Introduction to appendices

The ten appendices provide supporting information for the main sections of Building Bulletin 93, including explanations of acoustic terms, sample calculations and other background information.

There are many technical terms and descriptors used in acoustics, which can not be covered in-depth in these short appendices. However, to help non-acousticians, Appendices 1 to 3 include definitions of those acoustic terms which are used in BB93, and describe the basic principles of the behaviour of sound in buildings. There are many acoustics text books available, some of which are listed in the bibliography These can be referred to for a more complete description of all acoustic terms and descriptors.

Nature of sound

Sound is usually generated by the vibrations of a surface, which give rise to pressure fluctuations in air or some other elastic medium. Sound is transmitted through the medium as sound waves, and may be described in terms of sound pressure or sound power. Noise is generally defined as unwanted sound.

Decibels

Sound levels are usually measured in decibels (dB) and relate absolute values to a reference value. The decibel scale is logarithmic and it ascribes equal values to proportional changes in sound pressure, which reflects the response of the human ear to sound. For example, an increase in sound pressure from 10 to 20 Pa would sound the same to the human ear as an increase from 1 to 2 Pa. Use of a logarithmic scale has the added advantage that it compresses the very wide range of sound pressures to which the ear may typically be exposed to a more manageable range of numbers.

Sound pressure level

The sound pressure level, L_p, is a measure of the total instantaneous sound pressure at a point in space. The threshold of hearing occurs at approximately 0 dB sound pressure level (which corresponds to a reference sound pressure of 2.10^{-5} Pa) and the threshold of pain is around 140 dB. Some typical sound pressure levels are shown in Figure A1.1.

Sound power level

The sound energy radiated by a source can also be expressed in decibels. The sound power is a measure of the total sound energy radiated by a source per second, in Watts. The sound power level, L_W, is expressed in decibels, referenced to 1 pW.

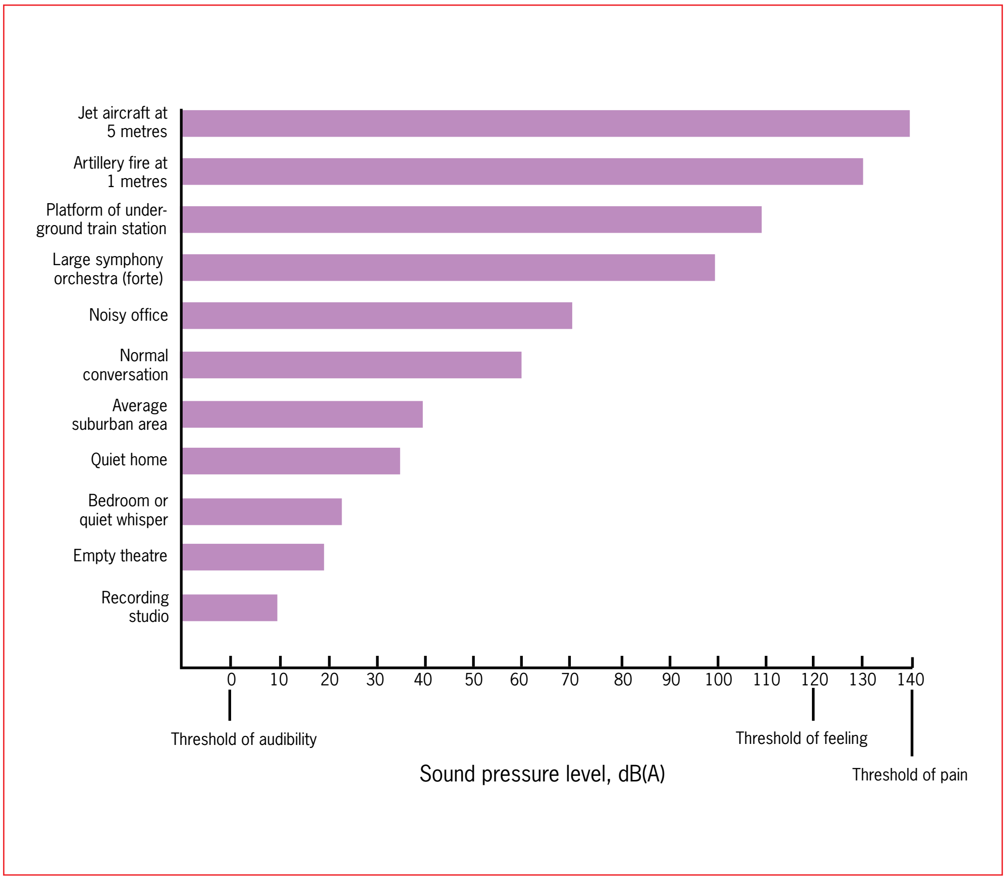


Figure A1.1: Typical sound pressure levels

Addition of sound levels

Because the decibel scale is logarithmic, levels in decibels can not be simply added together. To combine two sound levels, *A* dB and *B* dB, to give the total sound level, *C* dB, the following equation is used:

$$C = 10 \lg (10^{A/10} + 10^{B/10}) \text{ dB} \qquad \text{A1.1}$$

When two identical sounds occur simultaneously, the resulting level is only 3 dB higher than for a single source. By contrast, an increase of 10 dB normally represents a doubling of perceived loudness of the sound. Hence doubling the amount of sound energy results in very much less than a doubling in subjective loudness.

To combine more than two levels, the following equation is used:

$$L = 10 \lg (10^{A/10} + 10^{B/10} + 10^{C/10} + 10^{D/10} + \ldots\ldots) \text{ dB} \qquad \text{A1.2}$$

Frequency of sound

Frequency is analogous to musical pitch. It depends upon the rate of vibration of the air molecules which transmit the sound and is measured as the number of cycles per second or Hertz (Hz). The human ear is sensitive to sound in the range 20 Hz to 20 kHz. Examples of the frequency ranges of musical instruments and the human voice are shown in Figure A1.2. For acoustic engineering purposes, the frequency range is normally divided up into discrete bands. The most commonly used are octave and one-third octave bands.

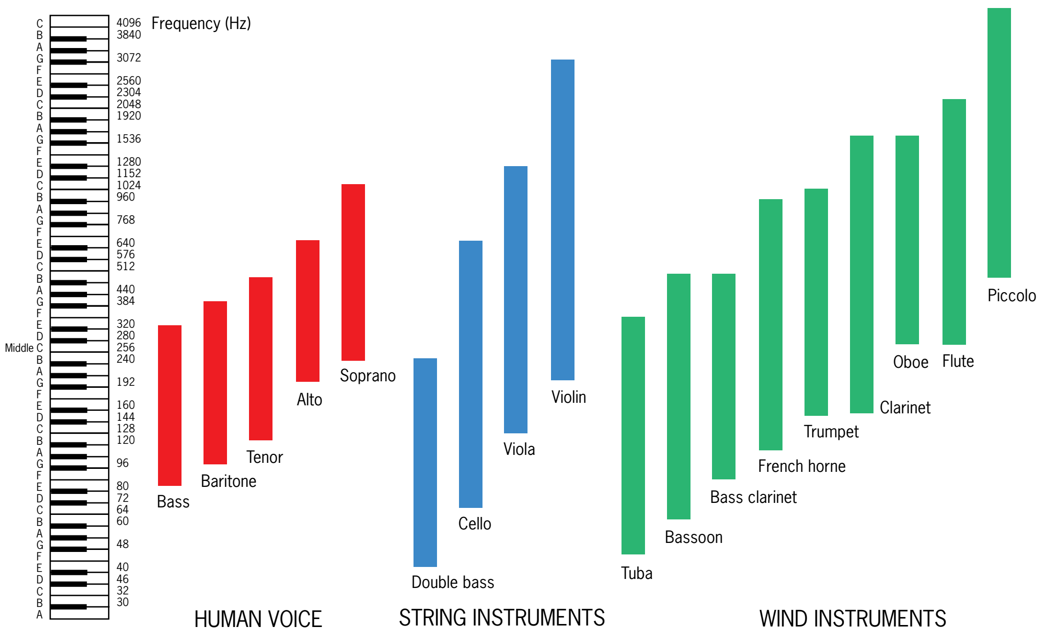
Octave bands

For an octave band the upper limiting frequency of each band is twice the lower limiting frequency. Octave bands are described by their centre frequency values and bands typically used for building acoustics purposes range from 63 Hz to 4 kHz.

One-third octave bands

Each octave band can be divided into three one-third octave bands. The one-third octave bands are described by their centre frequency values and bands typically used for building acoustics purposes range from 50 Hz to 5 kHz.

Figure A1.2: Frequency range of musical instruments and vocals



Octave band centre frequency (Hz)	63	125	250	500	1 k	2 k	4 k
A-weighting correction (dB)	–26.2	–16.1	-8.6	-3.2	0	1.2	1.0

Table A.1.1: A-weighting corrections

A-weighted levels

The sensitivity of the ear is frequency dependent. Sound level meters are fitted with a weighting network which approximates to this response and allows sound levels to be expressed as an overall single figure value, in dB(A). For clarity and convenience, the 'A' is often included in the acoustic descriptor, eg L_{Aeq}, rather than in brackets after the units. For example, A-weighted levels can be quoted as 55 dB L_{Aeq}.

The A-weighted level can also be calculated manually from octave band or one-third octave band data. For octave band data, see Table A1.1, values are added to the respective sound levels and the resulting values for all octave bands are combined logarithmically (using Equation A1.2)

Measurement of time-varying sounds

Most sounds are not steady and the sound pressure level fluctuates with time. Therefore, it is necessary to express the results of a measurement over a period of time in statistical terms. Some commonly used descriptors are discussed below.

Equivalent continuous sound level

The most widely used unit is the equivalent continuous A-weighted sound pressure level ($L_{Aeq,T}$). It is an energy average and is defined as the level of a notional sound which (over a defined period of time, T) would deliver the same A-weighted sound energy as the actual fluctuating sound.

Percentile level

A percentile level is the highest level exceeded for a certain percentage of a measurement period. The most commonly used percentile levels are:

$L_{A1,T}$ - This is the A-weighted level exceeded for 1% of the measurement period. It is often used to represent typical maximum levels that occur during the measurement period.

$L_{A10,T}$ - This is the A-weighted level exceeded for 10% of the measurement period. It is often used to represent the sound level from road traffic.

$L_{A90,T}$ - This is the A-weighted level exceeded for 90% of the measurement period. It is often used to represent the background level.

Maximum and minimum sound levels

$L_{Amax,T}$ is the maximum sound pressure level measured during the measurement period T. $L_{Amin,T}$ is the minimum sound pressure level measured during the measurement period T.

Sound level meter time constants

To give meaningful results, sound level meters use sound pressure levels averaged over short intervals (within the overall measurement period, T). Time constants for this averaging, defined in international standards, include 'fast' (125 ms) and 'slow' (1 s).

The percentile levels described above are affected by the choice of time constant. By definition, all percentile levels must be measured with the fast time constant.

$L_{Aeq,T}$ is not affected by the sound level meter time constant.

$L_{Amax,T}$ and $L_{Amin,T}$ can be measured with either fast or slow time constants so it is important that the results state which time constant has been used.

Reflection and absorption of sound

Once emitted from a source, sound waves in a room travel through the air until they reach a boundary surface or other obstacle. When a sound wave reaches a surface it will be partly reflected off the surface back into the room and continue travelling in a new direction, and it will be partly absorbed by the surface with the absorbed energy being dissipated as heat.

Absorption coefficient, α

The amount of sound energy that can be absorbed by a surface is given by its absorption coefficient, α. The absorption coefficient can take values in the range 0 to 1. A surface that absorbs no sound (ie a totally reflective surface) has an absorption coefficient of 0 and a surface that absorbs all sound incident upon it has an absorption coefficient of 1. Thus the higher the value of α, the more sound will be absorbed. In practice, most surfaces have values between 0 and 1. Some typical absorption coefficients are given in Table A6.1 and on the DfES acoustics website.

