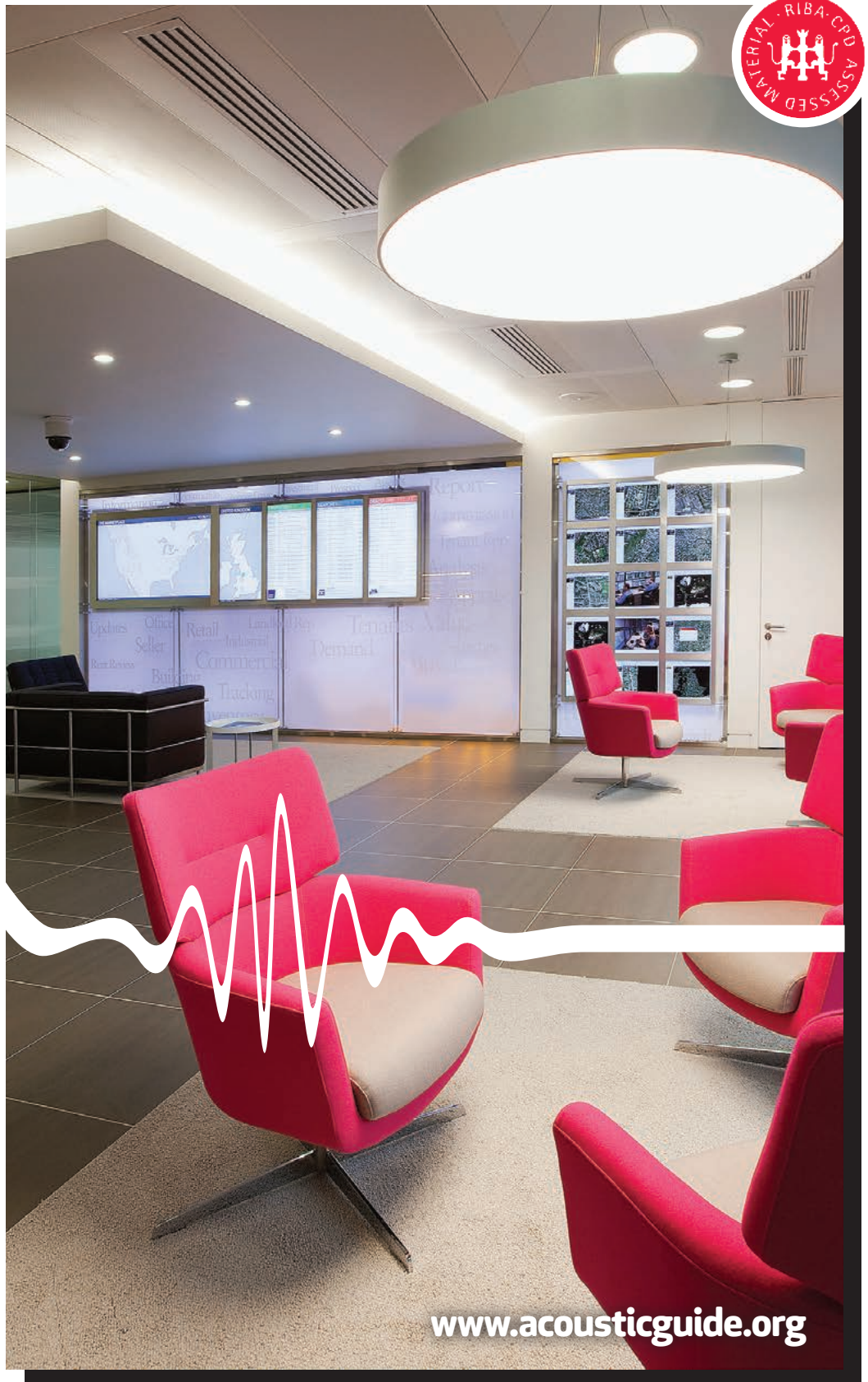


# FIS


FINISHES & INTERIORS SECTOR

## A GUIDE TO OFFICE ACOUSTICS

[www.thefis.org](http://www.thefis.org)



[www.acousticguide.org](http://www.acousticguide.org)



Acoustic rafts, allowing the soffit to be exposed while reducing reverberation.

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## A GUIDE TO OFFICE ACOUSTICS

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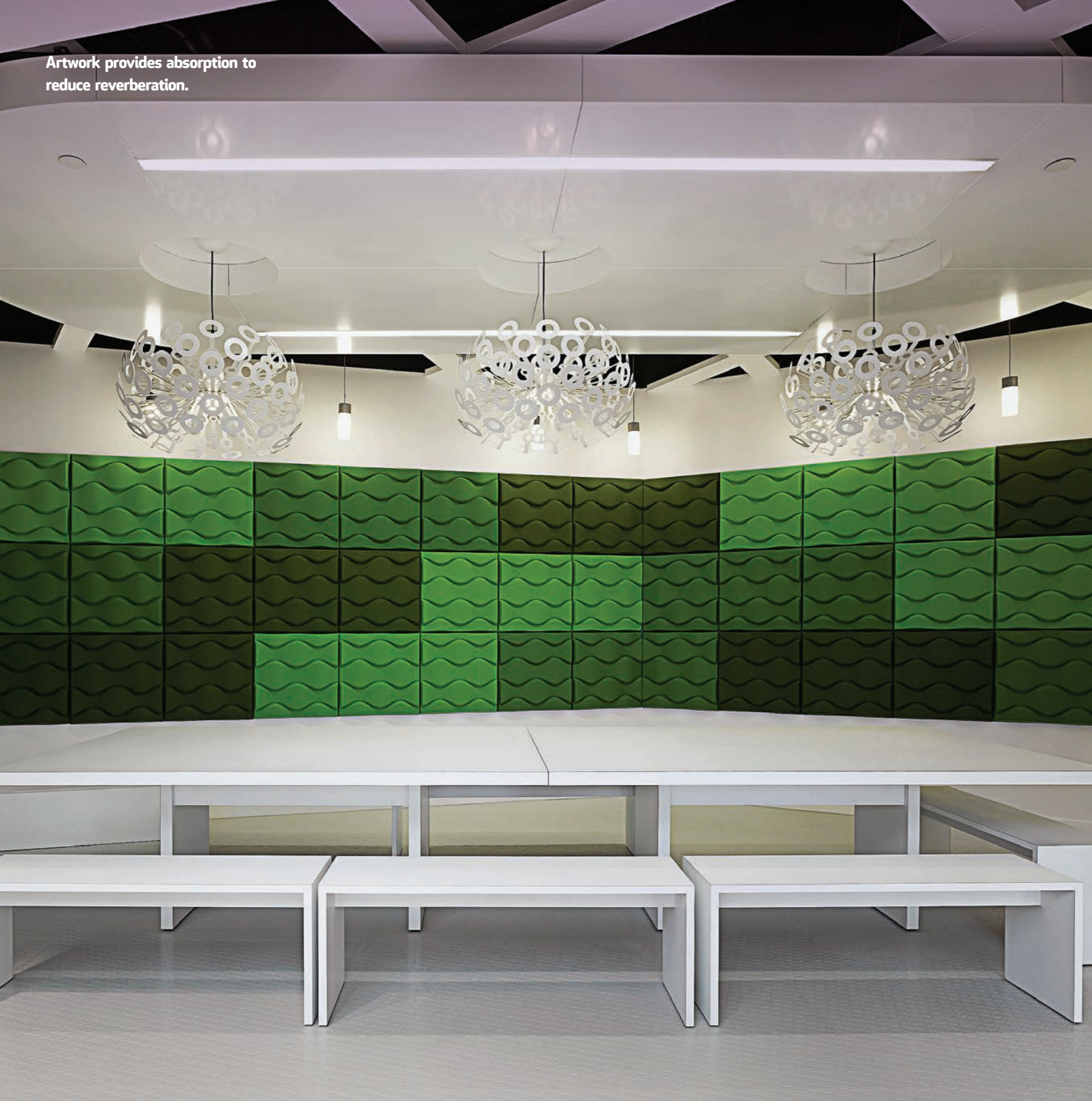
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While every care has been taken to ensure the accuracy of the details presented in this document, we regret that FIS cannot be held responsible for any errors or omissions contained herein.

Artwork provides absorption to reduce reverberation.



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Perforated acoustic metal ceiling helps counteract the effects of hard flooring.



## FOREWORD

1

This guide to office acoustics has been developed by FIS to promote best practice in the design and installation of acoustic solutions in offices.

Good acoustics are essential to productivity and creativity in the workplace. Indeed they can be key to the success of a building. Those of you who have worked in an environment with poor room acoustics, insufficient privacy or excess or lack of background noise will testify to the crucial role acoustics plays.

FIS has grown over the past 50 years to become the leading trade association for the interiors fit out sector of the construction industry, representing companies involved in the manufacture, supply and installation of all aspects of interior fit out and refurbishment. Its members can provide optimum solutions for controlling sound within office environments.

