning authority will be guided by the following government publications:

- in England and Wales: Department of the Environment (now Department of the Environment, Transport and the Regions) Planning Policy Guidance PPG 24, 1994: *Planning and Noise* [7] and Circular 1/85 *The use of conditions in planning permissions* [8];
- in Scotland: Scottish Development Department (now The Scottish Administration) Circular 23/73, *Planning and noise*, with SDD Memorandum 24/73, *Planning and Noise* [9];
- in Northern Ireland: as for England and Wales.

5.2.2 Need for noise assessment

To ensure a smooth passage through the planning system, even when a full environmental assessment (see 5.7.2) 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:

- a) noise generated outside that enters the building;
- b) noise generated inside the building that may disturb people outside the building.

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

5.2.3 Noise originating inside or outside the building

For noise disturbance originating and heard within the building, the relevant design features are the internal construction and layout of the building (see clause 8 for more details).

For noise sources outside the building under consideration, 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;
- g) replanning the interior layout of the building.

Factors a) to g) may also be applicable for protecting neighbouring buildings that are likely to be disturbed by noise sources operating within the building.

5.3 External noise sources — Meteorological effects

The main sources of noise are air, road and rail traffic, and industrial/commercial activities.

Information on these sources is given in clause 6.

Whether noise levels are measured or predicted, it should be borne in mind that wind gradients, temperature gradients and turbulence affect the level of received sound over short periods. The effects range from increasing the level by typically 2 dB downwind, to reducing it by typically 10 dB upwind — or even more in extreme conditions. It is not usually practicable to use this factor in design, but the prevailing wind direction should be considered when planning building orientation. For example, for a site with similar noise sources on two opposite sides, noise sensitive rooms should be oriented on the leeward side.

5.4 Noise criteria and limits

To achieve a satisfactory noise environment inside the building it is necessary to know how each space will be used so that appropriate criteria can be chosen.

Having chosen the appropriate criteria, noise limits can be set for specific situations.

NOTE Advice on criteria and limits for various building types is given in clause 7.

5.5 Noise control measures

5.5.1 General approach

The purpose of noise control is to ensure that all reasonable steps are taken to ensure that people are neither harmed nor disturbed by noise. Effective design for noise control requires a good understanding of the behaviour of sound.

NOTE 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 [10]. Specialist advice will be required for more complex situations, such as those listed in annex D.

Noise from outside can be reduced in the following ways:

- a) by quietening or removing the source of noise;
- b) by attenuating the sound on its path to the receiver;
- c) by obstructing the sound path between source and receiver;
- d) improving the sound insulation of the building envelope.

5.5.2 Quietening the source

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

5.5.3 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.

All these mechanisms which attenuate the noise become more effective the greater the distance between the source and the receiver. Spreading is usually the most important effect. For small sources, the reduction is up to about 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 about 3 dB for each doubling of distance.

The worst situation occurs with traffic in city streets with high buildings on both sides. The noise level diminishes very slowly as the storey height increases because of multiple reflections between the façades (canyon effect).

Ground attenuation is negligible for hard ground. For grassland, the attenuation varies with frequency.

A belt of trees less than about 30 m deep provides little extra sound attenuation. For this reason, tree planting is not normally a practical noise control measure.

5.5.4 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 efficiency as a sound insulator is reduced by weaknesses in the envelope (e.g. ventilation openings, thin glazing, and doorways), especially when windows are open in the summer.

Solid barriers cast a shadow within which the sound level is reduced. Barriers that are not complete enclosures (e.g. fences) are most effective when tall, long and close to either the source or the receiver. They may be solid fences, walls, earth bunds or buildings, and should extend to the ground.

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

5.6 Sound insulation of the envelope

5.6.1 General

In the past, experience often played an important role in the design of sound insulation measures, but as limits are set more tightly now, calculation methods should be regarded as the normal approach.

5.6.2 Calculation

5.6.2.1 General

An assessment should first be made of:

- a) the level and characteristics of the noise outside the building (see clause 6);
- b) the desirable/acceptable noise levels in the rooms of the building (see clause 7).