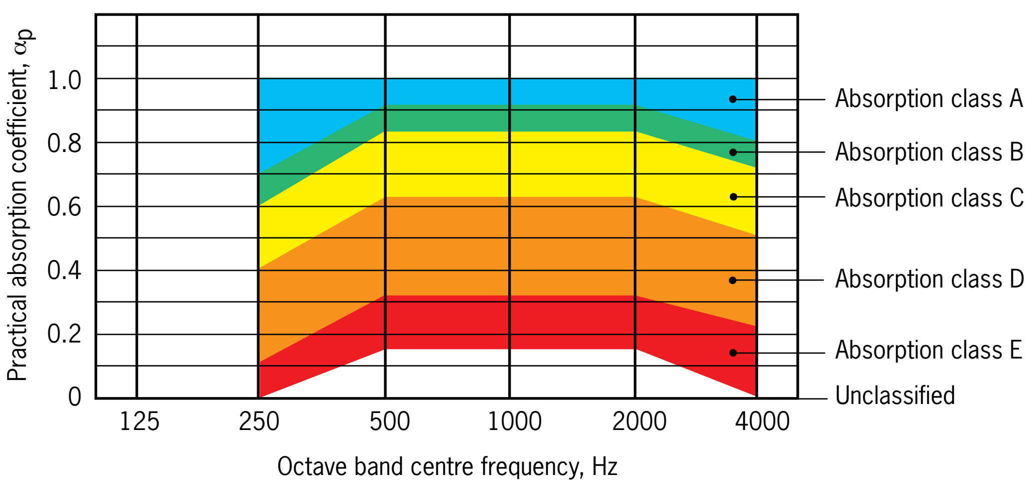
Absorption classes

The absorption of surfaces varies with frequency. Therefore, absorption coefficients are generally given for each octave band. A surface is categorised as being in a particular absorption class, A to E (according to BS EN ISO 11654:1997) depending on its absorption coefficients across the frequency range. To determine the absorption class the octave band values are plotted on a graph from BS EN ISO 11654:1997 as shown in Figure A2.1. Note that a very reflective surface may be unclassified.

Scattering coefficient, *s*

When sound is reflected from a surface it is partly reflected in a specular direction (ie the angle of incidence equals the angle of reflection) and partly scattered into other directions. The amount of reflected sound energy that will be scattered is given by the surface's scattering coefficient, *s*. This is in the range of 0 to 1 where a perfectly smooth surface giving pure specular reflection has a scattering coefficient of 0 and a very irregular surface scattering all sound away from the

Figure A2.1: Absorption classes from BS EN ISO 11654: 1997



specular direction has a scattering coefficient of 1. Scattering coefficients are a relatively new measure in room acoustics so there is little data currently available but they are important in room acoustics computer modelling.

Reverberation time, *T*

After being emitted from a source, sound waves are repeatedly reflected from room surfaces and, as a result of absorption, gradually reduce in strength. The reverberation time, *T*, of a space is a measure of the rate at which the sound decays. It is defined as the time taken for the reverberant sound energy to decay to one millionth of its original intensity (corresponding to a 60 dB reduction in the sound level).

The reverberation time is proportional to the volume of the room and inversely proportional to the quantity of absorption present:

$$T = 0.16\, V / \sum S_i \alpha_i \quad \text{s} \qquad \text{A2.1}$$

where S_i and α_i are respectively the surface area and absorption coefficient of each surface *i* in the room. An example of the application of this equation is given in Appendix 6.

Mid-frequency reverberation time, T_{mf}

The sound absorption of surfaces usually varies with frequency and therefore the reverberation time in a space also varies with frequency. Hence, values of *T* are normally given in frequency bands. In BB93 the reverberation time criteria are set in terms of the average value of the three octave bands, 500 Hz, 1 kHz, and 2 kHz, denoted as T_{mf}

$$T_{\text{mf}} = (T_{500} + T_{1\text{k}} + T_{2\text{k}}) / 3 \quad \text{s} \qquad \text{A2.2}$$

Other acoustic measures

Sound heard in a room generally comprises an extremely complicated combination of many reflected and scattered sound waves. This situation is made manageable by considering only the overall statistics of the sound field such as the reverberation time. Unfortunately, this does not convey all the intricate details of the sound field that determine peoples' subjective responses. There are many other measures used to represent various aspects of subjective response to room acoustics. For school acoustics there is a need to have criteria for subjective speech intelligibility for which the objective measure selected for BB93 is the Speech Transmission Index.

Speech Transmission Index, STI

The intelligibility of speech in a room is a complex function of the location of the speaker, the location of the listener, ambient noise levels, the acoustic characterisics of the space, and the loudness and quality of the speech itself. In addition, if a sound reinforcement system is used, it depends on the design and adjustment of this system. The Speech Transmission Index, STI, is an objective measure defined in BS EN 60268-16:1998, which accounts for all these factors.

To measure the STI, a special sound source is located at the position of the talker (with the normal microphone in place for any sound reinforcement system). The resulting signal is detected at the listening position. Signal processing using the modulation transfer function between transmitted and received signals is carried out to determine the STI.

STI is a value between 0 and 1, the higher the value, the better the speech intelligibility. Speech intelligibility ratings corresponding to STI values are as follows:

STI	Speech Intelligibility
0.1 to 0.3	Bad
0.3 to 0.45	Poor
0.45 to 0.6	Fair
0.6 to 0.75	Good
0.75 to 1	Excellent

Airborne sound insulation

Speech, AV systems, and musical instruments are all sources of airborne sound in buildings. Sound in a room (the source room) causes the surrounding surfaces, such as walls, ceilings and floors to vibrate. This vibration is transmitted through the building structure and radiated into other rooms (receiving rooms) in the building. Depending upon the building construction, varying amounts of energy are lost during the sound transmission process, resulting in airborne sound insulation between rooms. The greater the airborne sound insulation between two rooms, the lower the resulting sound level in the receiving room.

Measurement of airborne sound insulation

The site measurement procedures for airborne sound insulation are given in BS EN ISO 140-4:1998. Normally, pink noise or white noise is played through an amplifier and loudspeaker in the source room, to provide a high sound level across the frequency range of interest. The sound level in the source room must be high enough to ensure that the levels in the receiving room are above the background noise level.

The resulting sound levels in the source and receiving rooms are measured in one-third octave bands. As the sound levels vary with location, they are averaged either across a number of fixed microphone positions or by using a continuously moving microphone. The resulting time and space averaged sound levels are denoted L_1 in the source room and L_2 in the receiving room.

Level difference, *D*

D is the difference in sound levels in dB between the source room and the receiving room in one-third octave bands:

$$D = L_1 - L_2 \text{ dB} \qquad \text{A3.1}$$

This level difference depends on:

- direct sound transmission through the separating element (ie separating wall or floor)
- flanking sound transmission (see Section 3) through flanking elements (eg flanking walls, suspended ceilings, access floors etc)
- wall and floor dimensions
- reverberation time of the receiving room.

Standardized level difference, D_{nT}

The reverberation time, *T*, measured in a room may be significantly different from the value predicted at the design stage due to a lack of detailed knowledge of finishes, furniture and fittings and their absorption characteristics. This means that the predicted sound level difference, *D*, which depends on *T*, is also subject to change. To avoid problems, a reference reverberation time, T_o, can be used in predictions of *D*. When the building is constructed and *D* is measured, the measured reverberation time, *T*, is referenced to T_o. This gives the standardized level difference, D_{nT}.

$$D_{nT} = D + 10 \lg (T / T_o) \text{ dB} \qquad \text{A3.2}$$

BB93 standardized level difference, $D_{nT(T_{mf,max})}$

D_{nT} is widely used to set sound insulation criteria for dwellings, where T_o is taken as 0.5 seconds. Although BB93 uses D_{nT} in the sound insulation criteria for schools, a value of T_o = 0.5 seconds would not be appropriate for many school rooms. Hence, T_o is specified in BB93 as the maximum value of T_{mf} given in Table 1.5 of Section 1. This new descriptor for airborne sound insulation in schools is written as $D_{nT(T_{mf,max})}$ to highlight the alternative value of T_o that is used.

Sound reduction index, *R*

The sound reduction index, *R*, of an element such as a wall, floor, door or window describes the sound transmitted through that element. It is measured in a laboratory with suppressed flanking transmission. *R* varies with frequency and is expressed as a value for each one-third octave band or octave band.

Apparent sound reduction index, R'

Using field measurements of the level difference, D, it is possible to estimate the value of the sound reduction index, R, for a partition. However, because field measurements include flanking transmission, the resulting quantity is called the apparent sound reduction index, R'.

The apparent sound reduction index, R', of wall or floor constructions in schools (and all other buildings), is usually lower than the laboratory measured value of R. The difference between the results is usually due to flanking transmission and a lower standard of workmanship on site. Guidance on flanking transmission is given in Section 3. Problems due to workmanship can be reduced by close supervision during the construction process.

Weighted sound reduction indices and level differences R_w, R'_w, D_w, $D_{nT,w}$, $D_{nT(T_{mf,max})}$

Most constructions provide higher airborne sound insulation against mid and high frequency sounds (such as speech) than low frequency sounds (such as the bass in music). This typical characteristic is defined in BS EN ISO 717-1:1997 as a rating curve that can be applied to one-third octave band values of R, R', D, D_{nT} or $D_{nT(T_{mf,max})}$ from 100 Hz to 3.15 kHz. The rating curve is used to calculate the following single-number quantities: weighted sound reduction index, R_w; weighted apparent sound reduction index, R'_w; weighted level difference, D_w; weighted standardized level difference, $D_{nT,w}$; weighted BB93 standardized level difference $D_{nT(T_{mf,max})}$.

Impact sound insulation

In the case of impact sound, the building construction is caused to vibrate as a result of a physical impact, such as footsteps on floors or stairs. The resulting vibration is radiated into other rooms in the building.

Measurement of impact sound insulation

The site measurement procedures for impact sound insulation are given in BS EN ISO 140-7:1998. Impact sound insulation is measured using an ISO standard tapping machine, which consists of a series of hammers driven by an electric motor so as to produce a continuous series of impacts on the floor under consideration. The resulting sound level in the receiving room is measured in one-third octave bands. The receiving room is usually the space directly below the floor excited by the tapping machine, although the impact sound insulation can also be measured in other neighbouring rooms. As the sound levels will vary with location in the receiving room, they are averaged either across a number of fixed microphone positions or by using a continuously moving microphone.

Impact sound pressure level, L_i

The impact sound pressure level, L_i, is the time and space averaged sound pressure level in the receiving room, while the ISO standard tapping machine excites the floor or stairs above the receiving room.

Standardized impact sound pressure level L'_{nT}

The impact sound pressure level, L_i, depends on the reverberation time, T, of the receiving room. In the same way that D is standardized to give D_{nT} for airborne sound insulation to avoid changes caused by variations of T, an equivalent descriptor is defined for impact sound as the standardized impact sound pressure level, L'_{nT}:

$$L'_{nT} = L_i - 10 \lg (T / T_o) \text{ dB} \qquad \text{A3.3}$$

BB93 standardized impact sound pressure level $L'_{nT(T_{mf,max})}$

L'_{nT} is widely used for dwellings, where T_o is taken as 0.5 seconds. In a similar manner to airborne sound insulation for schools, a value of T_o = 0.5 seconds is not appropriate for many school rooms so T_o is specified in BB93 as the maximum value of T_{mf} given in Table 1.5 of Section 1. This new descriptor for impact sound insulation in schools is written as $L'_{nT(T_{mf,max})}$ to highlight the alternative value of T_o that is used.

Weighted standardized impact sound pressure levels $L'_{nT,w}$ and $L'_{nT(T_{mf,max}),w}$

To reduce the impact sound pressure level data from values in frequency bands to a single-number quantity, BS EN ISO 717-2:1997 contains a rating curve that can be applied to one-third octave band values of L'_{nT} or $L'_{nT(T_{mf,max})}$ from 100 Hz to 3.15 kHz. The rating curve is used to calculate the following single-number quantities: the weighted standardized impact sound pressure level, $L'_{nT,w}$ or the weighted BB93 standardized impact sound pressure level, $L'_{nT(T_{mf,max})}$.

It is important to note that impact sound insulation is measured in terms of an absolute sound level, so that a lower number indicates a better standard of impact sound insulation. This is the opposite of airborne sound insulation, which is based on differences in levels so that a higher number indicates a better standard of airborne sound insulation.

Appendix 4: Classroom sound insulation – sample calculations

Figure A4.1 shows a secondary school classroom adjacent to a science laboratory, plantroom and corridor. In this example, the designer has decided to build the separating walls between these spaces with masonry. The calculations below are used to determine the specification of the masonry wall (eg mass per unit area, thickness, surface finishes) required to meet the performance standards in Section 1.