The starting point for this document was a lack of comprehensive guidance on office acoustics. FIS commissioned a review of available research, which was carried out by Professor Bridget Shield, professor of Acoustics in the Faculty of Engineering, Science and Built Environment at London South Bank University. Using this as a basis, FIS collaborated with leading acoustic and industry experts to develop 'A guide to office acoustics'.

It has been designed to encompass the needs of a range of audiences, from first time office occupiers and clients, through to specialist contractors and suppliers of interior products, designers, architects and acousticians.

It defines best practice in office acoustics and I commend it to you.

**Martin Romaine, FIS President 2009-2011**

A well designed auditorium has acoustics at its heart.



## INTRODUCTION

2

It is clear from the many studies that have been carried out over the past 40 years that exposure to office noise has a detrimental effect on performance, which in turn has a negative impact on an organisations efficiency and ultimately profit margins. In fact ten times as many occupants complained about noise in large open plan offices (60%) as in cellular offices (6%) (Pejtersen et al, 2006).

The evolution of the open plan office, flexible working, new technology, and team working are just a few of the driving forces behind changes to office space design. These have led to the requirement for a wide variety of work zones all of which place increasing demands on acoustic performance. These include:

- Training and learning areas
- Meeting rooms and spaces for both informal and formal meetings
- Social and relaxing space
- Quiet working space or rooms
- Workstations for both residential and nomadic staff
- A printing, copying and stationery hub
- Back of house functions, including storage, server rooms and post rooms
- Staff welfare space, including toilets, showers, cloakrooms, first aid and faith rooms
- Atria and receptions

Changes in the way offices are designed and function, and the way we communicate, as well as an increase in workstation density have all impacted on noise levels. The balance between the need to communicate, the need for privacy and the ability to concentrate need to be managed. Acoustic problems can be alleviated easily and economically by applying knowledge and care at the design stage.

For example, noise levels in open plan offices can be addressed by the introduction of quiet working rooms for concentrated work and quiet zones for meetings and private discussions.

Acoustic problems and disturbance in a room are often derived from either long reverberation times, which give a room an echoey feel or from noises outside the room and poor sound insulation.

Café areas are a prime example. Often containing a range of hard surfaces, the reverberation time may last several seconds and the noise is compounded as it bounces off the hard internal surfaces. But if soft furnishings (acoustically absorbent material) were introduced, the noise would soften, the reverberation time would reduce and the people in the room would be far less disturbed and better able to enjoy the environment.

These types of issues have long been acknowledged in the education sector. In the late 1990s, awareness of poor acoustics in schools led to the production of Building Bulletin 93 (BB93), which substantially improved the acoustic environment for learning.

Offices are not covered by Part E of the Building Regulations ('Resistance to the passage of sound'), which means any available design guides are not mandatory and are used to varying degrees and with varying amounts of success. What guidance there is tends to be based on trying to achieve the privacy benefits of cellular spaces in open plan areas.

This guide aims to set out the parameters for noise, reverberation and privacy, in order to heighten awareness and promote best practice in office design.

Frameless glass doors closing into rebated frames help to control background noise in the study rooms, and the cross walls protruding through the front runs help reduce flanking sound.

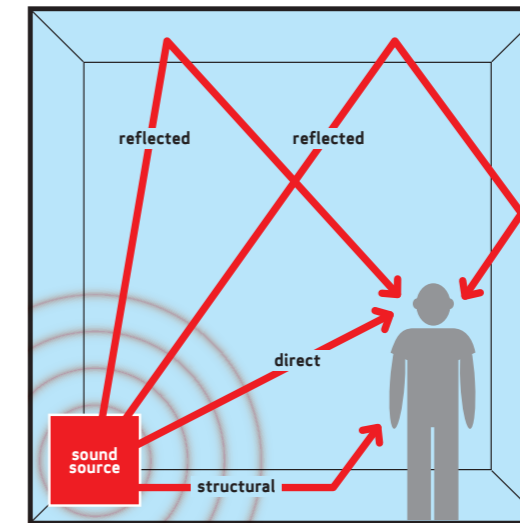
## BASIC ACOUSTICS

3

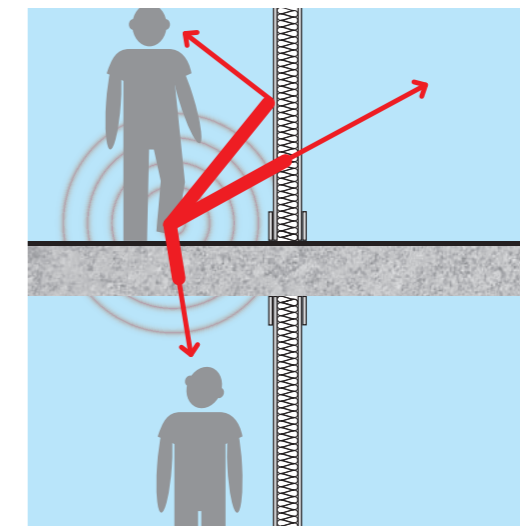
Acoustics - or the science of sound - can be traced back to the Greeks, who understood how sound travelled and used that knowledge in the building of amphitheatres. The word acoustics comes from the Greek word ακουέιγ (akouein), which means 'to hear'.

Sound is a series of waves or pressure fluctuations, which start with an object vibrating, such as a guitar string or vocal cord. From its source it moves or propagates in the air in all directions at about 1,200km/h or 786mph (the speed of sound).

What happens next depends on the sound's distance from its source or what it encounters. As it travels from the source, the arc or radius of the imaginary line of sound grows larger and the energy in the sound dissipates. However, if it hits a hard surface the reflection can lead to a build up of sound energy, effectively amplifying the sound. Conversely, if it hits a soft surface some of the energy can be absorbed. As the sound encounters objects such as walls the energy passing through them is reduced.



Sound from the source is received in a number of ways.



Impact sound can affect those within spaces as airborne sound, and those in other parts of the building as structure borne sound.

Sound travels through most media - solid, liquid or gas (air) - but will not pass through a vacuum. This guide deals with sound travelling through solids and air. When it travels through air it is described as airborne; when it moves through a solid it is termed structure borne. It is important to distinguish between the two as the method of control is generally different.

Sound is measured in terms of the frequency of the wave, expressed in hertz (Hz), and the wavelength and pressure level, expressed in decibels (dB).

The human ear detects fluctuations in sound pressure, which the brain processes as electrical impulses and converts to auditory signals. Humans hear between 20Hz and 20,000Hz.

Decibels, which are measured using a logarithmic scale, are the most common expression of sound levels, and are best described using three typical noises: shouting (80dBA), a pneumatic drill (100dBA), a propeller aircraft taking off (120dBA). Sound levels above 120dBA would be the threshold for pain in most humans. Because people perceive an increase of 10dB as a doubling of sound, a pneumatic drill at 100dB seems four times louder than someone shouting at 80dB, and a jet aircraft taking off at 120dB four times louder again. Conversely, a sound reduction of say 10dB would be perceived as 50% quieter, and a further 10dB 50% quieter again (ie a 75% reduction on the original sound). Most humans will not detect a change in sound level difference of below 3dB.

Sound level dBA (log scale)	Sound source
0	Threshold of audibility
20	Whisper
30	Quiet conversation
40	Background noise in unoccupied office
50	Normal conversation
60	Occupied offices
70	Inside a travelling railway carriage
80	Roadside, busy street
100	Inside a nightclub
120	Jet aircraft taking off 100m away or MP3 player at maximum volume
120-130	Threshold of pain
140>	Damage to hearing

Table 1  
Typical sound levels.

Humans hear best in the middle frequency range (500Hz to 4,000Hz), generally known as the speech range. This range is affected by factors such as a person's age and whether they are or have been subjected to a loud sound over a prolonged period. To account for this in calculations, a weighting system known as dBA is used by acousticians.

In our everyday lives, we are accustomed to sound around us. To communicate effectively, normal speech levels between 10dB and 15dB above the background noise level need to be achieved.

Acousticians use this information when calculating maximum sound levels in each room from, say, ventilation or machinery.

Sound reflects in a similar way to light - too much reflection can have the perceived effect of increasing the sound. For example, at lunchtime in a canteen with hard reflective surfaces, sound reflects, the ambient sound level increases and people raise their voices in order to be heard, creating a sometimes painfully noisy environment.

The acoustic quality of a room can be expressed by measuring the reverberation time (RT) - the length of time it takes for reverberation to die down. If a room has a long reverberation time, one spoken word does not have time to die out before the next reaches the listener. With this overlapping of sound, speech intelligibility is poor. Generally, the shorter the reverberation time the better the speech intelligibility.

Many office interiors are built using hard, reflective surfaces such as glass, concrete and

plaster. In order to reduce reverberation times, sound absorbing products, such as ceilings, rafts, wall panels, carpets and free standing structures can be introduced.

Acousticians can calculate the effect these products will have by understanding the sound absorbency of the products. To do this they use data which lists the sound absorption coefficients of a particular material.