The noise reduction required can be calculated from a) and b).

Usually, the designer will have a form of construction in mind, which takes into account cost and other constraints. The proposed design should be examined and calculations carried out to see if the target noise reduction is likely to be achieved. The results will indicate whether a higher standard of noise control should be considered or whether a lower standard will be adequate. If a change in the design is indicated, further calculations should be carried out and the process repeated until a satisfactory result is predicted. In a situation where a low standard will suffice it may be prudent to consider future uses of the building.

5.6.2.2 Initial estimates

Initial estimates may be no more than simple arithmetic 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 ($L_{Aeq,T}$) at the location of the nearest façade 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 non-uniform partitions such as a façade comprising windows and cladding.

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

It is important to stress that there is no simple relationship connecting these single-figure data and that the results will be approximate (see clause 6).

5.6.2.3 Detailed calculations

For detailed calculations, knowledge of the following is required:

- the frequency characteristics of the noise source;
- the frequency characteristics of the sound reducing elements;
- the surface area of the common construction separating the two areas;
- the reverberation time of the receiving space.

Generally, frequency data should be for contiguous octave bands.

Comprehensive numerical data are essential for the use of performance standards in buildings to become more common [11]. Calculation methods will grow in importance as numerical data on the characteristics of noise sources and sound reducing elements are compiled.

5.7 New noise producing development

5.7.1 General

Much of the advice already given in 5.1 to 5.6 can also be applied to a new noise producing development. As the local planning authority may require noise control measures, and if these are not carried out properly there may be widespread annoyance and legal ramifications, it is necessary to consider the legislative framework.

5.7.2 Legislative framework and guidance

There now exists a considerable body of legislation and authoritative recommendations on noise. For certain types of project, and projects having a significant environmental impact, a full environmental assessment (EA) is required, an important part of which is often noise. Even when an EA is not mandatory, it is important to avoid complaints and the risk of legal action after the project is completed. It is, therefore, prudent to consult, at an early stage, with local authority and other officials for the area in which building works are proposed.

Organizations which should be consulted may include:

- the local planning authority;
- the local authority environmental health department;
- the building control authority.

5.7.3 Environmental assessment (EA)

A limited number of project types, such as major aerodromes, always require an EA [12]. For a wider range of projects, including local roads, other new aerodromes, industrial estate developments, and projects involving disposal of non-toxic waste and mineral extraction, an EA is required if the proposal is likely to have significant environmental effects.

Where an EA is required, the likely effects of noise will be among the factors to be assessed, and dealt with in the environmental impact statement prepared by the developer and submitted to the planning authority with the planning application.

NOTE For further information see *Guidelines on noise and vibration assessment* [13].

5.7.4 Construction noise

Part III of the Control of Pollution Act 1974 [14] gives local authorities powers to control noise from construction sites.

NOTE Useful advice on controlling construction noise is given in BS 5228-1.

5.7.5 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 amounts to a statutory nuisance. Any new noise source is a potential nuisance. Furthermore, an existing industrial/commercial noise source may become a nuisance if people are introduced into its vicinity.

In England and Wales, a local authority's power comes under section 80 of the Environmental Protection Act 1990 [11]; in Scotland it comes under section 58 of the Control of Pollution Act 1974 [14]; in Northern Ireland consult Pollution Control and Local Government (Northern Ireland) Order 1978 [15]. These Acts also make provision for private individuals to take complaints directly to a magistrates 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 becomes a statutory nuisance. Each case is considered on its merits and account taken of the likely reaction of a reasonable person. The noise complained of need not be injurious to health; the criterion can be one of interfering with ordinary comfort or amenity.
- 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 has been used.

5.7.6 Common law

Civil action can be taken against noise 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.

5.7.7 Contracts

It is possible to guard against noise nuisance by express provisions in contracts. This may be useful for certain types of building. For example, it may be possible in a tenancy agreement to restrict the use of musical instruments, providing the restriction is sufficiently specific to be enforceable.