There are three walls to consider:

- Wall 1 - between classroom and science laboratory
- Wall 2 - between classroom and corridor
- Wall 3 - between classroom and plantroom.

The performance standards for airborne sound insulation are contained in Section 1. For each of the three walls the following apply:

- The performance standard for Wall 1 is in terms of the weighted BB93 standardized level difference, $D_{nT(T_{mf,max}),w}$, in Table 1.2. To determine the blockwork specification, the weighted sound reduction index of the wall is estimated from $D_{nT(T_{mf,max}),w}$.

- The performance standard for Wall 2 is in terms of the weighted sound reduction index in Table 1.3.

- For Wall 3, between the plantroom and the classroom, there are no explicit performance standards in Section 1. Therefore the sound insulation between the plantroom and the classroom needs to ensure that the performance standards are met for the indoor ambient noise level in the adjacent classroom (Table 1.1). The sound insulation is calculated using the noise levels of the actual equipment in the plantroom.

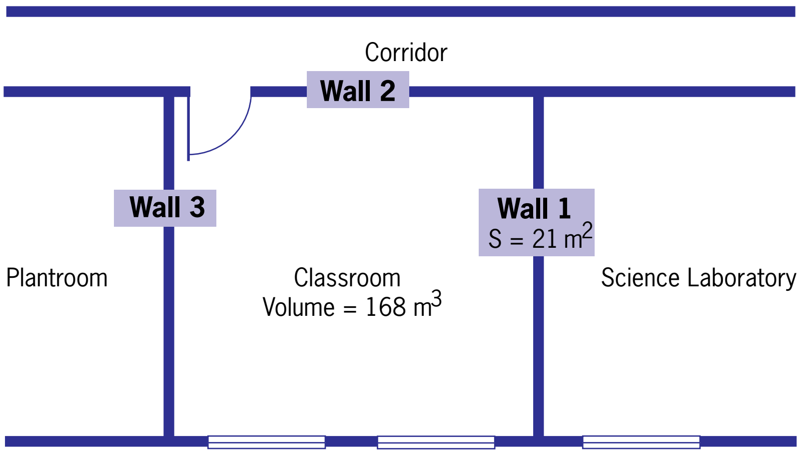


Figure A4.1: Plan of secondary school classroom and adjacent spaces

Wall 1

From Tables 1.1, 1.2 and 1.5 in Section 1 the minimum performance standards for the airborne sound insulation are:

Classroom to Science Laboratory:
40 dB $D_{nT(0.8s),w}$

Science Laboratory to Classroom:
45 dB $D_{nT(0.8s),w}$

As the two room dimensions are similar and the values of $T_{mf,max}$ are both 0.8 s, the specification for the masonry wall is based on the more stringent criterion, 45 dB $D_{nT(0.8s),w}$.

As an initial estimate, the procedure described in Section 3.10 can be used to estimate the weighted sound reduction index, R_w, for the separating wall. The first stage is to calculate $R_{w,est}$.

$$R_{w,est} = D_{nT(Tmf,max),w} + 10 \lg (S \times T_{mf,max} / V) + 8 \text{ dB}$$

$$R_{w,est} = 45 + 10 \lg (21 \times 0.8 / 168) + 8 \text{ dB}$$

$$R_{w,est} = 43 \text{ dB}$$

To obtain R_w the factor X is added to $R_{w,est}$ to account for less favourable mounting conditions and workmanship than in the laboratory test. From Section 3.10, X can be estimated to be 5 dB.

$$R_w = R_{w,est} + X \text{ dB}$$

$$R_w = 43 + 5 \text{ dB}$$

$$R_w = 48 \text{ dB}$$

Therefore, suitable specifications for masonry separating walls and appropriate surface finishes that achieve at least 48 dB R_w can be identified by the designer.

Wall 2

The performance standards for the airborne sound insulation of the corridor wall and door are given in Table 1.3:

Wall between a classroom and a corridor:
40 dB R_w

Door between a classroom and a corridor:
30 dB R_w

In this example there are no ventilators or glazing in the wall. If there were ventilators then they would have to meet the performance standard in Table 1.3. Glazing in the corridor wall does not have a separate performance standard because the performance standard for the wall is for the combined sound insulation of any glazing and the wall. An example of a corridor wall with glazing is included at the end of this appendix.

From Section 3, Figure 3.11, a 44 mm thick timber door with half hour fire rating typically achieves 30 dB R_w if it is "a well fitted solid core doorset where the door is sealed effectively around its perimeter in a substantial frame with an effective stop".

Blockwork Specification

The minimum R_w values for the walls are:

Wall 1: 48 dB R_w
Wall 2: 40 dB R_w

Figure 3.9 can be used to draw up an initial specification for the walls along with laboratory test reports from the manufacturer. For Wall 1 and Wall 2 the following specifications might be proposed:

Wall 1: 100 mm medium density blocks (140 kg/m^2) with a 13 mm plaster finish on both sides

Wall 2: 100 mm low density block (70 kg/m^2) with a 13 mm plaster finish on both sides

The R_w specification for Wall 1 is only an estimate of the type of separating wall performance needed to achieve 45 dB $D_{nT(0.8s),w}$ and takes no account of flanking transmission which is usually critical in determining the performance. Therefore, at this stage the designer should seek specialist advice from an acoustic consultant to assess whether the proposed combination of separating and flanking walls is likely to achieve the performance standards.

Wall 3

Wall 3 has to provide sufficient sound insulation to ensure that the indoor ambient noise levels in the classroom do not exceed 35 dB $L_{Aeq,30min}$ (Table 1.1). As there will be other noise sources contributing to the indoor ambient noise level, the level due to noise transmitted through Wall 3 will have to be significantly less than 35 dB $L_{Aeq,30min}$. BB93 does not recommend a standard method for this situation but one approach is to design Wall 3 so that the noise transmitted from the plantroom is at least 10 dB below the indoor ambient noise level in the classroom. Using this method, the noise transmitted through Wall 3 needs to be less than 25 dB $L_{Aeq,30min}$ in the classroom.

The noise transmitted from the plantroom to the classroom depends on the frequency spectrum of the noise in the plantroom and the sound insulation spectrum of the separating wall. For these calculations, plantroom equipment locations and noise emission data are required. Precise equipment details are usually not known until the later stages of a project, therefore generic sound level data are normally used in calculations and the assumptions quoted in the specification.

The calculations are often complex and normally require an acoustic consultant. Guidance for these calculations can be found in the following references:

CIBSE (2002). Guide B5: Noise and Vibration Control for HVCA. CIBSE. ISBN 1903287251.
Fry, A. ed. (1988). Noise control in building services. Oxford: Pergamon. ISBN 0080340679.

Wall 2 with glazing

Walls between classrooms and corridors may contain glazing, therefore this example is a reassessment of Wall 2 with the following areas:

	Area
Masonry	16.6 m^2
Glazing	5.6 m^2
Door	1.8 m^2
Total wall	24 m^2

The door is treated in the same way as in the example above with a value of 30 dB R_w.

The combined R_w criterion for the masonry wall and the glazing also remains at 40 dB R_w.

This combined criterion would be achieved if the masonry wall and the glazing each provide at least 40 dB R_w. A masonry wall specification for this has already been described above and there are three glazing configurations given in Figure 3.10, which also provide 40 dB R_w. However, these glazing configurations can sometimes be relatively expensive due to the use of thick and/or laminated glass and/or wide cavities.

An alternative approach is to improve the masonry wall specification to allow the use of another glazing configuration.

From Figure 3.9 the following masonry wall should give at least 45 dB R_w: 100 mm medium density blocks (140 kg/m^2) with a 13mm plaster finish on each side.

From Figure 3.8, glazing with different R_w values can be assessed to see whether the criterion of 40 dB R_w will be met by the combined value for the wall and glazing. A potential solution would be to use glazing with sound insulation of 35 dB R_w. This is 10 dB lower than the 45 dB R_w sound insulation of the masonry wall. For a glazing area of 25% of the wall area that excludes the door, Figure 3.8 gives a correction factor of approximately 5 dB. The combined R_w is calculated from the R_w for the glazing plus the correction factor, which equals 40 dB R_w. Hence this combination of masonry wall and glazing meets the performance standard. Further reductions in glazing specification could be obtained by reducing the area of glazing or by using a wall with a higher R_w.

This appendix describes two methods that can be used to calculate the indoor ambient noise level due to external noise as described in Section 3. The first method calculates the indoor ambient noise level according to the principles of BS EN 12354-3:2000. The second method calculates the indoor ambient noise level using the measured façade sound insulation data from an identical construction at another site.

Principles of the calculation method based on BS EN 12354-3:2000

This section describes the calculation procedure based on BS EN 12354-3:2000.

The chosen frequency range should include all frequency bands that determine the indoor ambient noise level, $L_{Aeq,30min}$. However, for many external noise levels, it is appropriate to calculate the façade insulation using octave bands between 125 Hz and 2 kHz.

Two main equations are used to calculate the internal level in each frequency band.

The first equation gives the internal level due to sound transmission through an element of the building envelope:

$$L_2 = L_{1,in} - R + 10\lg(S/V) + 11 + 10\lg T \text{ dB} \qquad \text{A5.1}$$

where

L_2 is the internal level due to the sound transmitted through the element (dB)
$L_{1,in}$ is the external free-field sound level incident on the element (dB)
R is the sound reduction index of the element (dB)
S is the internal surface area of the element (m^2)
V is the room volume (m^3)
T is the room reverberation time (s).

The second equation gives the internal level due to sound transmission through a ventilator installed in the building envelope:

$$L_2 = L_{1,in} - D_{n,e} - 10\lg V + 21 + 10\lg T \text{ dB} \qquad \text{A5.2}$$

where
$D_{n,e}$ is the element-normalised sound level difference of the ventilator (dB).

The overall A-weighted internal level is obtained by combining (as in Equation A1.2) the contributions from all elements and ventilators within each frequency band, adding the relevant A-weighting correction to each resultant frequency band level, and then combining all the A-weighted frequency band levels together.

Elements: Laboratory sound insulation data

Laboratory testing of building elements should be conducted in accordance with BS EN ISO 140-3:1995 to obtain the required sound reduction index, R.

Ventilators: Laboratory sound insulation data

Laboratory testing of ventilator units should be conducted in accordance with BS EN 20140-10:1992 to obtain the required element-normalized level difference, $D_{n,e,w}$.

Some ventilators may have the facility to control the air flow rate, either by being fully opened or fully closed, or by having some form of variable control. In such cases calculations should be based on the performance in the fully open position.

The mounting position of ventilators, for example in the middle or near an edge of a wall, or in a corner, affects the airborne sound insulation. Manufacturers' data on ventilators should give information on the position of the ventilator during the laboratory test according to BS EN 20140-10:1992. This should be used to ensure that the laboratory mounting position is representative of the mounting position in the field.

Some ventilators are available in a variety of sizes but performance data may correspond only to one size. In such cases an estimate can be made for the area correction, A_c, to be added to each frequency band $D_{n,e}$ value. The area correction A_c in dB is given by:

$$A_c = 10 \lg (A_{ref} / A_{actual}) \text{ dB} \qquad \text{A5.3}$$

where
A_{ref} is the area in m^2 of the ventilator from the laboratory sound insulation test
A_{actual} is the area in m^2 of the ventilator to be used.

Excel spreadsheet

An Excel spreadsheet to calculate the sound insulation of building envelopes based on BS EN 12354-3:2000 is available via the DfES acoustics website. This Excel spreadsheet allows users to select from a range of typical building elements and ventilators and enter data obtained from laboratory tests of elements or ventilators.

The spreadsheet provides two options, A and B, to calculate internal levels using octave bands between 125 Hz and 2 kHz.

Option A allows the user to enter measured free-field octave band data as a 'user-defined spectrum'. Option A is the preferred option. However, if measured data are not available then option B can be used to give an estimate based upon an A-weighted value and an assumed spectrum shape, either C or C_{tr} from BS EN ISO 717-1:1997. Estimations using option B can be useful with some prediction methods such as CRTN for road traffic noise and CRN for railway noise, which generate only A-weighted levels. The user can enter external free-field L_{Aeq} levels and choose from the generic spectra described in BS EN ISO 717-1:1997. The C spectrum (Spectrum No. 1) is used to represent railway traffic at medium and high speed, and road traffic travelling at greater than 80 km/h. The C_{tr} spectrum (Spectrum No. 2) is used to represent noise from urban road traffic, jet aircraft at large distances, propeller driven aircraft, and railway traffic at low speeds.