This data comes from tests carried out in a laboratory controlled reverberation room where the reverberation time is measured when the room is empty. This calculation is measured when the level has dropped by 60dB from when the sound source has stopped and is expressed in seconds (or fractions thereof). In order to provide a comparative figure the test is repeated again after a 10-12m<sup>2</sup> sample of a particular material is placed in the room.

The results are usually expressed as a weighted single figure ( $\alpha_w$ ) - 0.0 being no absorbency and 1.0 being 100%. For ease of comparison, manufacturers categorise products using five performance bands, A to E, where A denotes the highest absorption, as set out in BS EN ISO 11654: 1997.

Sound absorption relates to the control of sound reflections within a room, while sound insulation - also referred to as attenuation - is associated with the control of sound transmission between adjacent rooms to achieve privacy. In an office environment, when related to sound, privacy can be defined as the ability to hold a conversation and not be overheard/understood in adjacent areas.

The sound insulation of a product such as a partition can be tested in a laboratory to produce a single figure rating reflecting the number of decibels by which sound reduces as it passes through the product. The figure will depend on the frequency of the sound in the source room, so measurements are generally taken across a range of frequencies between 50Hz and 5,000Hz and are taken at one third octaves.

Test results are then compared to a standardised reference curve to produce a weighted sound reduction index ( $R_w$ ) where figures across a range of frequencies between 100Hz and 3,150Hz are used, in accordance with BS EN ISO 717-1: 1997.

Sound can also be transmitted through hollow building elements such as cladding or columns, ventilation trunking, pipes and through voids above suspended ceilings and below raised floors. This requires careful and considered thought in the design and construction process to avoid costly and disruptive remedial work after occupation.

A range of acoustic products have been used in this atrium to reduce reverberation. As well as an acoustic ceiling, the wall discs and the panels below the glass barriers are made of sound absorbing material.



Noise in offices is generated from various sources. Some of the most annoying is the noise created by general office activity.



## NOISE IN OFFICES

4

Noise, by definition, is unwanted sound. People can put up with a certain amount of noise before inconvenience turns into annoyance, which turns into discomfort and dissatisfaction. Most people who work in office environments will have been affected by noise, often without realising it.

Noise in the workplace is increasing as a result of greater activity and higher density of people. This must be managed through a combination of design, protocol, facilities and careful specifying and selection of materials.

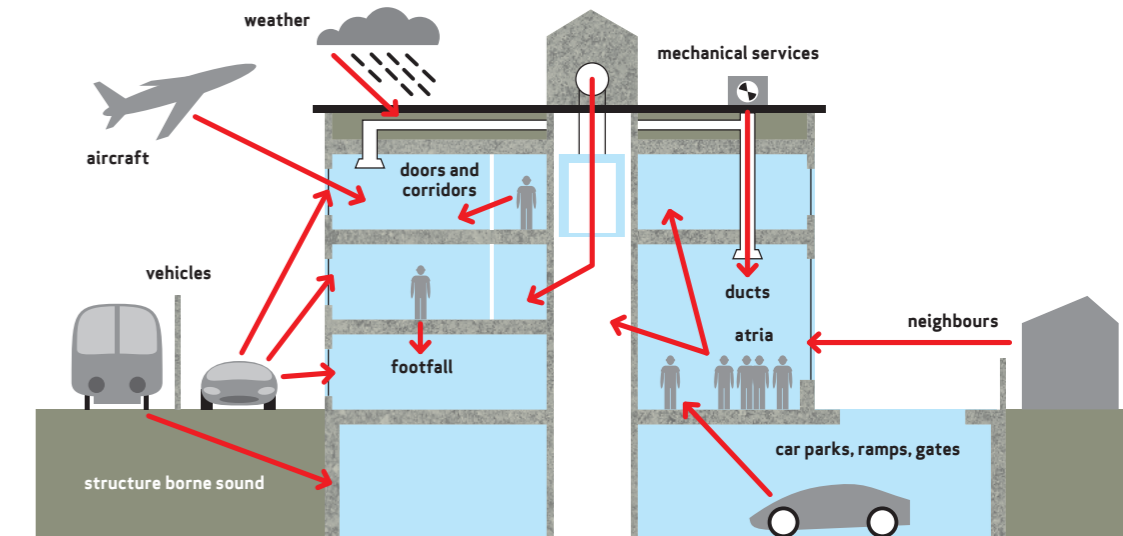
Offices are being designed and built to provide cost effective and pleasant environments with flexible workspaces that can accommodate a range of tasks and activities as well as spaces to meet, communicate and train, store records, share knowledge and information, and socialise. Each function will have its own acoustic requirements, which will form the basis for providing the correct acoustic environment for each area.

### NOISE SOURCES

#### Background noise level

It is commonly accepted that if the background noise of an office is too high, productivity is likely to suffer. Fluctuating noise, such as phones ringing, laughter and loud speech, affect concentration. Conversely, if background noise levels are too low, privacy can suffer.

For this reason, many existing guidance documents - BS 8233: 1999 and BREEAM 2008 - contain minimum and maximum background noise levels. Research (Kjellberg



Noise sources within a building and from external sources.

and Landstrom 1994) shows the optimum level of steady background noise is between 45dBA and 50dBA. This provides a good degree of speech masking, but is not so high as to be intrusive.

Steady levels of background noise can be regulated in mechanically ventilated buildings, but where natural ventilation is used, low background noise levels are typical, with the increased risk of fluctuation when external noise sources vary in level and frequency.

#### Transportation noise

Any office that is naturally ventilated and in a built up area will be subject, to a greater or lesser extent, to noise from transportation sources such as road traffic, trains and planes. Some transportation noise can be tolerated, and is inevitable, but too much can cause problems.

#### Building services

All offices need heating, lighting and ventilation, some also need cooling, all of which are provided by the building services. Some are a source of noise - mainly mechanical services such as boilers, pumps, circulation fans, air-handling units, chillers and so on.

Noise from building services calls for a variety of responses:

- Internal and external plant rooms or installations can have an impact on the internal office environment if noise and vibration is transmitted through walls, floors, ducts or risers. This should be assessed and steps taken to ensure the workforce is not disturbed.
- Ventilation systems create noise due to the movement of air along ducts and from the fans that move the air. While the masking noise of ventilation systems can be helpful in



the provision of privacy, care should be taken to ensure the noise is not too high or too low. Nor should it contain any tonal elements - whines, hums or rattles - as these can be annoying and distracting, even at low levels.

- Electronic equipment such as printers, fax machines and vending machines can disturb office workers because the noise is not constant. Care should be taken to locate such machinery away from work areas. Printers and other equipment operated by staff, however, need to be close to workers who control them.

#### Activity noise

Research into office acoustics shows that some of the most annoying noises in an office are those relating to normal office activities - telephones ringing, people laughing and speaking loudly, loud footsteps on the floor. While physical measures can be taken, such as area division and laying sound absorbing floorcoverings to help control noise and footfall, workers also need to show consideration to their colleagues.

Office etiquette should be encouraged at all times.

#### Noise leakage

Airborne sound can travel from one adjacent area to another through gaps or cracks in building elements and services which will affect acoustic performance.

Typical sound leakage paths include:

- Keyholes or air vents in doors or around their edges, resulting from poorly fitted doors or



Sound absorbing feature wall behind a reception desk.

lack of threshold acoustic seals.

- Openings in walls or floors through which pipes, ducts, wiring or similar distribution services pass.
- Junctions at the perimeter, and joints between the modular elements of partitions, ceilings and raised floors.
- Recessed air handling luminaires within the suspended ceiling to a common ceiling plenum above adjacent areas.
- Recessed continuous lighting troughs or

linear air diffusers in the suspended ceiling, which span across a common partition.

- Ventilation grilles or diffusers that share common ductwork systems or are connected to each other via a common ceiling or raised floor air moving plenum (cross talk).
- Continuous perimeter piped heating or power/data cable conduit systems running behind partitions.
- Continuous perimeter curtain walling and internal lining systems.

### MANDATORY REQUIREMENTS

Health and Safety Executive regulations on Noise at Work do not normally apply in an office environment. The only exception would be if an office is attached to a manufacturing facility, although careful design of sound insulation should mitigate any potential problems. For more information on Noise at Work visit [www.hse.gov.uk](http://www.hse.gov.uk)

As part of their fire strategy, some office buildings are fitted with sounders or voice alarm equipment. Design of any such life safety system should comply with statutory requirements, such as BS EN ISO 5839 (Parts 1 to 8) and BS EN ISO 60849: 1998.

Part E of the Building Regulations lays out the acoustic requirements for domestic buildings. Non-domestic buildings can fall within the requirements when there is a party wall in, say, a mixed use or a 'work live' development. If overnight accommodation is provided in an office scheme, it would be worth checking the regulations in more detail at the design and planning stage.