5.8 Checklist for the design

5.8.1 General

The checklist given in 5.8.2 to 5.8.6 is intended as an aid for the designer.

Not all items on the checklist are necessarily applicable (e.g. a noise contour map is not necessary when building a single house). However, quality control and workmanship (see 5.8.6) should always be considered very carefully. Experience has shown that many noise control measures fail to perform adequately because the construction details are not built as the designer intended. Variations in detailing which might appear ordinarily to be unimportant often have serious implications for noise control, e.g. slight warps in a window frame may reduce the effectiveness of the seals.

5.8.2 Evaluation of external noise sources

The levels of existing and future noise sources can be predicted if there is reliable information. Otherwise measurement will be necessary, either of the existing noise, or of a noise source similar to that proposed.

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

- a) Select quantities to use for measuring or predicting noise levels (e.g. $L_{Aeq,T}$ 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 may 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.

5.8.3 User requirements

To satisfy user requirements the designer should apply the following procedures.

- a) Select measurement quantities to match external noise quantities.
- b) Choose criteria and appropriate noise levels for sensitive areas (see clause 7).

5.8.4 Building performance requirements

To establish performance requirements the designer should carry out the following:

- a) compare external noise levels with internal design limits;
- 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 an acceptable level outside the building.

5.8.5 Design steps

In the design process the designer should include 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 methods for meeting building performance requirements (see 5.8.4);
- e) examine the effects of noise control measures on natural ventilation, fire regulation requirements, health and safety etc.;
- f) carry out a cost exercise to assess the viability of alternative solutions.

5.8.6 Quality control and workmanship

To establish good quality control and workmanship the following activities should be considered by the designer and discussed with the builder.

- Detailed specifications should be given.
- The required standards of materials and workmanship should be specified in contract documentation.
- Consideration should be given to including a performance specification in the contract documentation.
- Any checking and testing procedures that will be used to assess the finished building should be specified.
- Specified checks and tests should be conducted when and where appropriate.

6 External noise sources

6.1 Introduction

Noise from commonly encountered sources is dealt with in 6.2 to 6.6. 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.

6.2 Noise from road traffic

6.2.1 Main factors

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

- traffic flow (which can vary considerably within and between days of the week);
- type of vehicles (i.e. predominately heavy or light);
- mode of operation (e.g. level or inclined road);
- surface texture of the road;
- speed (and whether flow is continuous or interrupted).

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

6.2.2 Typical noise spectrum

NOTE A typical noise spectrum of free flowing traffic on a main road is given in Figure 1.

For a typical urban situation where road speed is below about 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 (80 km/h) 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 sound heard within a building, and should be kept in mind when different sound control measures are being considered.

For initial design purposes, typical noise levels are given in Table 2 for three common situations.

Table 2 — Typical traffic noise levels measured about 1 m from the façade

Situation	$L_{Aeq,16h}$ dB
At 20 m from the edge of a busy motorway carrying many heavy vehicles; average traffic speed 100 km/h; intervening ground grassed	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

6.2.3 Prediction of 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 from the $L_{A10,1h}$ values on a normal working day. This is a well validated method for calculating levels up to 300 m from a road. Typical noise propagation conditions are assumed, e.g. moderately adverse wind velocity and direction. Although not explicitly stated the prediction method also assumes dry conditions. It has been validated for roads carrying more than 1 000 vehicles per 18 h day or 50 vehicles per hour. It is usual to make predictions for flow rates forecast 15 years ahead.

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

The prediction method takes the following factors into account:

- hourly traffic flow rate;
- mean traffic speed;
- percentage of heavy vehicles (those greater than 1 525 kg).

Other information required for the calculation includes:

- road surface and gradient;
- ground type;
- height of noise source;
- shielding of barriers and cuttings;
- reflections at façades and from nearby buildings;
- angle of view of the road.

The method can be used to draw noise contours on a site plan. However, where traffic conditions are complex or unusual it may be necessary to measure noise levels on site.