Spectra of aircraft noise at relatively close distances are likely to depend greatly on aircraft type and operation, and specialist advice should be sought.

Principles of the calculation method based on field test data

This section describes the calculation of the indoor ambient noise level using the measured façade sound insulation data from an identical construction at another site.

The chosen frequency range should include all frequency bands that determine the indoor ambient noise level, $L_{Aeq,30min}$. However, for many external noise levels, it is appropriate to calculate the façade insulation using octave bands between 125 Hz and 2 kHz.

Field tests of building envelope insulation according to BS EN ISO 140-5:1998 give results in frequency bands expressed as the standardized level difference, $D_{2m,nT}$.

The internal level in each frequency band may be calculated according to the following equation:

$$L_2 = L_{1,in} - D_{2m,nT} + 6 + 10\lg T \text{ dB} \qquad \text{A5.4}$$

where
L_2 is the internal level due to the sound transmitted through the facade (dB)
$L_{1,in}$ is the external free-field sound level incident on the facade (dB)
$D_{2m,nT}$ is the standardized level difference (dB)
T is the room reverberation time (s).

The overall A-weighted internal level is obtained by adding the relevant A-weighting to each frequency band level, and then combining all the A-weighted frequency band levels, according to Equation A1.2.

Appendix 6: Calculation of room reverberation times

For empty rooms with volumes less than 200 m^3, simple room geometry and a reasonable distribution of sound absorption, the reverberation time, T, can be calculated using Sabine's formula and absorption coefficients appropriate to the room surfaces as shown below.

$$T = \frac{0.16V}{A} \text{ seconds}$$

where V is the volume of the room in m^3 and A is the absorption area in the room in m^2.

Table 1.5 gives the recommended mid-frequency reverberation times for rooms. The mid-frequency reverberation time, T_{mf}, is the arithmetic average of the reverberation times in the 500 Hz, 1000 Hz and 2000 Hz octave bands.

$$T_{mf} = \frac{T_{500\text{ Hz}} + T_{1000\text{ Hz}} + T_{2000\text{ Hz}}}{3} \text{ s}$$

For n surfaces in a space, the total absorption area, A, can be found using the following equation:

$$A = \alpha_1 S_1 + \alpha_2 S_2 + \ldots + \alpha_n S_n$$

where $\alpha_1,\ldots,\alpha_n$ are the absorption coefficients of the different surfaces in the room and $S_1,\ldots,S_n$ are the areas of the surfaces having absorption coefficients $\alpha_1\ldots\alpha_n$.

Absorption coefficients can be obtained from the spreadsheet on the DfES acoustics website and/or from manufacturers' data. Values for some common materials, used in the worked example which follows, are given in Table A6.1.

Two decimal places should be used for the absorption coefficient values for calculations.

In empty teaching rooms with volumes less than 200 m^3 and simple room geometry, the absorption area, A, needed to give the required reverberation time, T, can be obtained by rearranging Sabine's formula as follows:

$$A = \frac{0.16V}{T} \text{ m}^2$$

For such rooms the formula can also be used to estimate the amount of additional

Note: Reverberation time calculations using Sabine's formula in all octave bands can be carried out using the method illustrated in the worked example that follows. However, neglecting air absorption slightly underestimates the equivalent sound absorption area in a room.

Table A6.1: Absorption coefficient data for some common materials

Material	Sound absorption coefficient, α 250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
Fair-faced concrete or plastered masonry	0.01	0.01	0.02	0.02	0.03
Fair-faced brick	0.02	0.03	0.04	0.05	0.07
Painted concrete block	0.05	0.06	0.07	0.09	0.08
Windows, glass façade	0.08	0.05	0.04	0.03	0.02
Doors (timber)	0.10	0.08	0.08	0.08	0.08
Glazed tile/marble	0.01	0.01	0.01	0.02	0.02
Hard floor coverings (eg linoleum, parquet) on concrete floor	0.03	0.04	0.05	0.05	0.06
Soft floor coverings (eg carpet) on concrete floor	0.03	0.06	0.15	0.30	0.40
Suspended plaster or plasterboard ceiling (with large airspace behind)	0.15	0.10	0.05	0.05	0.05

absorption area required to give a desired mid frequency reverberation time. (Note that the absorption due to any surface that is to be covered with additional absorption must be discounted.)

The procedure is illustrated in the worked example shown below.

Specialist advice may be needed for large (>200 m^3) rooms or rooms where music is to be performed

Worked example

A school laboratory is required to have a mid-frequency reverberation time of less than 0.8 seconds. The room is rectangular in plan, is 7 m wide, 9 m deep and has a ceiling height of 3 m. There is one door and the glazing is located in one of the 7 m x 3 m walls. The room volume is 7 m x 9 m x 3 m = 189 m^3. The glazing has an area of 6 m^2 and the door has an area of 2 m^2.

Step 1 Calculate the surface area related to each material in the room (ie floor, walls, doors, ceiling and windows)

Surface	Surface finish	Area (m^2)
Floor	Hard floor covering	63
Door	Timber	2
Walls (excluding door and glazing areas)	Painted concrete block	88
Ceiling	Suspended plaster	63
Windows	Glass	6

Step 2 Obtain values of absorption coefficients for the room surfaces. In this case, the values are taken from Table A6.1.

		Absorption coefficient α		
Surface	**Area (m^2)**	**500 Hz**	**1000 Hz**	**2000 Hz**
Floor	63	0.04	0.05	0.05
Door	2	0.08	0.08	0.08
Walls	88	0.06	0.07	0.09
Ceiling	63	0.10	0.05	0.05
Windows	6	0.05	0.04	0.03

Step 3 Calculate the absorption area (m^2) related to each surface in octave frequency bands (Absorption area = surface area × absorption coefficient)

		Absorption area (m^2)		
Surface	**Area (m^2)**	**500 Hz**	**1000 Hz**	**2000 Hz**
Floor	63	63 × 0.04 = 2.52	63 × 0.05 = 3.15	63 × 0.05 = 3.15
Door	2	0.16	0.16	0.16
Walls	88	5.28	6.16	7.92
Ceiling	63	6.30	3.15	3.15
Windows	6	0.30	0.24	0.18

Step 4 Calculate the sum of the absorption areas (m^2) obtained in Step 3

	500 Hz	1000 Hz	2000 Hz
Total absorption area (m^2)	14.56	12.86	14.56

Step 5 Calculate the reverberation time for the room using Sabine's formula

	500 Hz	1000 Hz	2000 Hz
$T = \frac{0.16V}{A}$ seconds	2.08	2.35	2.65

Step 6 Calculate the mid-frequency reverberation time (T_{mf}) from the reverberation times in the 500 Hz, 1000 Hz and 2000 Hz octave bands.

$$T_{mf} = \frac{2.08 + 2.35 + 2.65}{3} = 2.36 \text{ seconds}$$

This reverberation time exceeds the required value.

Step 7 Identify a sound absorbing material that is suitable for use in a school laboratory and determine the best position for the material.

A manufacturer produces a non-flammable sound absorbing material that can be cleaned relatively easily. The following absorption coefficient data is provided for the material.

	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
α	0.20	0.45	0.85	1.00	1.32

Because the room is used as a laboratory, it is decided that the most appropriate place for the sound absorbing material is on the ceiling or high on the walls.

Step 8 Estimate the required area of the sound absorbing material and calculate the mid-frequency reverberation time when it is in place.

As a first estimate, it is decided to cover the entire ceiling with the sound absorbing material. The total absorption areas in the 500 Hz, 1000 Hz and 2000 Hz octave frequency bands are then calculated.

		Absorption area (m^2)		
Surface	**Area (m^2)**	**500 Hz**	**1000 Hz**	**2000 Hz**
Floor	63	2.52	3.15	3.15
Door	2	0.16	0.16	0.16
Walls	88	5.28	6.16	7.92
Ceiling	63	63.0 x 0.45 = 28.35	63 x 0.85 = 53.55	63 x 1.00 = 63.00
Windows	6	0.30	0.24	0.18
Total absorption area		36.61	63.26	74.41
		Reverberation time (s)		
$T = \frac{0.16V}{A}$ seconds		0.83	0.48	0.41

Note: Because the mid-frequency reverberation time is required, calculations need only be conducted in the 500 Hz, 1000 Hz and 2000 Hz octave bands. However, should reverberation times need to be calculated for all octave bands, the calculation method is the same as that illustrated for each octave band.

Step 9 Calculate the new mid-frequency reverberation time.

$$T_{mf} = \frac{0.83 + 0.48 + 0.41}{3} = 0.57 \text{ seconds}$$

This reverberation time meets the reverberation time requirements in Section 1.1 for the school laboratory.

Appendix 7: Calculation of sound absorption required in corridors, entrance halls and stairwells

Approved Document E contains guidance on the addition of sound absorption to common areas in buildings containing dwellings. Where the addition of sound absorption to common areas in schools, such as corridors, entrance halls or stairwells, is required, it is advised that the approach described in Approved Document E be used.

Approved Document E describes two methods, A and B, for controlling reverberation in common internal parts of buildings. These methods are reproduced below from Approved Document E.

Method A

For entrance halls, corridors or hallways, cover an area equal to or greater than the floor area, with a Class C absorber or better. It will normally be convenient to cover the ceiling area with the additional absorption.

For stairwells or a stair enclosure, calculate the combined area of the stair treads, the upper surface of the intermediate landings, the upper surface of the landings (excluding ground floor) and the ceiling area on the top floor.

Either, cover at least an area equal to this calculated area with a Class D absorber, or cover an area equal to at least 50% of this calculated area with a Class C absorber or better. The absorptive material should be equally distributed between all floor levels. It will normally be convenient to cover the underside of intermediate landings, the underside of the other landings, and the ceiling area on the top floor.

Method A can generally be satisfied by the use of proprietary acoustic ceilings. However, the absorptive material can be applied to any surface that faces into the space.

Method B

In comparison with Method A, Method B takes account of the existing absorption provided by all surfaces. In some cases, Method B should allow greater flexibility and require less additional absorption than Method A.

For an absorptive material of surface area S in m^2, and sound absorption coefficient, α, the absorption area A is equal to the product of S and α. The total absorption area, A_T, in square metres is defined as the hypothetical area of a totally absorbing surface, which if it were the only absorbing element in the space would give the same reverberation time as the space under consideration.

For n surfaces in a space, the total absorption area, A_T, can be found using the following equation.

$$A_T = \alpha_1 S_1 + \alpha_2 S_2 + ... + \alpha_n S_n$$

For entrance halls, provide a minimum of 0.20 m^2 total absorption area per cubic metre of the volume. The additional absorptive material should be distributed over one or more of the surfaces.

For corridors or hallways, provide a minimum of 0.25 m^2 total absorption area per cubic metre of the volume. The additional absorptive material should be distributed over one or more of the surfaces.

Absorption areas should be calculated for each octave band between 250 Hz and 4 kHz inclusively.

Absorption coefficient data (to two decimal places) should be determined as follows:

For specific products, use laboratory measurements of absorption coefficient data determined using BS EN 20354:1993 Acoustics – Measurement of sound absorption in a reverberation room. The measured third octave band data should be converted to practical sound absorption coefficient data, α_p in octave bands, according to BS EN ISO 11654:1997 Acoustics – Sound absorbers for use in buildings – Rating of sound absorption.

For generic materials, use the octave band data in Table 7.1 of Approved Document E or the more comprehensive data on the DfES acoustics website. These contain typical absorption coefficient data for common materials used in buildings and may be supplemented by other published data.

Appendix 7: Calculation of sound absorption required in corridors, entrance halls and stairwells

Worked example

A school has an entrance hall that has parquet on a concrete floor (7 m x 5 m) with a ceiling height of 3.2 m. The ceiling area is equal to that of the floor. The 5 m x 3.2 m façade is completely glazed and incorporates a glass door. Wooden doors having a total surface area of 2.4 m x 2.7 m lead to the corridor described below. The walls are of fair-faced brick.

The corridor has equal floor and ceiling areas of 20 m x 2.4 m and a ceiling height of 2.7 m. The 20 m x 2.7 m external wall of the corridor has half its surface area (27 m^2) glazed. The corridor has parquet on a concrete floor and its unglazed walls are of painted concrete blocks.