As with other mandatory requirements, the Equality Act 2010 (previously the Disability Discrimination Act) must be considered at all stages of design. Although there are no specific requirements regarding acoustics, it is clear from experiences in the education sector that a correctly designed space will benefit all occupants, regardless of their ability to hear. More information can be found at

- [www.direct.gov.uk](http://www.direct.gov.uk)
- [www.legislation.gov.uk](http://www.legislation.gov.uk)
- [www.rnid.org.uk](http://www.rnid.org.uk)

### THE ROLE OF THE ACOUSTICIAN

While it is never too early to seek advice from an acoustician, it is often left too late.

Fundamental noise problems are often the most difficult to solve and should be given attention in the early stages of a project. A noise survey can determine whether environmental noise is an issue, and expensive construction solutions can be avoided by arranging noise sensitive areas sensibly.

In the case of environmental issues, an early noise survey can highlight potential credits (eg for BREEAM, Ska, LEED) and determine whether or not they will be possible or practical to achieve. BREEAM Offices 2011 gives guidance on the sound insulation between acoustically sensitive rooms and other occupier spaces. See [www.breeam.org.uk](http://www.breeam.org.uk) [www.ska-rating.com](http://www.ska-rating.com)

Double glazed operable walls provide flexibility and good levels of sound insulation.



Circular meeting pods require additional absorption such as carpet and a mineral fibre ceiling as shown, to reduce reverberation.



Acoustic requirements in an office environment will be different dependant on the space and its use. For example, a store room will have very different requirements to an interview room, where privacy is required and interruption from external noise should be avoided. Cellular rooms can be designed in a number of ways according to the use of the room and its acoustic requirement.

The integration of circulation space, common and core areas with the main working space, is vital to the success of a building. But while access between the two is important, the distractions of the circulation space must be considered too. For example, the constant opening and shutting of doors is an irritation to office workers, so core access doors could be replaced by fire shutters or doors held on door restraints and linked to the fire alarm system.

### ACOUSTIC CONTROL

Sound can be controlled in two distinct ways: absorption, which deals with reverberation within the space, this makes the space a better place to work in; and insulation, which deals with the control of sound from one space to another. Ceilings, rafts and wall panels are generally used for absorption, while partitions and cavity barriers are used for insulation.

Generally speaking, for acoustic control, the 'softer' the material the better its absorption capabilities, while the more dense the material, the better it is at reducing sound transmission.

This transfers well into the built environment where soft materials are generally used to

manufacture acoustic ceiling and wall tiles, which provide the greater opportunity for sound absorption. Denser materials are used in the construction of partitioning where sound insulation is used to provide privacy, or division from a noisy and potentially disturbing activity.

The third element of control is through diffusers. These can be manufactured from hard materials such as wood, concrete or GRG. Diffuse surfaces scatter sound and are used

to great effect in atria, offices, classrooms and auditoria.

There have also been recent developments and research in to absorptive Perspex and foils utilising microperforated slots and holes to reduce reverberation.

Wall panels provide sound absorption in this boardroom.



Table 2

**WHAT TO CONSIDER WHEN DESIGNING AND INSTALLING AN OFFICE FIT OUT.**

Steps required for **sound absorption...**

**Outset considerations** common to both **sound absorption** and **sound insulation...**

Zone the space, putting areas of communication in the quietest part of the building, and areas of privacy with higher levels of background noise.

Determine the acoustic requirement of the space.

Understand the background noise of the space from all external and internal sources.

**Type of space**

**Atria, open plan, rest area, restaurant etc.**

**Communication** generally important.



Establish suitable reverberation times and noise levels for the space (see performance criteria in the guide for reference).

The size, including height, shape and internal finishes will affect the acoustic properties of the space: ensure these are taken into account.

Consider the services of an acoustician - a list of qualified professionals is at [www.ioa.org.uk](http://www.ioa.org.uk) and [www.association-of-noise-consultants.co.uk](http://www.association-of-noise-consultants.co.uk)

Remember that sound insulation affects users in adjacent spaces, while sound absorption affects the quality of the sound in the space.

Understand the effect on acoustics if an exposed soffit is used, as the lack of an absorbant ceiling could result in increased reverberant noise level or the lowering of background noise where mechanical ventilation is absent.

**Deployment considerations**

Where privacy is important ensure that a speech transmission index of  $\leq 0.4$  can be achieved between adjacent areas.

The suspended ceiling will provide the greatest effect on absorption in a space.

Consider absorbent baffles on the walls or ceiling to absorb and diffuse sound.

Consider installing ceiling rafts and islands to increase absorption where exposed soffits are used.

Consider lowering the ceiling between work clusters.

When looking at test data, check that the test data is still relevant, and ask to see the whole report detailing the composition and assembly of the system.

Ensure that the products are installed fully in accordance with the manufacturer's method of build.

Consider additional absorption in areas of highly reflective surfaces, such as glass or polished plaster.

**Other considerations**

Too much absorption can make a space unnaturally dead. Too little will mean long reverberation times, leading to increased sound levels as people raise voices to be heard over sound that has not decayed.

Be prepared to carry out additional works to fine tune the space in use.

Steps required for **sound insulation...**

**Meeting room, conference room, cellular space etc.**

**Privacy** generally important.



Consider planning offices and meeting areas where background sound (eg from ventilation or office activity) can mask conversation and assist in privacy.

Where communication is important ensure that a speech transmission index of  $\geq 0.6$  can be achieved within the communication zone.

Look at the sound insulation requirements separately to sound absorption, ie partitions, doors, floors.

Where privacy is important ensure that the partition can achieve the required  $D_{nf,w} / D_w$  by specifying the insulating factors of all the elements separately from sound absorption.

When considering the insulating value of partitioning, understand that an onsite test  $D_{nf,w} / D_w$  will be lower to the laboratory test of  $R_w$  by between 3-8dB dependant on the partition type (eg lightweight stud or blockwork).

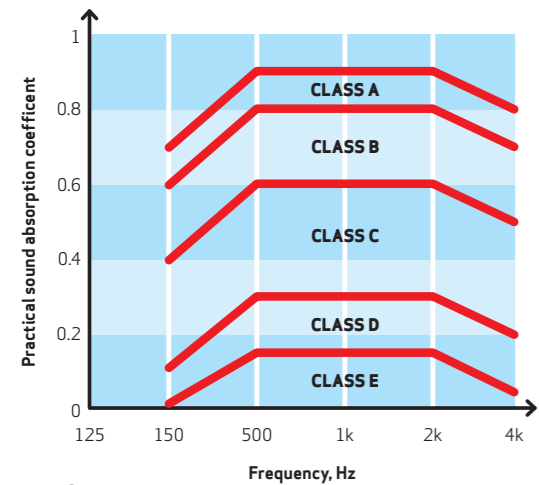
Consider the effect of flanking paths above ceilings or building services.

Balance the benefit of flexibility afforded by installing partitioning to the underside of the suspended ceiling (with appropriate cavity barriers in place) against additional performance but with additional cost and disruption should the partition need moving.

Understand that curved meeting rooms can create an unnatural focal point for sound within the space.

**CEILINGS**

Research has shown that ceilings have the biggest impact on the acoustic quality of open plan offices by providing a surface that can either be sound absorbing or sound insulating or a combination of the two.



**Table 3**  
Illustration of the reference curve limiting the different sound absorption classes, from BS EN ISO 11654: 1997.

**Sound absorption**

A ceiling's sound absorbing properties are described in sound absorption classes (A-E), class A being the highest level of sound absorption.

Resin bonded mineral wool (sometimes referred to as 'soft') ceiling tiles are inherently effective sound absorbers. Most will achieve class A performance unless heavily painted post installation. Some manufacturers offer enhanced levels of sound insulation by integrating dense material to the back of, or

as a sandwich layer within, the tiles.

Medium density mineral fibre boards perforated with needles or fissures to create sound absorbing surfaces typically achieve class C. Sound absorbing products range in weight, density, thickness and surface finish, and each has its relative merits in terms of its ability to provide sound insulation and/or absorption.

Plain, unperforated gypsum boards or panels are inherently poor absorbers and high reflectors, but when perforated they achieve class A, B, C or D performance, depending on the perforation patterns, filament and suspension distance. Perforated metal tiles can achieve class A, B or C when enhanced with mineral wool pads on the metal trays.

**Sound insulation (attenuation)**

Density and mass are key to blocking the passage of sound from one room to another or reducing noise from buildings or services outside.

Higher density tiles provide the best performance - typically up to 40-45dB  $D_{nf,w}$  - but will usually be limited in the sound absorption performance they can achieve. Unperforated plasterboard, wood and metal products offer good sound insulation, although perforated versions require a high density backing to provide higher levels of sound attenuation.

Medium density materials of greater than normal thickness (18mm, 20mm or 33mm) can achieve 40-49dB  $D_{nf,w}$  or more, room to room.