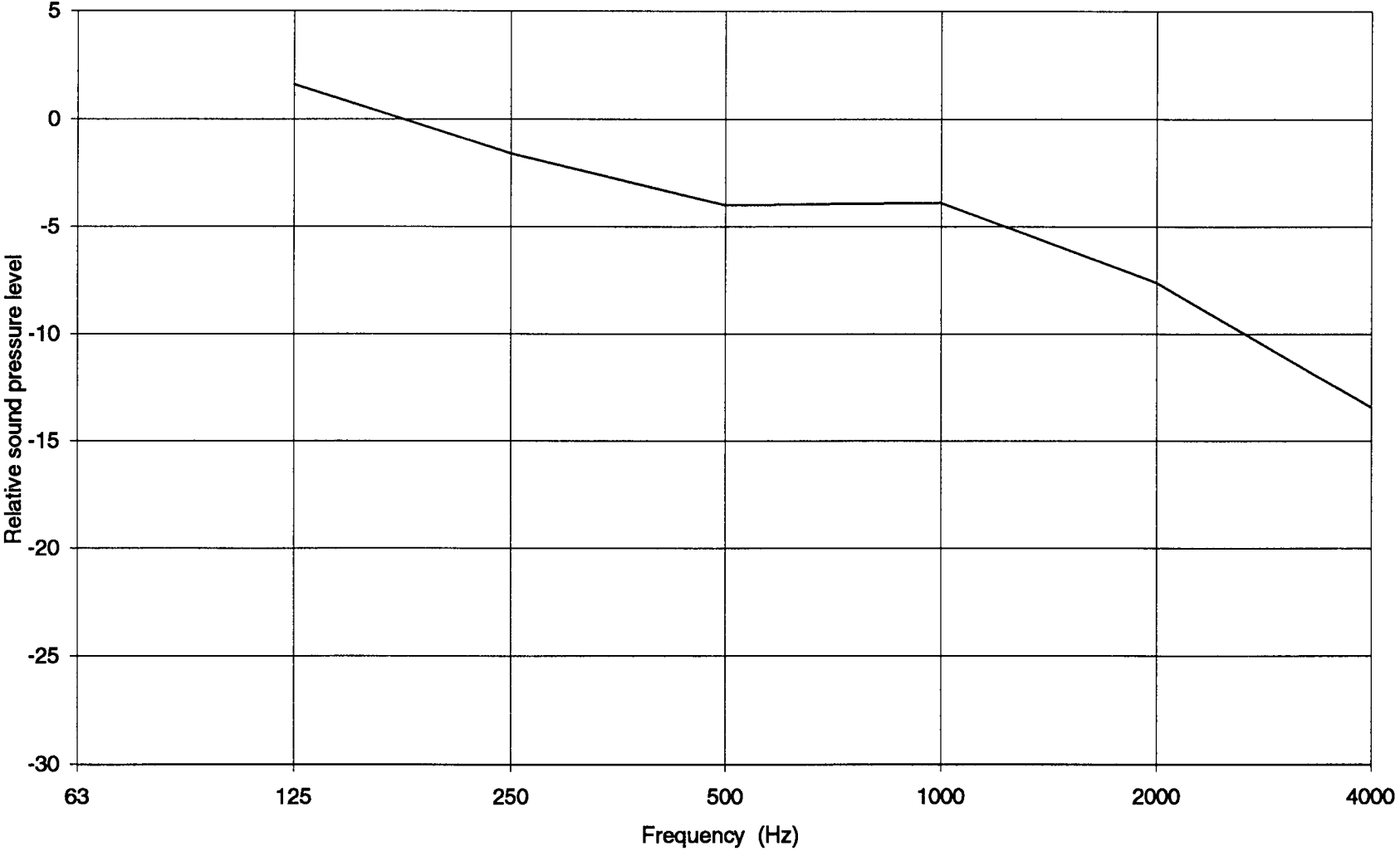


Figure 1 — Normalized road traffic noise spectrum derived from BS EN 1793-3:1998

6.3 Noise from aircraft

6.3.1 General

The Department of the Environment, Transport and the Regions (DETR) is responsible for policy on the control of civil aircraft noise in the UK, and specifically for noise control at airports designated for this purpose under section 80 of the Civil Aviation Act 1982 [17], namely Heathrow, Gatwick and Stansted.