Each end of the corridor consists of wooden doors, of surface area 2.4 m x 2.7 m. In addition there are two wooden doors, each of area 2 m x 1.8 m, leading to classrooms off the corridoor.

The sound absorption coefficients necessary to control reverberation in the two spaces using Method B are calculated as shown below.

Example calculation for an entrance hall (Method B)

Step 1 Calculate the surface area related to each absorptive material (ie for the floor, walls, doors and ceiling).

Surface	Surface finish	Area (m^2)
Floor	Parquet on concrete	35.00
Doors (wooden)	Timber	6.48
Walls (excluding door area)	Fair-faced brick	54.32
Façade (and door)	Glazing	16.00
Ceiling	*To be determined*	35.00

Step 2 Obtain values of absorption coefficients for the floor, walls, glazing and doors. (The values below are taken from Table 7.1 of Approved Document E.)

Surface	Area (m^2)	Absorption coefficient (α) in octave frequency bands				
		250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
Floor	35.00	0.03	0.04	0.05	0.05	0.06
Doors (wooden)	6.48	0.10	0.08	0.08	0.08	0.08
Walls	54.32	0.02	0.03	0.04	0.05	0.07
Glazing (façade & door)	16.00	0.08	0.05	0.04	0.03	0.02
Ceiling	35.00	*To be determined*				

Step 3 Calculate the absorption area (m^2) related to each surface in octave frequency bands.
(Absorption area = surface area x absorption coefficient)

Surface	Absorption area (m^2)				
	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
Floor	1.05	1.40	1.75	1.75	2.10
Doors (wooden)	0.65	0.52	0.52	0.52	0.52
Walls	1.09	1.63	2.17	2.72	3.80
Glazing (façade and door)	1.28	0.80	0.64	0.48	0.32

Step 4 Calculate the sum of the absorption areas (m^2) obtained in Step 3

	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
Total absorption area (m^2)	4.07	4.35	5.08	5.47	6.74

Step 5 Calculate the total absorption area (A_T) required for the entrance hall.
The volume is 112 m^3 and therefore $A_T = 0.2 \times 112.0 = 22.4\ m^2$.

Step 6 Calculate additional absorption area (m^2) to be provided by the ceiling. If values are negative in any octave band then there is sufficient absorption from the other surfaces to meet the requirement without any additional absorption in this band.
(Additional absorption = A_T –total absorption area (from Step 4))

	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
Additional absorption area (m^2)	18.33	18.05	17.32	16.93	15.66

Step 7 Calculate required absorption coefficient (α) to be provided by ceiling
(α = Additional absorption area / area of ceiling)

	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
Required absorption coefficient	0.52	0.52	0.49	0.48	0.45

Step 8 Identify a ceiling product from manufacturers' laboratory measurement data that provides absorption coefficients that exceed the values calculated in Step 7.

Example calculation for a corridor (Method B)

Step 1 Calculate the surface area related to each absorptive material (ie for the floor, walls, doors and ceiling).

Surface	Surface finish	Area (m^2)
Floor	Parquet on concrete base	48.00
Glazing		27.00
Doors	Timber	20.16
Wall (excluding door area and glazing)	Painted concrete block	73.80
Ceiling	*To be determined*	48.00

Step 2 Obtain values of absorption coefficients for the floor, walls, glazing and doors. (The values below are taken from Table 7.1 of Approved Document E.)

		Absorption coefficient (α) in octave frequency bands				
Surface	**Area**	**250 Hz**	**500 Hz**	**1000 Hz**	**2000 Hz**	**4000 Hz**
Floor	48.00	0.03	0.04	0.05	0.05	0.06
Glazing	27.00	0.08	0.05	0.04	0.03	0.02
Doors	20.16	0.10	0.08	0.08	0.08	0.08
Wall (excluding door area and glazing)	73.80	0.05	0.06	0.07	0.09	0.08
Ceiling	48.00	*To be determined*				

Step 3 Calculate the absorption area (m^2) related to each surface in octave bands.
(Absorption area = surface area x absorption coefficient)

	Absorption area (m^2)				
	250 Hz	**500 Hz**	**1000 Hz**	**2000 Hz**	**4000 Hz**
Floor	1.44	1.92	2.40	2.40	2.88
Glazing	2.16	1.35	1.08	0.81	0.54
Doors	2.02	1.61	1.61	1.61	1.61
Wall (excluding door area and glazing)	3.69	4.43	5.17	6.64	5.90

Step 4 Calculate the sum of the absorption areas (m^2) obtained in Step 3

	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
Total absorption area (m^2)	9.31	9.31	10.26	11.46	10.93

Step 5 Calculate the total absorption area (A_T) required for the corridor.
The volume is 129.6 m^3 and therefore A_T = 0.25 x 129.6 = m^2.

Step 6 Calculate additional absorption area (m^2) to be provided by ceiling. If values are negative in any octave band then there is sufficient absorption from the other surfaces to meet the requirement without any additional absorption in this band.
(Additional absorption = A_T – total absorption area (from Step 4))

	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
Additional absorption area (m^2)	23.09	23.09	22.14	20.94	21.47

Step 7 Calculate required absorption coefficient (α) to be provided by ceiling
(α = Additional absorption area / area of ceiling)

	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
Required absorption coefficient	0.48	0.48	0.46	0.44	0.45

Step 8 Identify a ceiling product from manufacturers' laboratory measurement data that provides absorption coefficients that exceed the values calculated in Step 7.

Standard loudspeakers

A standard specification for loudspeakers is difficult, since there are circumstances when specialised solutions are required. The specification provided below is a general recommendation for typical loudspeakers used in a set of four to six in a classroom within the normal range of sizes.

Specification Descriptor	Standard Symbol	Recommended value or range	Comments
Characteristic sensitivity	L_p	>85 dB @ 1 W	
RMS power		>10 W continuous band limited pink noise 150 Hz to 8 kHz	
Frequency response		+/– 3 dB over range 150 Hz to 8 kHz	
Coverage angle		Min 90° H x 60° V Min 90° H x 90° V	Wall mounting type Ceiling mounting type
Loudspeaker type		2-way, 100 V preferred	Must be matched to amplifier and system suitably wired.
Enclosure		Flame retarding for wall mounted applications. Fire rated back enclosure for all ceiling loudspeakers that penetrate a fire rated ceiling. Acoustically rated back enclosure for all ceiling loudspeakers that penetrate a ceiling separating classroom floors.	
Brackets		Brackets for wall mounted enclosures should provide lockable adjustment vertically and horizontally. Fixing to wall and loudspeaker to be a minimum of two secure screws or bolts each. Secondary safety bond to be provided between loudspeaker and mounting surface.	

NXT or other distributed mode loudspeakers

These loudspeakers use new and emerging technology. An 'exciter' causes a panel to vibrate and the panel emits sound. The characteristics of the exciter, its location on the panel and the panel material are all important for correct operation. Products include ceiling tiles, wall mounting posters, projection screens and whiteboards that serve also as loudspeakers. There are advantages in the use of these loudspeaker types, as they provide a better average sound coverage in a room and provide a better average speech intelligibility under some conditions. The reason for this is not fully understood. Fewer NXT type loudspeakers are required, and it may be found that one wall mounted whiteboard model will suffice for the smaller classroom.

Specification Descriptor	Standard Symbol	Recommended value or range	Comments
Characteristic sensitivity	L_p	>85 dB @ 1 W	
RMS power		>10 W continuous band limited pink noise 150 Hz to 8 kHz	
Frequency response		+/– 3 dB over range 150 Hz to 8 kHz	
Coverage angle		Average 120° H x 120° V	
Loudspeaker type		100 V preferred for ceiling type as several will be connected in parallel.	Must be matched to amplifier and system suitably wired.
Enclosure		Most require no enclosure, but usually have to be spaced away from the wall on a mounting frame. Units for classroom use should be of Class 1 or better for spread of flame. Where used in an acoustically separating ceiling, provision must be made to maintain the sound insulation behind the loudspeakers.	
Brackets		Adjustment of aiming angle is not necessary. Brackets must provide a minimum of two fixing points.	

Mixer Amplifier

Specification Descriptor	Standard Symbol	Recommended value or range	Comments
Inputs	1 mic/line 1 stereo line 1 mic/line	Mic (-50 dBu sensitivity) line (-10 dBu sensitivity) switchable Stereo phono or 3.5 mm jack (-10 dBu sensitivity) Min/line switchable as above	• 1 mono, compatible with teacher radio microphone receiver • 1 stereo (mixed to mono), to enable music playback, connection to computer audio output. Alternatively built-in cassette player • Prefer minimum of 1 additional mono input to enable second microphone for class discussion use when child using personal FM system is present.
Equivalent input noise	Mic input	<-110 dB	
Frequency response		+/– 3 dB over range 80 Hz to 15 kHz	Mic or line input
Outputs	1 line level 1 speaker	-10 dBu, unbalanced, phono or mini-jack continuous band limited pink noise 150 Hz to 8 kHz 100 V, 40 W continuous band limited pink noise 150 Hz to 8 kHz	For connection of personal FM or induction loop amplifier. Can be formed by resistively attenuating the speaker output. For connection of 100 V type loudspeakers. Amplifiers are available with both low impedance and 100 V outputs. Usually only one should be used at a time. Amplifier MUST match with type of loudspeaker used.
Dynamic range		>75 dBA from amplifier noise floor to clipping point	Allows for usable listening range and scope for adjustment of controls.
Distortion	THD+N	< 2% from 150 Hz to 8 kHz	
Equalisers	Bass Treble	min +/– 6 dB variation @ approx 100 Hz min +/– 6 dB variation @ approx 10 kHz	Minimum 2 band equaliser operating on the mixed output signal. Preferred minimum 2 band equaliser operating on each input.
Hum and noise		>85 dB below maximum output level	Under normal range of control settings.

Radio Microphone System

A diversity receiver is preferred. See sidebar for further details.

Specification Descriptor	Standard Symbol	Recommended value or range	Comments
System main parameters		Wideband FM Radio Microphone System operating in the VHF high band channels allocated for use in personal FM systems.	These channels are provided for service to the hearing impaired without requirement for a licence.
		Must conform to IR 2030, published by the Radiocommunications Agency under the category Short Range Devices. See www.radio.gov.uk for latest standards.	
		If necessary to accommodate a large number of channels within a single school or site, licensed radio microphone units operating in the UHF band can be used.	These channels require a licence, with an associated annual fee.
Channel selection		It is preferred that the system has a user programmable channel selection.	This enables a spare unit to support all units within a school or group of schools. Also enables channels to be easily changed in the event of interference or the desire to tune the system to match a compatible personal FM receiver brought in by a student.
Microphone input		Compatible with plug-in dynamic and electret microphones. Robust connector with locking mechanism and high quality cable retention is required. A permanently wired microphone is not acceptable.	
Transmitter antenna connection		Can be used with a ¼ wave cable antenna. Robust connector with locking mechanism and high quality cable retention is required. A permanently wired antenna is not acceptable.	
Transmitter controls and indicators	Volume or gain	Transmitter should be provided with a means to adjust the level of the signal. This should be recessed or screwdriver controlled to minimise the risk of accidental adjustment.	Some cheaper transmitters provide no gain adjustment. This limits use with other microphones and some users. This actually controls the modulation of the radio section of the transmitter.
	On/Off Switch	A switch should be provided to enable the transmitter to be switched off to preserve battery life. This should be recessed to prevent accidental operation.	An on/off switch should not be used unless the receiver is also turned off. If the TX is off, the receiver may pickup an alternative source on the same channel.

continued	Mute switch	A switch should be provided to enable the audio signal output from the transmitter to be muted without turning off the transmitter.	This allows the audio to be turned off to allow private conversation, etc.
	Battery switch	A means of indicating the battery transmitter to be switched off to preserve battery life. This should be recessed to prevent accidental operation.	An alternative means of testing batteries can be provided instead.
	Transmitter level indicator	It is preferred that there is a means of checking the operating level of the transmitter, either on the transmitter unit, or on the receiver.	Transmitter level is actually easy to measure at either end.
	Channel selector	Channel selection should be available by means of an easy to understand control that is protected against accidental operation.	
Receiver antenna		Diversity receiver with dual antennas. Built-in or detachable telescopic or helical antennas.	Diversity provides protection against signal loss due to reflections in the room. Reduces signal 'drop-out'.
Receiver controls and indicators	Volume Control	An output volume control aids in setting up a system.	Alternatively, given compatibility with the amplifier, the gain may be adjusted there instead.
	On/Off switch	A front panel operable on/off switch is required.	
System frequency response		100 Hz to 10 Hz ± 1 dB	Performance of whole transmitter to receiver system without microphone connected.
Dynamic range		≥ 85 dB	This sets the maximum signal to noise ratio available from the equipment. It is the performance of the whole transmitter to receiver system without the microphone connected.
Distortion	THD+N	< 0.5% from 150 Hz to 8 kHz at any signal level	
Transmitter battery	Life	≥ 6 hours from a rechargeable nicad battery under continuous transmission conditions Battery compartment should be robust, enabling battery to slide in. A loose, plug-on battery connection is not acceptable.	Battery life should be measured under real operating conditions. Many published figures are not trustworthy as they are actually for a standby condition.