The sound insulation properties of a ceiling

can be measured as a single pass ( $R_w$ ,  $D_w$ ,  $D_{nT,w}$  etc), but usually two pass attenuation ( $D_{nc,w}$  or  $D_{nf,w}$ ), which can be done on site to verify performance.

**TYPES OF CEILINGS**

**Mineral fibre**

Mineral fibre ceiling tiles can be installed on exposed or concealed grid systems or as baffles, islands and rafts solutions.

Their porosity, thickness and density can be varied to alter their acoustic properties to meet the required performance. They can be plain, perforated or fissured and are normally finished with a paint coating or a decorative facing.

Mineral fibre ceilings can also be split into two categories: wet felt mineral fibre ceilings and resin bonded mineral fibre ceilings.

Wet felt mineral fibre ceiling tiles are manufactured using mineral fibres (glass or rock wools) with other ingredients such as recycled newspapers, perlite and binders.

Resin bonded mineral fibre ceilings are manufactured using mineral fibres (glass or rock wools) which are resin bonded and finished with paint coating or decorative facing.

**Plasterboard**

Plasterboard ceilings can be split into two types: monolithic boarded ceilings and modular ceiling tiles.

Plain unperforated plasterboard monolithic boarded ceilings are traditionally installed on a metal furring (MF) system to form monolithic

Type	Maximum absorption $\alpha_w$		Maximum insulation $D_{nf,w}$						
	0.0	1.0	15	20	25	30	35	40	45
Plasterboard MF (unperforated)	0.05	0.05	15	20	25	30	35	40	45
Plasterboard MF (perforated)	0.15	0.25	15	20	25	30	35	40	45
Plain gypsum	0.05	0.05	15	20	25	30	35	40	45
Perforated gypsum	0.15	0.25	15	20	25	30	35	40	45
Metal faced, plain	0.05	0.05	15	20	25	30	35	40	45
Metal faced, perforated	0.15	0.25	15	20	25	30	35	40	45
Wet felted mineral fibre	0.15	0.25	15	20	25	30	35	40	45
Stretch	0.15	0.25	15	20	25	30	35	40	45
Resin bonded mineral wool / glass wool / stonewool	0.15	0.25	15	20	25	30	35	40	45
Wood (unperforated)	0.15	0.25	15	20	25	30	35	40	45
Wood (perforated)	0.15	0.25	15	20	25	30	35	40	45

**Table 4**  
Typical performance matrix for ceilings by type. Not to scale.

Legend:   
■ All manufacturers   
■ Some manufacturers   
■ Limited number of manufacturers

Higher performance figures may require additional fleece, dense boards or quilt.

ceilings with no apparent joints. Plasterboard sheets are screw fixed to the galvanised MF sections suspended from or fixed direct to the soffit. The joints are then taped, filled and sanded to provide a smooth ceiling ready for decoration or as an alternative to taping and filling a full skim plaster coating is applied.

When perforated plasterboard panels are used most plasterboard manufacturers provide a proprietary jointing and filler system.

Plasterboard is available in different thicknesses, densities and reinforced with glass fibre. This system can be used to create feature ceilings, upstand, bulkheads and wall panel details. Alternative suspension systems

using exposed ceiling grid components are also available.

Plasterboard modular ceiling tiles are available in plain and perforated varieties for installation on exposed or concealed suspended ceiling grid systems. Vinyl faced tiles are also available for humid and hygienic environments.

**Metal**

Metal ceilings, typically manufactured from steel or aluminium, come in a variety of options, from tiles to planks and open cellular elements. They are usually finished with a polyester powdercoat paint and are available for installation within a variety of exposed and concealed suspension systems. Metal ceilings can either be plain (unperforated) or perforated with a choice of acoustic infills and backings, depending on the desired acoustic performance.

Metal ceilings can be manufactured to provide custom solutions such as lighting rafts, canopies, trapezoidal panels and bulkheads.

**Wood**

Wooden ceilings are typically divided into two types: solid wood and veneered panels/strips. These are then subdivided into open or closed configurations normally supported on exposed or concealed metal suspension components. In each case it is possible to perforate the ceiling panel or strip or use the gap between the panels to enhance absorptive performance. A choice of backing materials provides a wide variety of acoustic performance. Wood as a carbon capture source also enhances the environmental credentials of a project.

**Stretch**

A stretch ceiling is a lightweight fabric membrane that is thermally tensioned from wall to wall on a perimeter track. Perforated fabrics have higher absorption

properties than plain fabrics. In addition to ceilings, the system can be used for wallcoverings, lighting rafts and diffusers.

**Exposed concrete**

This type of ceiling is simply the exposed concrete slab left in a raw state, sometimes undecorated. Some have shapes cast into the concrete soffit to increase diffusion.

Exposed soffits can be used to provide thermal mass, and so aid thermal control without the need for forced ventilation or mechanical cooling. However, because of their hard surfaces they can increase reverberation times.

As part of a holistic approach to acoustics and thermal control, additional sound absorption from ceiling canopies, barriers, baffles, islands and rafts should be considered. These are often custom designed and can be curved, flat, concave or convex. Because they are directly suspended from the soffit, they allow free air movement to the exposed concrete. Any sound reflected from the soffit is absorbed in the top surface, as well as the surface exposed to the space. Similarly, vertically suspended baffles allow absorption to both faces. Lighting and other services can also be integrated.

**Factors affecting acoustic performance**

The sound insulation performance of the ceiling may be compromised when penetrated by lighting fixtures, ventilation ducting grilles, speakers etc. Additional measures such as acoustic hoods and ducting dampers may be needed to maintain sound insulation quality.

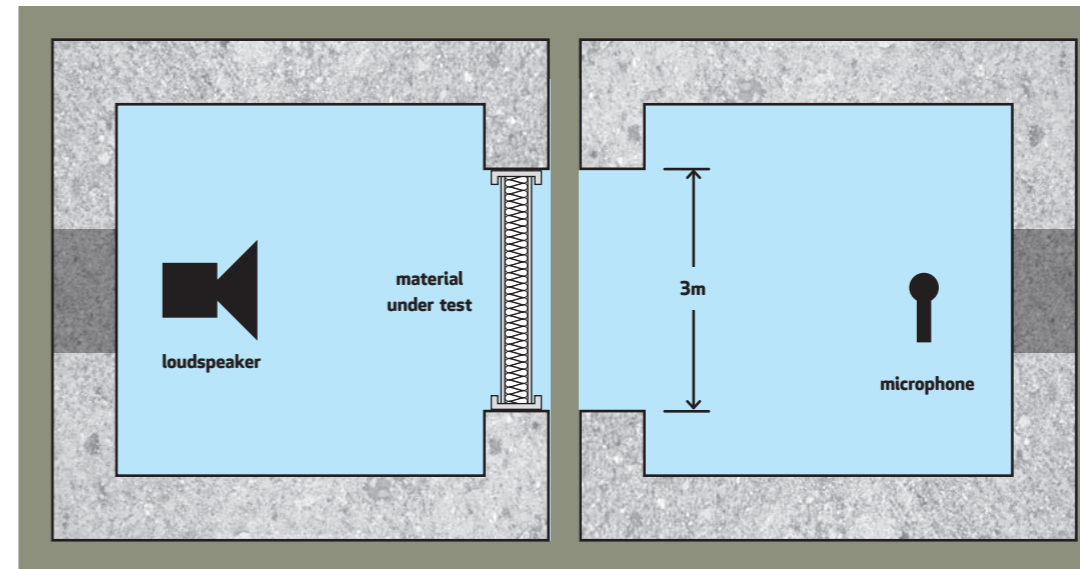
**PARTITIONS**

Partitions can provide good sound insulation but are generally not used for sound absorption. However, they can be used as a supporting medium for acoustic wall panels.

**Sound insulation (attenuation)**

Partitions are tested to internationally recognised standard BS EN ISO 140-3: 1995/ BS EN ISO 10140-2: 2010 under laboratory conditions to determine the sound reduction index (**R**). From these results the single figure weighted sound reduction index dB (**R<sub>w</sub>**) is determined in accordance with BS EN ISO 717-1: 1997.

It is important to understand when specifying partitioning that it is tested in a laboratory under controlled conditions. The partition is installed between two acoustically independent rooms, which means there is no sound leakage. It is therefore considered good practice when specifying partitioning to deduct 6dB to 8dB for lightweight stud partitions and between 3dB and 5dB for heavy construction partitions such as masonry walls - assuming good installation and detailing, especially where deflection heads are required on the underside of a structural slab. This represents the difference between a laboratory test and what can be achieved on site, as site conditions will include other elements such as abutments to walls, soffits and floors, which will transmit sound through the phenomenon known as flanking (see page 34). This phenomenon can also be adversely affected by incorrect



Typical test room showing independent source and receiving rooms.

specifications or poor quality of installation.

When selecting the performance rating of a partition background noise levels need to be accounted for. BS 8233: 1999 encourages the principle of acoustic zoning, using the concepts of intrusive noise and privacy factors.