NOTE For information about the major Scottish airports contact Scottish Airports Ltd., St Andrew's Drive, Glasgow Airport, Paisley PA3 2SW.

At other airports, noise control is primarily a matter for the airport management. Noise can be controlled by use of noise preferential routes (NPRs) which ensure aircraft avoid centres of population as far as possible. Restrictions can also be made on the number of movements and/or the classes of aircraft that can be used. Unattended noise monitoring sites coupled with radar records are used to monitor aircraft movements and noise levels, more information about which is given in PPG 24 [7].

6.3.2 Prediction of noise from aircraft

Prediction of noise from aircraft or airports is complex. However, contours of daytime $L_{Aeq,T}$ levels are available for most major airports (see Figure 2) which can be used to give an estimate of the internal noise climate.

Where it appears that sound insulation treatment will be necessary, noise exposure data should be obtained by on site noise measurements, taking account of wind direction and runway usage. However, take-off and landing spectra can be very different.

NOTE Typical noise spectra for a jet airliner after take-off and before landing are shown in Figure 3.

As noise contours do not include noise from ground running, this should be considered separately.

6.4 Noise from railways

6.4.1 General

Noise from railways is characterized by short periods of high noise levels, resulting from the nature of rail time-tabling. The basic noise level of a diesel locomotive is about 90 dBA at 25 m. However, as the level and spectra depend on the operating conditions, the level can vary by up to 20 dBA.

NOTE Typical train noise spectra are given in Figure 4.

6.4.2 Prediction of noise from railways

The standard calculation method is given in *Calculation of railway noise (CRN)* [18], [19]. The procedure enables calculation of three $L_{Aeq,T}$ values:

- day $L_{Aeq,16h}$ (07.00 to 23.00);
- night $L_{Aeq,8h}$ (23.00 to 07.00);
- busiest half-hour $L_{Aeq,0.5h}$.

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

- L_{AE} of the train(s);
- number, and times of train movements;
- distance from track;
- ground type;
- angle of view;
- reflection effects.

6.5 Noise from industry and construction

6.5.1 General

Industrial noise may originate from specific processes, from related transport operations or from construction-related activities.

6.5.2 Assessment of industrial noise

Where industrial noise affects residential areas, the method for rating the noise in BS 4142 should be applied. The noise level outside the dwelling should be established, and penalties should be added to this level if the spectrum has subjectively annoying characteristics. For example, if acoustic features such as hums, tones, impulses or banging, are present, a single 5 dB correction should be added. The complaint assessment procedure compares this corrected level (called the rating level) with the background level. If this difference is around 10 dB or more, complaints are to be expected. A difference of around 5 dB is of marginal significance. The rating method thus gives an indication of when further noise control measures may be needed.

6.5.3 Noise from construction sites

As noise from construction sites may annoy occupants of nearby buildings, it may be necessary for the contractor to use quiet plant, adopt quiet working methods, and to limit working hours.

6.5.4 Prediction of construction site noise

Construction site noise is produced by many different activities and types of plant. Guidance on its control and prediction is covered by BS 5228-1, which uses the following data to estimate $L_{Aeq,T}$ levels:

- source power measurements (from actual measurements or a database of sound powers);
- activity information, e.g. duration of use;
- attenuation due to distance from building and screening.

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

NOTE Slightly different procedures exist for stationary and mobile plant.

6.6 Other sources of noise

Many other noise sources exist, many of which originate from leisure activities, e.g. model aircraft, clay target shooting, water sports, entertainment noise.

Most of these noise sources have codes of practice associated with them, which give an idea of likely noise levels or frequency of events.

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