Headworn Microphone

Specification Descriptor	Standard Symbol	Recommended value or range	Comments
Microphone type		Omni-directional headworn microphone. Robust cable and connector with locking mechanism and good cable retention. Condenser microphone types must be compatible with radio microphone transmitter powering system or contain easily changed battery with long service life.	
Frequency response		100 Hz to 12 kHz ± 3 dB when used in recommended operating position	Microphone response is partly dependent upon surrounding surfaces. Microphone response should be considered when used as intended, not in an anechoic measurement.
Sensitivity		Microphone sensitivity should match the gain range of the transmitter enabling full transmitter modulation to be achieved when worn as recommended and used with a raised voice level.	
Dynamic range		> 65 dBA	
Sensitivity		> -46 dBV re 1 V/Pa Suitable for use in close proximity to the mouth	

Appendix 9: Noise at Work Regulations relating to teachers

There is growing concern about the possibility of long-term hearing damage to those teachers who generally work in the noisier school environments, for example PE teachers, CDT teachers and music teachers. The Health and Safety Executive has recently carried out a study of noise exposure among these teachers due to their potential for exposure to high noise levels. It is known that orchestral musicians are at risk of noise induced hearing damage[1,2] and therefore peripatetic music teachers may experience additional risk. It is necessary under the Noise at Work Regulations[3] to ensure that teachers of 'noisy' subjects are not exposed to levels of noise likely to cause, or increase, risk of hearing damage. The noise levels to which teachers are exposed can be reduced to some extent by good acoustic design of schools, for example by ensuring that the reverberation time is short so as not to increase the noise level in a room. However, there will inevitably be some occasions when the noise associated with a particular teaching activity approaches, or is above, the levels known to pose a risk to hearing.

The risk of noise induced hearing damage is a function of both noise level and the duration of exposure to the noise. The noise levels to which employees may be exposed, and the wearing of hearing protection, are currently subject to the Noise at Work Regulations 1989[3]. However, in February 2003 the European Union published a new directive, the Physical Agents (Noise) Directive[4], relating to noise at work which will result in the UK legislation being changed in 2006.

The main points of the current regulations, the European Directive and the likely changes to UK legislation in 2006 are summarised below.

Action levels

The current regulations are expressed in terms of action levels, that is levels of noise exposure at which certain actions are required by employers and/or employees (together with manufacturers of equipment).

Action levels are defined in terms of daily personal noise exposure $L_{EP,d}$ which takes account of both level and exposure time. $L_{EP,d}$ is similar to $L_{Aeq,T}$ (see Appendix 1) but is always normalised to an exposure time of 8 hours. For example, a person exposed to a continuous noise level of 85 dB(A) for 8 hours per day experiences a daily personal noise exposure of 85 dB(A) $L_{EP,d}$. For each halving of the daily exposure time, the $L_{EP,d}$ reduces by 3 dB(A), so that a daily exposure of 4 hours to a noise level of 85 dB(A) is equivalent to 82 dB(A) $L_{EP,d}$, and a daily exposure of 2 hours to a noise level of 85 dB(A) is equivalent to 79 dB(A) $L_{EP,d}$. Similarly, a doubling of exposure time increases $L_{EP,d}$ by 3 dB(A).

Current Regulations

The Regulations apply to employers, employees and self-employed people (who have the duties of both employers and employees). Peripatetic music teachers, for example, may fall into this last category.

Whatever the level of noise, employers have a duty under the Regulations to reduce the noise level to the lowest level reasonably practicable.

The first action level is 85 dB(A) $L_{EP,d}$. If any employee is likely to be exposed to this level or above, employers' duties under the Regulations include the following :

- to ensure that a competent person makes a noise assessment which is adequate to identify which employees are exposed to this level or above
- to inform employees of the risks of noise and ways in which the risk may be reduced
- to provide, and maintain, hearing protection for those who request it.

Employees also have a duty at this action level to maintain any equipment that is provided by the employer to reduce the risk of hearing damage, and to report any defects in the equipment.

The second action level is 90 dB(A) $L_{EP,d}$. If any employee is likely to be exposed to this level or above, employers' additional duties under the Regulations include the following :

- to reduce noise exposure of employees through noise control measures other than hearing protection
- to mark hearing protection zones where noise reaches the second action level with recognised signs
- to provide hearing protection to all employees and to ensure that it is worn.

At this action level employees must again maintain any equipment provided, and must also wear the hearing protection provided.

The regulations also specify a peak action level of 200 Pascals (equivalent to an unweighted sound level of 140 dB). This represents an instantaneous sound level, caused for example by a loud bang. Where this level is exceeded, employers and employees have the same duties as at the second action level. Exposure to the peak action level is normally linked with the use of cartridge operated tools, guns or similar loud explosive noises, but can occur during the loud playing of a musical instrument[1].

Changes to the Regulations

New legislation will come into force in February 2006 to comply with the Physical Agents (Noise) Directive. For musicians, who may include music teachers, the new legislation will not be enforced until 2008.

The main changes to the legislation are that, in effect, the action levels will be lowered by 5 dB(A). In general, the actions currently required at 85 and 90 dB(A) $L_{EP,d}$ will be mandatory at 80 and 85 dB(A) $L_{EP,d}$ respectively. In addition an overall personal exposure level of 87 dB(A) $L_{EP,d}$ is to be introduced; this is the limit of exposure at the ear which means that the level at the ear (with or without hearing protection) must never exceed 87 dB(A) $L_{EP,d}$.

Two peak exposure limit values are included in the directive: 112 Pa at which the duties required at 80 dB(A) $L_{EP,d}$ apply, and 140 Pa at which the duties at 85 dB(A) $L_{EP,d}$ are required. 200 Pa remains as an overall peak exposure limit.

Another feature of the new directive which may be relevant to teachers is that it will be possible to assess noise exposure on a weekly, rather than a daily basis, if exposure varies significantly from day to day.

Further information

The above summary of some aspects of the Noise at Work Regulations is included for information, but does not purport to be a complete statement of the Regulations. Employers and employees who believe that they may have duties under the Regulations should obtain a copy of the Regulations and should be familiar with the requirements. For a full version of the regulations see the HMSO web site[5]. For information on the effects of noise, the current regulations, the new Directive and its implications for the UK see the Health and Safety Executive website[6]. The text of the Directive may be found on the website of the Official Journal of the Euopean Union[4]. For a discussion of the implications for music teachers see www.musiced.co.uk.

References

[1] R Canham and B Shield. Noise surveys of orchestral musicians at the Barbican concert hall. Proc. Institute of Acoustics 21(6), 217-225, 1999.

[2] A Wright Reid. A sound ear. Association of British Orchestras 2001.

[3] Noise at Work Regulations 1989.

[4] Directive 2003/10/EC of the European Parliament and of the Council of 6 February on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (noise). Official Journal of the European Union L042, 15 February 2003, 38-44.

[5] www.hmso.gov.uk

[6] www.hse.gov.uk

All submissions to the Building Control Body (BCB) should clearly identify the relevant performance standards from Section 1, how they will be met, and the performance that the design is expected to achieve. Calculations, test reports etc should preferably be included in appendices to the submission, rather than in the main body of the submission. The extent of acoustic information required to satisfy the BCB may vary between Authorities and individuals. This example provides an indication of the minimum level of information that should be provided. The right hand column contains a commentary on the submission.

A set of symbols has been created for use on plans in submissions to allow a quick visual inspection of the BB93 performance standards for each acoustic criterion and the performance that the design is expected to achieve. The symbols can be downloaded from the DfES acoustics website. Hand-produced drawings would also be acceptable.

Example submission

The following items are provided in support of the submission to the Building Control Body to demonstrate compliance with the acoustic requirements of Part E of the Building Regulations.

The ground floor plan of the rooms and the acoustic performance standards are shown in Figure A10.1. On the first floor there are classrooms above the ground floor classrooms and music classrooms.

A 10.1 Indoor ambient noise levels in unoccupied spaces

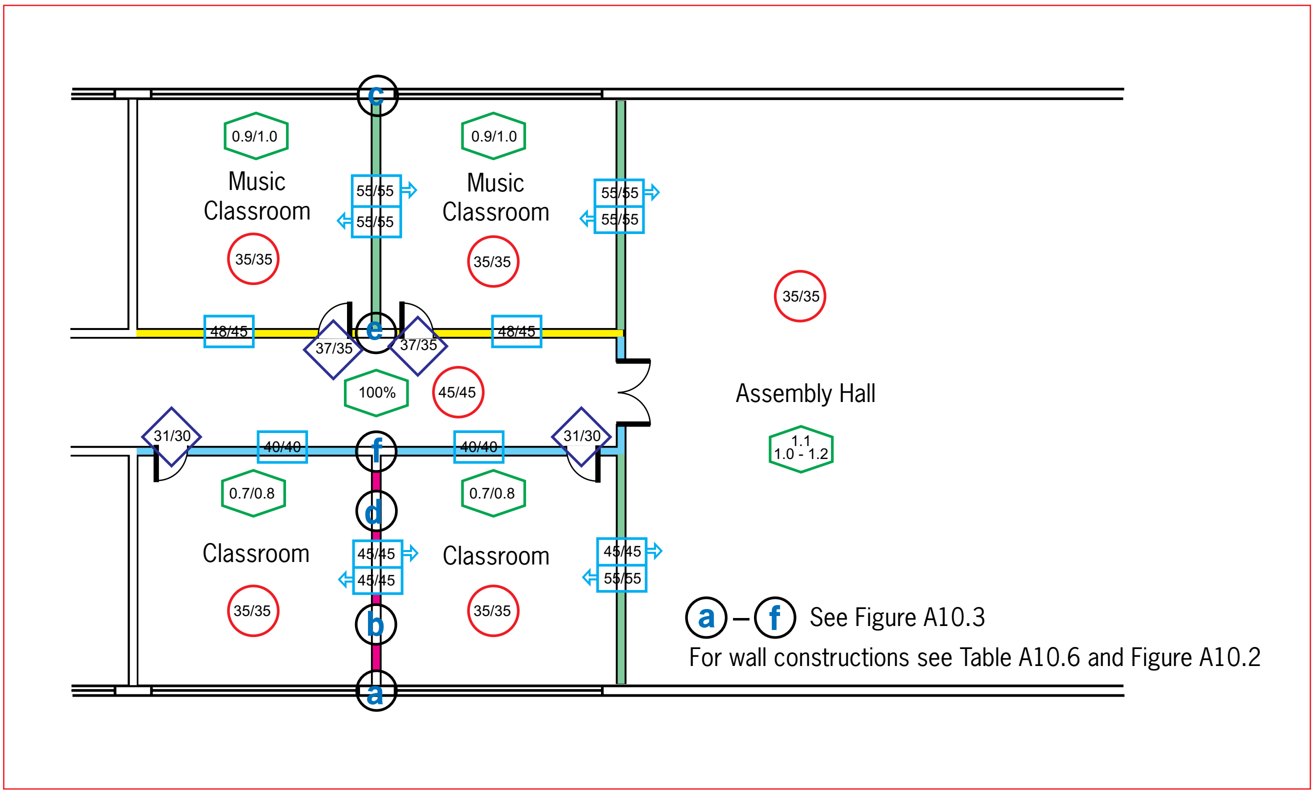
The performance standards in Table A10.1 for indoor ambient noise levels

This example submission focuses on only a few of the rooms, although the same level of detail would be required for all relevant rooms in the school.