Background noise can provide vital masking. By carefully increasing or introducing sound, privacy can be increased and intelligibility reduced. Care must be taken to ensure background sound levels do not cause distraction. Recent studies indicate that a maximum level for background sound masking should be 48dBA.

One method of selecting the performance criteria of a partition is a method known as speech privacy potential (SPP). The SPP combines the partition sound insulation

performance expressed in terms of installed **D<sub>w</sub>** with the background noise level in the receiving room expressed in terms of dBA. The higher the resulting SPP, the higher the level of privacy between the rooms. Where amplified speech is used (eg video conference rooms, large seminar room) then higher values of speech privacy may be required.

**Sound absorption**

Walls do not provide the same opportunity as ceilings for large absorbent surface areas because they are interrupted by windows, doors, artwork, furniture and other elements. But where space permits, wall mounted sound absorbers may be used to reduce reverberation times or complement the absorption of the ceilings.

**Wall panels**

Wall mounted absorbers are available as pre-framed units, sometimes made using perforated steel with absorbent infills. These may incorporate artwork or soft panels retained with framing constructed on site from perforated plasterboard integrated within the walls and soffits.

Perforated steel faced panels are available for areas requiring robust wall absorbers.

Privacy rating	Speech privacy
High	85
Raised voices are barely audible and unintelligible.	
Good	75
Normal speech is barely audible, raised voices are mostly unintelligible.	
Basic	65
Normal speech can be overheard some of the time, raised voices can be heard.	
Poor	<65
Normal speech can be heard most of the time.	

Table 5 Speech privacy potential.



Free standing screens can provide informal meeting spaces, where any background noise would be used to effectively provide privacy between the spaces.

**Wallcoverings**

The wide range of wallcoverings available, which mainly use vinyl as a facing, have a negligible impact on absorption. However, some specialist manufacturers have developed products with sound absorbing properties, which when used as part of a holistic approach can contribute to the overall absorption of a space.

**Spray/trowel applied plaster**

Acoustic synthetic plasters can be trowelled or spray applied to substrates, giving a smooth or textured finish. The plaster is self finished, impregnated with a constant colour and has  $\alpha_w$  figures in the region of 0.8. These products have been tested with and without a void, and can be redecorated using spray applied emulsion paint, as long as the thickness is no more than 50/60 microns (dry film).

**TYPES OF PARTITIONING**

**Plasterboard partitions (drywall)**

Drywall partitions are constructed on site from a framework of steel or sometimes timber studs, faced with one or two layers of gypsum plasterboard, the void can be left empty or tightly filled with a glass or mineral wool blanket to increase its sound insulation values or fire rating.

This type of partition offers good levels of attenuation.

**Modular partitions (relocatable)**

Where flexibility and a cellular environment is required, modular panel partitioning can be installed between the floor and underside of the suspended ceiling/soffit. These systems can achieve high levels of attenuation and flexibility, in addition to a fast, dry construction.

Because this type of partition is generally installed to the underside of a suspended ceiling, it should be used in conjunction with a sound barrier in the ceiling void.

**Glazed partitions**

Glass in a partition can perform at good levels of attenuation, especially if double glazed using different thicknesses of glass or if toughened glass is mixed with a laminated glass. Some laminated glass products use special interlayers to achieve an enhanced acoustic rating. These types of glass, originally developed to improve attenuation to external glazing near airports, have migrated to

Weighted sound level difference of partition, $D_w$	Typical construction	Privacy of speech from next room with a background level of...			
		25dBA	30dBA	35dBA	40dBA
32dB	8mm laminated glass	Very poor	Very poor	Poor	Poor
37dB	12mm laminated glass with acoustic interlayer	Very poor	Poor	Fair	Words intelligible but not whole sentences
42dB	100mm thick partition comprised of a single layer of plasterboard either side of a galvanised stud partition with an insulating quilt	Poor	Fair	Words intelligible but not whole sentences	Good
47dB	125mm partition comprised of two layers of plasterboard either side of galvanised stud with an insulating quilt	Fair	Words intelligible but not whole sentences	Good	Very good
52dB	155mm partition comprised of two layers of plasterboard either side of a galvanised stud with an insulating quilt	Words intelligible but not whole sentences	Good	Very good	Very good

**Table 6**  
Privacy of speech (loud speech level) from the next office, depending on weighted sound level difference and background noise level in receiving room (assuming full-height partitions).

Type		$R_w$ dB						
		25	30	35	40	45	50	55
50mm bonded board		[Bar chart showing performance from ~28 to ~32 dB]						
6.4mm laminated glass, single glazed		[Bar chart showing performance from ~32 to ~38 dB]						
6.4mm laminated glass, double glazed		[Bar chart showing performance from ~35 to ~45 dB]						
12.5mm plasterboard over 50mm stud with infill (75mm overall)		[Bar chart showing performance from ~35 to ~48 dB]						
2 x 12.5mm plasterboard over 50mm stud with quilt (100mm overall)		[Bar chart showing performance from ~38 to ~52 dB]						
2 x 12.5mm dense plasterboard over 50mm stud with quilt (100mm overall)		[Bar chart showing performance from ~40 to ~55 dB]						
12mm toughened glass, single glazed		[Bar chart showing performance from ~32 to ~38 dB]						
12mm toughened glass, double glazed		[Bar chart showing performance from ~38 to ~45 dB]						
12mm toughened glass with 10mm acoustic glass, double glazed		[Bar chart showing performance from ~40 to ~48 dB]						
Bipanel modular		[Bar chart showing performance from ~40 to ~50 dB]						
Monobloc modular		[Bar chart showing performance from ~40 to ~45 dB]						
Operable wall		[Bar chart showing performance from ~45 to ~58 dB]						
Plastered block work wall 100mm overall		[Bar chart showing performance from ~40 to ~50 dB]						

Table 7  
Typical performance matrix for partitions by type.

■ All manufacturers
 ■ Some manufacturers
 ■ Limited number of manufacturers

commercial interiors as costs have fallen.

Designers should ensure from the outset that reverberation caused by sound reflecting from hard surfaces such as glass will not make the space uncomfortable to work in. Incorporating products with a high sound absorbency can help offset the effect of large amounts of glass or hard surfaces. It is also important to ensure the glass is not parallel to other reflective surfaces, and circular glass rooms should be avoided, where possible.

**Operable walls**

Operable walls, also known as movable walls, are designed so they can be moved easily to one side of a room to open two rooms into a larger space for meetings and functions. They fall into four groups: concertina, folding, panel and retractable.

Concertina walls are lightweight flexible dividers with relatively low acoustic performance, while folding walls are individual panels linked by a hinge mechanism.

Panel based operable walls, supplied as individual solid or glass panels, are either top hung or sit between a top and bottom track.

Top hung panels can be fully automatically, semi-automatically or manually operated to engage acoustic seals and position the panels along tracks to divide space or store away when opening up rooms.

Retractable partitions retract fully into the ceiling cavity.

All operable walls require an independent support structure, which is usually installed in

the ceiling void but can be used with an exposed soffit. In either case, consideration should be made at design stage to ensure the support is suitably boxed in to maintain the design performance of the partition.

Designers should also take into account the abutments of the operable wall at the perimeter of the rooms. Sound should not be allowed to pass through gaps where the closing panels meet an adjacent wall. It is also worth considering introducing a break in the raised floor tiles at this point to reduce flanking sound, which can be transmitted through the floor tiles.

Because operable walls are designed to be reconfigured following initial installation, a regular maintenance agreement should be implemented to ensure the acoustic seals perform consistently over time.

**Factors affecting acoustic performance**

When installing acoustic performance partitioning it should be made as airtight as possible.

Therefore partitioning fixed between structural floor and structural soffit will provide the highest level of attenuation between two spaces because the partition line is unbroken.

Any service penetrations will weaken the performance of the wall and should be kept to a minimum, including partial penetrations from power sockets.

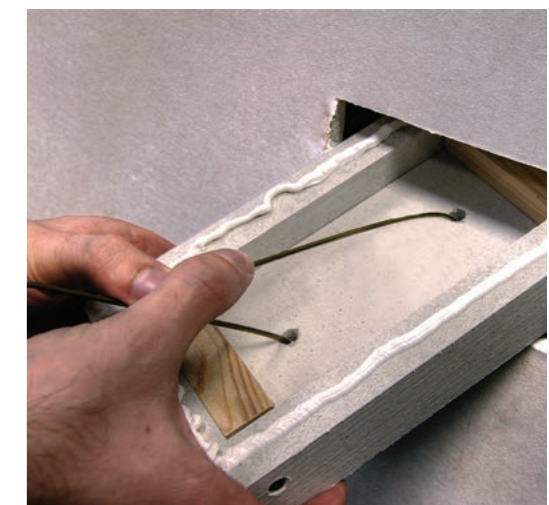
Wall sockets should not be installed back to back but in separate panels. They should be installed with additional acoustic boxes or sound absorbers behind the sockets within

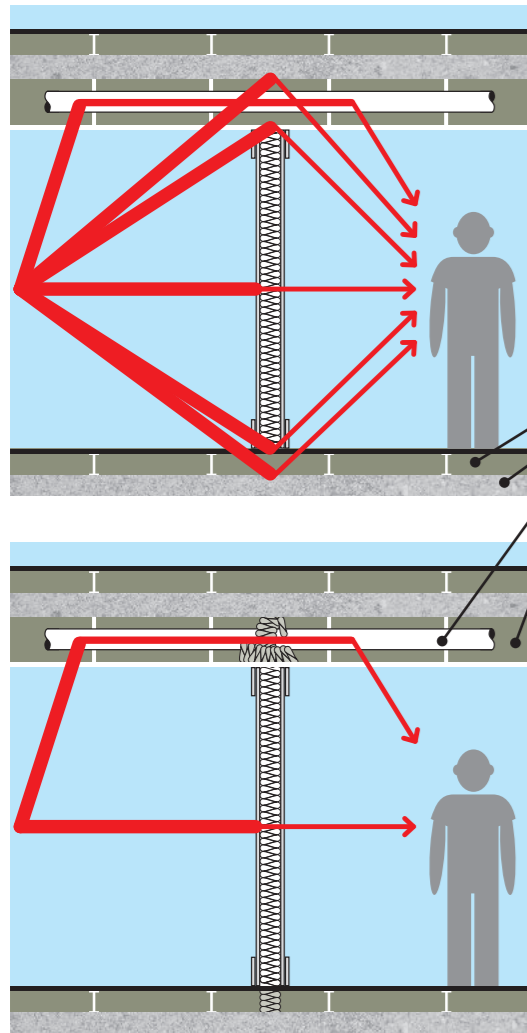
the void to help alleviate the effect of the partial penetration.

A structural engineer should be consulted to ensure any deflection under a live load to the soffit or floor is accommodated using a deflection head in the partition. It should be noted, however, that this may affect the acoustic performance of the installed wall.

A typical high performance composite partition formed from one or two layers of gypsum based plasterboard either side of a 70mm steel stud, and incorporating a 60mm glass fibre quilt within the void, can have performance figures of 52dB ( $R_w$ ).

Installing sound insulation behind a partial penetration in partitioning to maintain its performance.





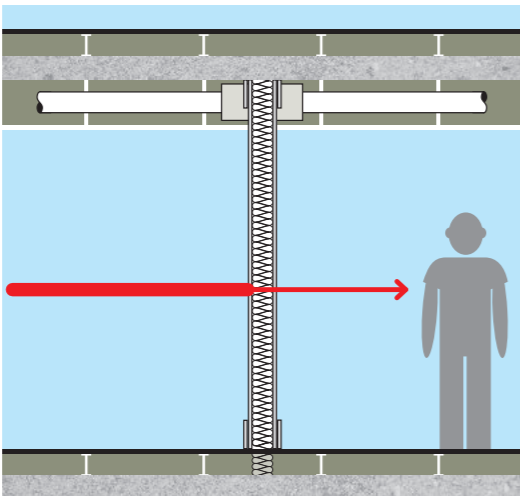
**Typical sound penetration paths**

Top: the partition is installed to the underside of the suspended ceiling, without a cavity barrier.

Lower left: the partition is installed to the underside of the suspended ceiling, with a cavity barrier in the ceiling and floor void.

Lower right: the partition is installed between the raised floor to the underside of the slab, with attenuators installed within the ducts.

Raised access floor and associated void  
Concrete floor structure  
Pipework and ducting  
Suspended ceiling and associated void



If flexibility is required, there may be a trade off between acoustic performance and savings in installation costs and future flexibility.

Partitioning can be installed between the finished floor and the underside of the suspended ceiling. When partitions are installed between the floor and a suspended ceiling, it

the suspended ceiling. Particular attention should be paid when installing partitions to a regular ceiling tile or open channel grid. Any gaps formed by the recess of the tile against the grid or the open channel in the grid should be sealed with a stopper or foam. This will seal any air paths along which sound can travel. It may be practical to install a non-setting acoustic bead between the elements - sometimes referred to as 'caulking the joints'.

**DOORS**

A door is an inherent weak point in any partition, as its performance is generally lower than the partition that surrounds it. This can be used positively in the design process, by allowing background sound to leak into a room to provide masking as part of a privacy strategy. Too little background sound can lead to problems with privacy between rooms.

When specifying doors within a sound performance partition, they must be as airtight as practical. Side hung doors that close into a rebate with seals will perform better than sliding doors which generally have a gap between the face of the door and the partition.

Acoustic seals will enhance the performance of a door. Threshold seals fitted to the bottom of a door, for example, will automatically drop down to seal the gap when the door is closed. These seals are sometimes marketed for their smoke seal abilities but have acoustic benefits.

It is also possible to increase the sound performance of a door by increasing its thickness from 44mm to 54mm. In all cases,

should be noted that sound will travel over the partition within the ceiling void, reflect from the soffit and be transferred to the adjoining rooms. This flanking sound can be reduced through the use of barriers within the ceiling and floor void.

Attention should be given to the seal between the head of the partition and the underside of



A door will affect the performance of a wall.

laboratory based evidence of a door set's performance should be examined at the specification stage.

Glass doors are increasingly being specified. They can be framed, frameless, single or double glazed, side hung or sliding. Each will have different levels of sound performance, which should be taken into account at the design stage.

**RAISED ACCESS FLOORING**

Raised access flooring systems are generally a continuously decked floor of individual panels, supported on pedestals to suit a determined height. Raised access floor panels are made to a regular size, are removable from the installed position and apart from cut panels are wholly interchangeable within the installed system.

Type of space	Minimum $R_w$ dB		Minimum $D_{ne,w} -10lgN$
	Wall inc. glazing	Door set	
Meeting rooms and single occupancy offices	40	30	39
Conference rooms, executive offices, AV rooms	45	30	45

Table 8 Effect on a partition's performance when doors installed (taken from BB93).

**Sound absorption**

As raised access flooring panels are made from hard reflective materials they need to be covered with carpet in order to provide a sound absorbing surface.

**Sound insulation (attenuation)**

Raised access flooring systems can provide varying levels of sound insulation to a space, with enhanced levels of sound insulation achieved by compartmentalising the underfloor area with either high density mineral wool bats or low level plasterboard drywalls under the line of partitioning. Most raised access flooring systems can be fitted with acoustic pads to provide a cushion between the panels and

supporting pedestals and/or between the pedestal base and structural floor. When the floor void is used as an air supply plenum, cross talk attenuators should be considered between compartmented areas.

**Factors affecting acoustic performance**

The sound insulation performance of a raised access floor can be compromised by the introduction of services such as air ventilation grilles and open cable apertures allowing sound transmission under the floor from room to room. If the floor panels are left bare or are fitted with a hard floorcovering this could increase noise levels within the space and generate structure borne sound along the floor.



Dense barrier under a raised access floor (see page 32).



**ACOUSTIC CAVITY BARRIERS**

These can be installed in the ceiling/floor void to help reduce airborne sound from around the partitioning. They should be installed along the line of the partition, ensuring that the width of the partitioning is fully covered at the point where the two elements meet.

There are a number of solutions using mineral fibre fire blankets hung singly or in twin runs along the partition line, as well as proprietary products hung from the soffit or installed above the suspended ceiling.

They can also be installed using gypsum boards as if they were a partition suspended

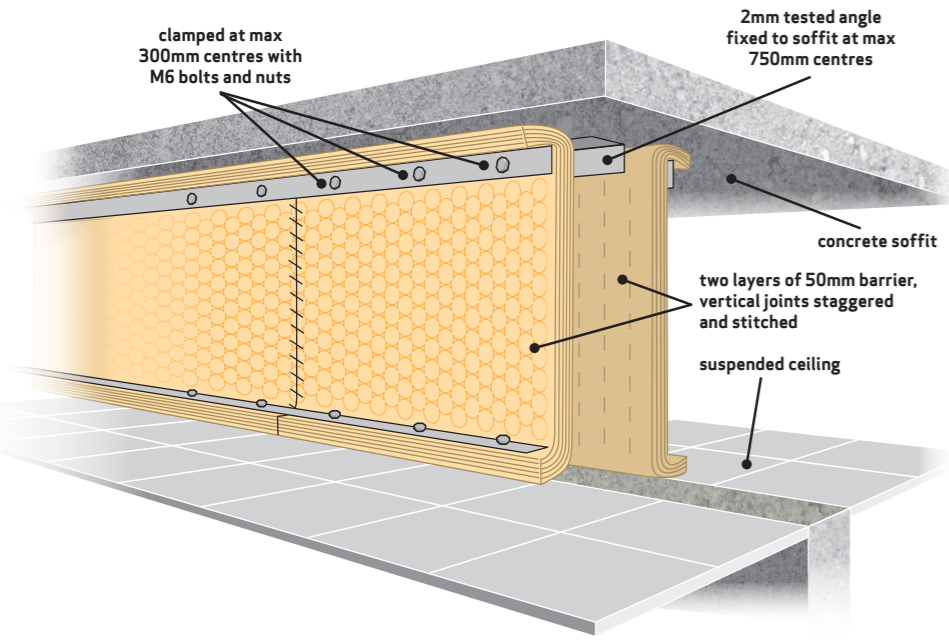
from the structural slab. A plasterboard constructed barrier will form a rigid structure between the slab and the ceiling, so a deflection detail should be considered in the design.