Table A10.1: BB93 performance standards – indoor ambient noise level

Room	BB93 performance standard $L_{Aeq,30min}$ (dB)
Classroom	≤ 35

Figure A10.1: The plan of the rooms and the acoustic performance standards



Details of the noise survey should be provided in an Appendix. Sufficient information should be provided to allow the BCB to confirm that the measurement times and positions are appropriate and representative for the proposed school.
The external noise spectrum is required to calculate the indoor ambient noise level due to sound transmission through the façade.
In this example, only a single noise measurement has been taken at the proposed façade position for the few classrooms under consideration. Normally, noise measurements would be taken at the positions of all the proposed school façades. In some cases these measurements would be adjusted to take account of some facades being shielded from the noise by the proposed building.

On sites where there is a greater incidence of individual noisy events such as from aircraft overflights or near a railway a more detailed noise survey would normally be expected.

Depending upon the site, each elevation could be exposed to a different level of noise. Therefore a different ventilation strategy could be used on each elevation. This would require separate calculations.

have been taken from Table 1.1, Section 1.

A noise survey was carried out at the site on XX.YY.ZZZZ to establish the noise climate. Free-field external noise levels in terms of $L_{Aeq,30min}$ and $L_{A1,30min}$ were measured at a position corresponding to the proposed school facade closest to the dominant external noise source, the nearby road. The measured data are shown in Table A10.2.

Table A10.2: Noise survey data – $L_{Aeq,30min}$ and $L_{A1,30min}$ (external noise)

Time	$L_{Aeq,30min}$ (dB)	$L_{A1,30min}$ (dB)
08:00 – 08:30	57.5	66.1
08:30 – 09:00	56.8	64.8
09:00 – 09:30	58.0	64.8
09:30 – 10:00	57.7	66.0
10:00 – 10:30	57.4	66.9
10:30 – 11:00	56.9	64.6
11:00 – 11:30	56.1	63.9
11:30 – 12:00	59.1	66.3
12:00 – 12:30	59.4	67.1
12:30 – 13:00	59.8	64.9
13:00 – 13:30	58.6	66.4
13:30 – 14:00	58.5	66.2
14:00 – 14:30	57.4	65.3
14:30 – 15:00	57.9	66.8
15:00 – 15:30	58.2	65.6
15:30 – 16:00	57.4	66.0
16:00 – 16:30	59.9	71.3
16:30 – 17:00	56.6	65.0

The 30 minute time period with the highest external noise level during the school day, 59.9 dB $L_{Aeq,30min}$, is highlighted in the table.

The $L_{eq,30min}$ noise spectrum corresponding to the 30 minute time period with the highest external noise level, 59.9 dB $L_{Aeq,30min}$, is shown in Table A10.3.

The construction of the external envelope of the school will be a cavity brick/block wall with 6/12/6 glazing. The sound transmitted through the façade has been calculated for the classroom to determine the indoor ambient noise level. The upper limit for the reverberation time of the classroom from Table 1.5, Section 1 has been used in the calculation.

Ventilation will be provided by an acoustic ventilator and a passive stack roof ventilator with acoustic attenuation treatment. The ventilation requirement has been calculated based on 3 litre/s per person.

The calculations have been carried out using the Excel spreadsheet based on BS EN 12354-3:2000 from the DfES acoustics website The results are shown in Table A10.4.

The indoor ambient noise level is calculated to be 34.7 dB $L_{Aeq,30min}$ which is just below the upper limit for classrooms, 35 dB $L_{Aeq,30min}$, and therefore satisfies the performance standards in Table 1.1, Section 1.

Note 1 of Table 1.1, Section 1 gives guidance on indoor levels from individual external noisy events. The facade will offer a similar reduction in performance for $L_{A1,30min}$ as for $L_{Aeq,30min}$, hence the indoor level should not regularly exceed 55 dB $L_{A1,30min}$.

For these classrooms there are no noise sources due to building services that require consideration.

Table A10.3: Noise survey data – $L_{eq,30min}$ external noise spectrum

$L_{eq,30min}$ (dB)	Octave band centre frequency (Hz)				
Time	125	250	500	1 k	2 k
16.00 – 16.30	62.0	58.5	56.1	55.9	52.7

Table A10.4: Calculation of indoor ambient noise level in the classroom due to external noise transmitted through the façade

		Octave band centre frequency (Hz)				
		125	250	500	1 k	2 k
External $L_{eq,30min}$ (dB)		62.0	58.5	56.1	55.9	52.7
	Area (m^2)	Façade element sound insulation R (dB)				
Double glazing 6/12/6	14	20.0	19.0	29.0	38.0	34.0
Brick/block cavity wall	7	41.0	45.0	45.0	54.0	58.0
	Number of ventilators	Ventilator sound insulation $D_{n,e}$ (dB)				
Acoustic vent	1	20.1	23.4	28.7	40.3	52.6
Passive stack roof ventilator	1	20.0	26.0	31.0	36.0	44.0
Reverberation time (s)		0.8				
Room volume (m^3)		168				
Internal $L_{Aeq,30min}$ (dB)		34.7				

The submission should reference the calculation procedure (eg BS EN 12354-3:2000, BS 8233:1999 etc). The submission should also contain references to the source(s) of all sound insulation data used in the calculations. The following options are suitable: copies of laboratory sound insulation test certificates in the appendices of the submission, reference to laboratory accreditation number and test report number, reference to books or papers.

In this example there are no significant internal noise sources. Hence, only external noise sources have been considered. When there are significant internal noise sources, Section 1.1.1 describes which internal sources should be considered in the calculation of the indoor ambient noise level.

A 10.2 Airborne sound insulation between spaces

The performance standards for the airborne sound insulation between spaces have been taken from Tables 1.1 and 1.2, Section 1.

The performance standard for airborne sound insulation between rooms has been assessed in both directions but only the highest $D_{nT(Tmf,max),w}$ values are shown in Table A10.5.

The minimum weighted sound

Table A10.5: Airborne sound insulation between spaces

Source room	Receiving room	BB93 performance standard $D_{nT(Tmf,max),w}$ (dB)
Classroom	Classroom	45
Classroom	Assembly hall	45
Assembly hall	Classroom	55
Music classroom	Music classroom	55
Assembly hall	Music classroom	55
Music classroom	Assembly hall	55

Table A10.6: Separating walls - airborne sound insulation between spaces

Source room	Receiving room	Separating wall construction *(Refer to Figure A10.2 for details)*	Minimum laboratory sound insulation for separating wall* R_w (dB)	Separating wall laboratory performance R_w (dB)	Laboratory test report
Classroom	Classroom	(3)	49	53	Test report No. XXXXXX, Laboratory accreditation No. ZZZZ
Classroom	Assembly hall	(2)	42	45	Test report No. ZZZZZZ, Laboratory accreditation No. ZZZZ
Assembly hall	Classroom	(3)	49	53	Test report No. XXXXXX, Laboratory accreditation No. ZZZZ
Music classroom	Music classroom	(4)	60	63	Test report No. YYYYYY, Laboratory accreditation No. ZZZZ
Assembly hall	Music classroom	(3)	50	53	Test report No. XXXXXX, Laboratory accreditation No. ZZZZ
Music classroom	Assembly hall	(3)	52	53	Test report No. XXXXXX, Laboratory accreditation No. ZZZZ

*Estimated using the approach described in Section 3.10.

The submission should reference the calculation procedure (e.g BS EN 12354-1:2000) that has been used to estimate the airborne sound insulation of the separating element and associated flanking elements. Details and assumptions made in the calculations should be contained in the appendices of the submission.

The submission should include all relevant flanking details and reference the calculation tools or software used to estimate the sound insulation due to the combination of direct and flanking transmission.

The submission should reference the source(s) of all sound insulation data. Copies of laboratory sound insulation test certificates can be included in the appendices of the submission, or reference can be made to the test report number and the laboratory accreditation number.

reduction indices (R_w) required to achieve the $D_{nT(T_{mf,max}),w}$ performance standards for the separating walls have been estimated using the approach described in Section 3.10.

The wall constructions to be used in the school are shown in Figure A10.2.

Table A10.6 contains information on the separating walls to be used between different rooms.

The proposed flanking details are shown in Figure A10.3. Each detail in Figure A10.3 corresponds to the detail identified on Figure A10.1. These flanking details have been used to estimate the field airborne sound insulation according to BS EN 12354-1:2000, to confirm that the performance standards in terms of $D_{nT(T_{mf,max}),w}$ can be achieved.

The floor construction to be used to satisfy the performance standards is shown in Figure A10.4. Test report No. XYZXYZ, laboratory accreditation No. ZZZZ contains the airborne sound insulation data for this floor.

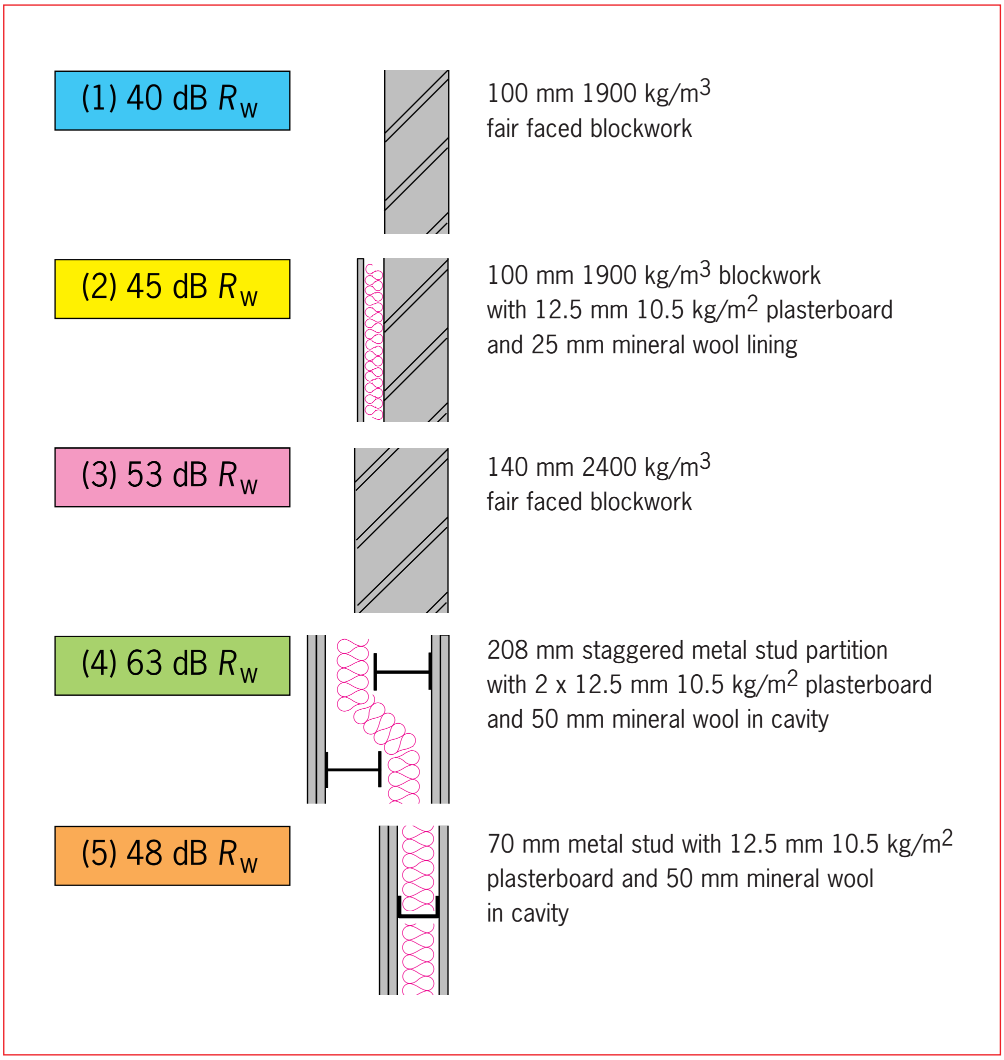


Figure A10.2: Wall constructions

A10.3 Airborne sound insulation between circulation spaces and other spaces used by students

The performance standards in Table A10.7 for airborne sound insulation between circulation spaces and other spaces used by students have been taken from Table 1.3, Section 1.

The walls and doorsets to be used in the school are referenced in Table A10.8 along with references to the laboratory sound insulation test certificates. Doorsets will have a vision panel and neoprene blade seals to the jambs and head, and drop threshold seals.

The submission should reference the source(s) of all laboratory sound insulation data for the walls, doorsets and ventilators. Copies of laboratory sound insulation test certificates can be included in the appendices of the submission, or reference can be made to the test report number and the laboratory accreditation number.

Table A10.7: BB93 performance standards - airborne sound insulation between circulation spaces and other spaces used by students

Space used by students	Circulation space	Separating element	BB93 performance standard R_w (dB)
Classroom	Corridor	Wall Doorset	≥ 40 ≥ 30
Music classroom	Corridor	Wall Doorset	≥ 45 ≥ 35

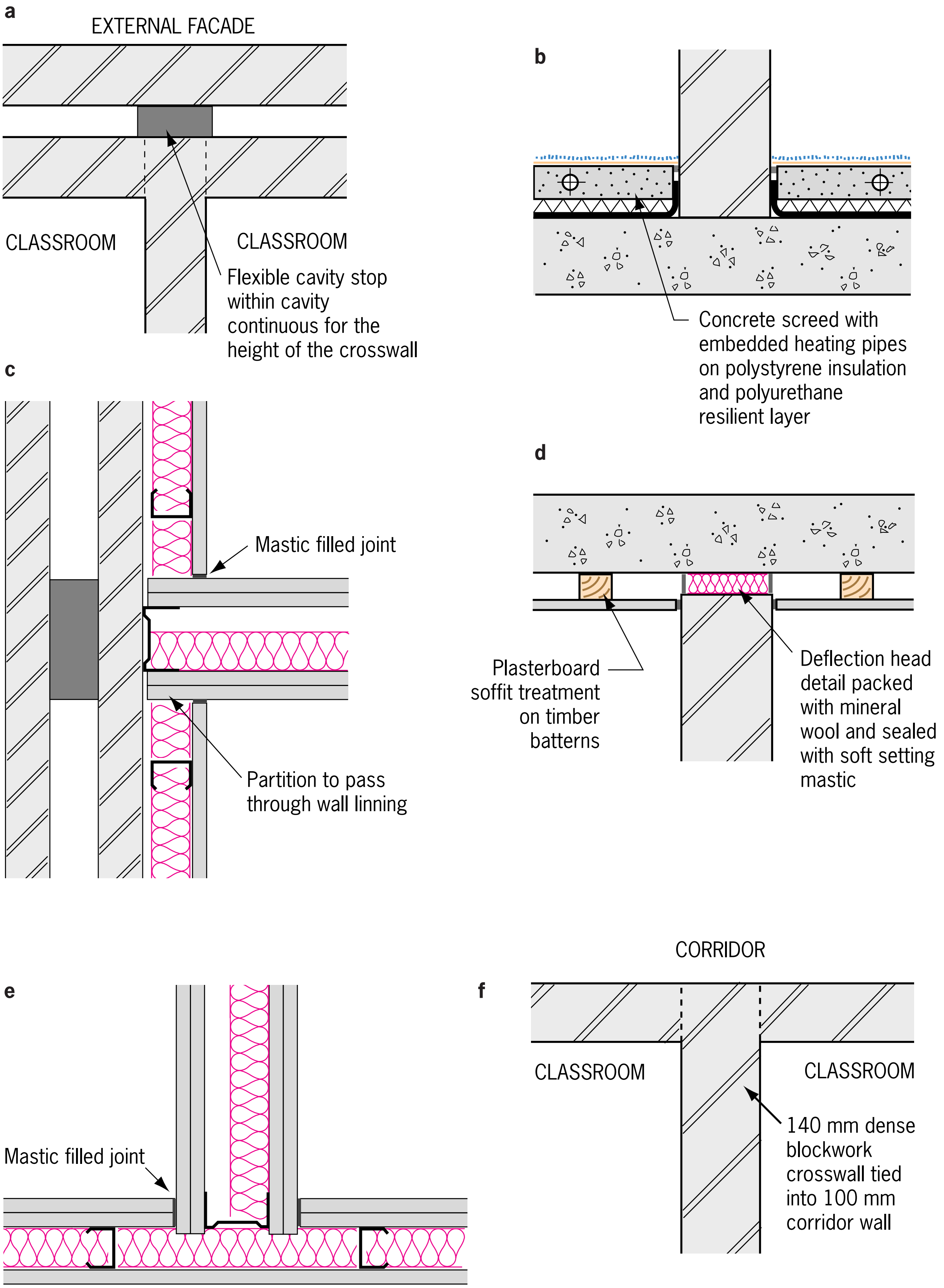


Figure A10.3: Flanking details

Table A10.8: Separating elements - airborne sound insulation between circulation spaces and other spaces used by students

Separating element	Separating element *(Refer to Figure A10.2 for wall details)*	BB93 performance standard R_w (dB)	Separating element laboratory performance R_w (dB)	Laboratory test report
Wall	(1)	≥ 40	40	Test report No. XXXXXX, Laboratory accreditation No. XXXX
Doorset	Product X, Manufacturer X	≥ 30	31	Test report No. YYYYYY, Laboratory accreditation No. XXXX
Wall	(2)	≥ 45	45	Test report No. ZZZZZZ, Laboratory accreditation No. XXXX
Doorset	Product Y, Manufacturer X	≥ 35	37	Test report No. YYYYYY, Laboratory accreditation No. XXXX

A10.4 Impact sound insulation of floors

The performance standards in Table A10.9 for impact sound insulation have been taken from Table 1.4, Section 1.

The floor construction to be used in the school is in Table A10.10 along with references to the estimation method and laboratory sound insulation test certificates.

The separating floor construction shown in Figure A10.4 with a permanent carpet (ie glued to the floor) will be used in the classroom and the music classroom to achieve the performance standards. The first floor science laboratories will have vinyl flooring instead of carpet.

The submission should include all relevant flanking details and reference the calculation tools or software used to estimate the sound insulation due to the combination of direct and flanking transmission.

Table A10.9: BB93 performance standards - impact sound insulation

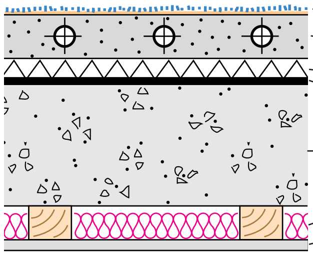
Ground floor room	First floor room	BB93 performance standard $L'_{nT(T_{mf,max}),w}$ (dB)
Classroom	Classroom	≤ 60
Music classroom	Classroom	≤ 55
Science laboratory	Classroom	≤ 65

The submission should reference the source(s) of all sound insulation data. Copies of laboratory sound insulation test certificates can be included in the appendices of the submission, or reference can be made to the test report number and the laboratory accreditation number.

Table A10.10: Separating floor - impact sound insulation

Ground floor room	First floor room	Floor construction	Estimation method	Estimated $L'_{nT(Tmf,max),w}$ (dB)
Classroom	Classroom	As Figure A10.4 with 5 mm permanent needlefelt carpet	Predictions using BS EN 12354-2:2000 and test report No. YYYYYY, laboratory accreditation No. XXXX	53
Music classroom	Classroom			53
Science laboratory	Classroom	As Figure A10.4 with permanent vinyl flooring instead of carpet	Predictions using BS EN 12354-2:2000 and test report No. YYYYYY, laboratory accreditation No. XXXX	62

Figure A10.4: Separating floor construction



Room data sheets may be a convenient way to present information about the various room finishes to the BCB as they may already have been generated for the school. These data sheets may also be an appropriate place to identify the other acoustic standards proposed for the school.

A10.5 Reverberation in teaching and study spaces

The performance standards in Table A10.11 for the reverberation times have been taken from Table 1.5, Section 1.

The reverberation times for the classrooms and the assembly hall have been calculated as described in Appendix 6 of BB93.

Table A10.11: BB93 performance standards - reverberation times

Room	BB93 performance standard T_{mf} (s)
Classroom	<0.8
Assembly hall	0.8 – 1.2

Table A10.12: Reverberation times for the classroom

	Area (m^2)	Octave band centre frequency (Hz) 125	250	500	1 k	2 k
		Absorption coefficients				
Painted blockwork	60	0.10	0.05	0.06	0.07	0.09
Carpet on concrete floor	56	0.05	0.05	0.1	0.2	0.45
Glazing	14	0.1	0.07	0.05	0.03	0.02
Suspended plasterboard ceiling	30	0.2	0.15	0.10	0.05	0.05
Absorbent ceiling - Product X Manufacturer Y	26	0.45	0.50	0.55	0.30	0.15
Absorbent tile for back wall - Product X Manufacturer Y	16	0.17	0.38	0.48	0.68	0.88
Volume (m^3)		168				
		Reverberation times				
T (s)		0.88	0.89	0.77	0.75	0.54
T_{mf} (s)		0.7				

Classroom

The absorption coefficients and the predicted reverberation times for the classroom are shown in Table A10.12. The predicted T_{mf} is 0.7 seconds which satisfies the performance standard of <0.8 seconds in Table 1.5, Section 1.

The predicted octave band reverberation times also satisfy the guidance in Note 1 of Table 1.5, Section 1 that the reverberation times in the 125 Hz and 250 Hz octave bands increase up to a value not more than 30% above T_{mf}.

The central section of the ceiling will be a suspended plasterboard ceiling to provide a reflective central section with the absorbent ceiling around the ceiling perimeter as shown in Figure 4.2(a), Section 4.

Assembly hall

The absorption coefficients and the predicted reverberation times for the assembly hall are shown in Table A10.13. The predicted T_{mf} is 1.1 seconds which satisfies the performance standard of 0.8 – 1.2 seconds in Table 1.5, Section 1.

The predicted octave band reverberation times also satisfy the guidance in Note 2 of Table 1.5, Section 1 that the reverberation times in the 125 Hz and 250 Hz octave bands increase up to a value not more than 50% above T_{mf}.

The central section of the ceiling will be a suspended plasterboard ceiling to provide a reflective central section with the absorbent ceiling around the ceiling perimeter as shown in Figure 4.2(a), Section 4.

The submission should reference the source(s) of all absorption data used in the reverberation time calculations. The following options are suitable: copies of laboratory sound insulation test certificates in the appendices of the submission, reference to test report number and laboratory accreditation number, or reference to books or papers.

Table A10.13: Reverberation times for the assembly hall

		Octave band centre frequency (Hz)				
	Area (m^2)	125	250	500	1 k	2 k
		Absorption coefficients				
Fair-faced blockwork	170	0.05	0.05	0.05	0.08	0.14
Parquet on concrete floor	192	0.04	0.04	0.07	0.06	0.06
Glazing	76	0.15	0.05	0.03	0.03	0.02
Suspended plasterboard ceiling	140	0.2	0.15	0.10	0.05	0.05
Absorbent ceiling - Product X Manufacturer Y	52	0.51	0.68	0.85	0.92	1.00
Absorbent tile for back wall and top of side walls - Product X Manufacturer Y	90	0.46	0.67	0.83	0.93	0.95
Volume (m^3)		1152				
		Reverberation times				
T (s)		1.50	1.35	1.18	1.12	1.02
T_{mf} (s)		1.11				

The submission should reference the source(s) of all absorption data for products (eg ceiling tiles) used in corridors, entrance halls and stairwells. The following options are suitable: copies of laboratory sound insulation test certificates in the appendices of the submission, reference to test report number and laboratory accreditation number, or reference to books or papers.

A10.6 Sound absorption in corridors, entrance halls and stairwells

The absorption treatment in the corridors has been assessed in accordance with Method A, as described in Appendix 7. It is proposed to install acoustically absorbing material in the form of a suspended ceiling, to provide an area equal to the total floor area. The ceiling system has an absorption class equal to, or better than, Absorption Class C according to manufacturers literature XYZ.

The submission should reference the source(s) of rain noise measurement or prediction data.

A10.7 Rain Noise

Laboratory measurement data for rain noise on the proposed lightweight metal roof construction is currently unavailable. However, the same roof construction has been used in another school, School X, in which field measurements were carried out. These tests are described in field test report XYZXYZ. These measurements demonstrate that the rain noise is not audible when the roof construction comprises a suspended plasterboard ceiling (10 kg/m^2) with a 150 mm void. Hence, the same roof construction with the suspended ceiling will be used.