These barriers can be installed along the line of the cross runs of partitioning, allowing some sound from the open plan areas to leak into the rooms, and so provide a degree of background noise that can aid in masking cross talk from room to room.

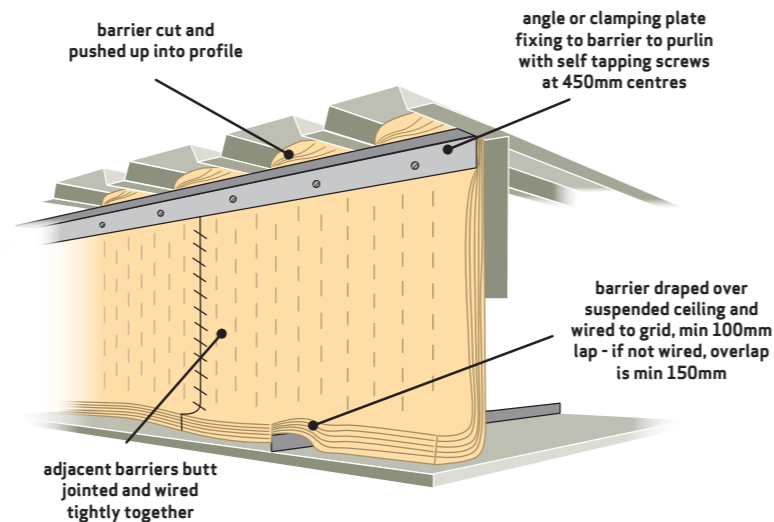
Any penetrations in the barrier will have an effect on its performance. Steps should be taken to minimise penetrations and use cross talk attenuators within any ducting.

Performance figures provided by the manufacturers are sometimes calculated on a given performance of a suspended ceiling. This figure is derived from a laboratory test which, for control purposes, is conducted without light or ventilation fittings. Therefore any calculations should take into account the site conditions or proposed detailing.

It should be noted that when any partitioning is reconfigured, the corresponding sound barriers should be repositioned or a new barrier installed where acoustic performance needs to be maintained.



Typical cavity barriers installed along a partition line within the ceiling void.



Possible reduction in dBA using 1800mm height screens

Sound at source dBA	Screen height	dBA at 2m	dBA at 4m	dBA at 6m
Shout 75	1800mm	53	48	47
Speech 65	1800mm	43	38	37

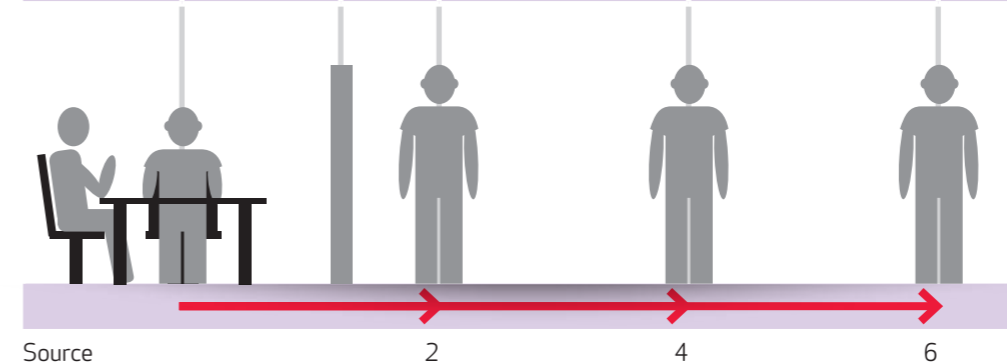


Table 9 Reduction in dBA when using screens.

**SCREENS AND FURNITURE**

Office furniture will affect the acoustic properties of a room, either positively or negatively. Hard surfaces, such as glass topped tables, will reflect sound, potentially amplifying the sound and increasing reverberation times. But soft surfaces can be introduced into an office to absorb sound, including fabric covered soft panels on the back of tall cabinets or freestanding partitions or screens.

Freestanding screens should be planned as part of a whole solution. Position, height and quantity should be considered alongside the absorption properties of the soffit treatment

and suspended absorbers - ceilings, rafts and so on - and background sound levels in occupancy (see table 9).

**FLOORCOVERINGS**

Although floors are a reflection of the soffit or suspended ceiling by area, they do not typically provide the same level of absorption. They can also be covered by furniture and equipment and, unlike ceilings - which have a void between them and the slab - carpets are installed directly to a floor surface.

Often the hard wearing carpets used in a commercial situation provide little absorption

due to their minimum pile depth and the fibre used, which can reduce over its practical life.

Carpets can, however, provide acoustic benefits in dealing with structure borne sound caused by footfall and a degree of additional absorption within the space, especially within a large, open area.

Hard heels create a loud sound on a wooden or laminate floor. One way to deal with this is to use a soft floor finish or isolated hard floorcovering. A soft floorcovering also minimises the noise of footfall in the source room as well as in the floor below. It is also worth considering gypsum based raised floors for tackling high impact sound.

**SECONDARY GLAZING**

The cavity or gap between an existing primary window and the secondary unit can make a big difference to the level of noise insulation. Unlike sealed units, where the two pieces of glass are rigidly coupled together, the primary and secondary windows act more like independent barriers to the transmission of noise. The greater the cavity between them, the better the insulation effect of the combined window. A minimum of 100mm is recommended.

Gaps around window frames representing just 1% of the frame area allow the passage of airborne sound that can reduce noise insulation levels by as much as 10dB.

Secondary windows are tailor made with seals that shield the whole window opening and minimise leakage.

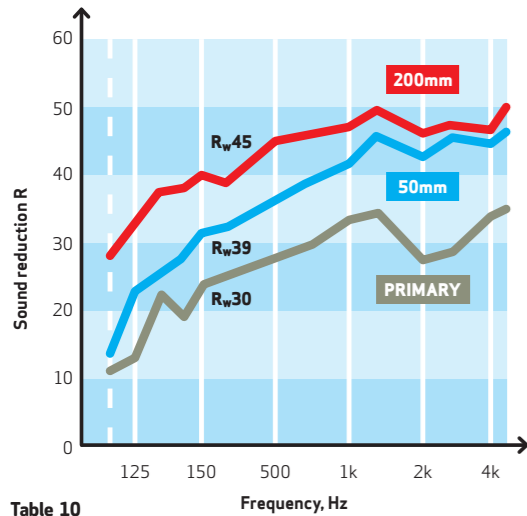


Table 10  
Effect of cavity.

It is possible to select from a wide range of glass types to ensure optimum performance. The inner and outer glass should have different mass to avoid sympathetic resonance, which will increase noise transmission at higher frequencies. Thicker glass has greater mass and improves performance, particularly at lower frequencies. Acoustic laminate glass has a special interlayer that helps improve high frequency performance.

Absorbent lining materials can be fixed between the window frames, raising insulation levels by 1-3dB. These are most effective at higher frequencies.

### INTERNAL FINISHES

Careful consideration must be given to all room finishes when designing an office environment. The location, placement and orientation of absorptive, reflective and diffusive finishes/

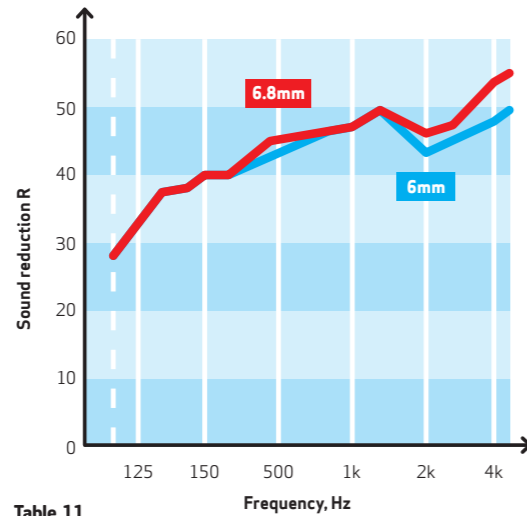


Table 11  
Effect of acoustic laminate.

furnishings can be used to good effect in promoting privacy or intelligibility.

For example, placing highly absorptive furniture near to noise sources can be effective in controlling the spread of the noise to other areas. Reflective surfaces will promote the propagation of sound, which is desirable in certain circumstances.

Diffusive surfaces can be helpful when reflections between parallel surfaces would otherwise cause acoustic discomfort, for example, flutter echoes or room modes. But while products such as diffusers are commercially available, it is possible to create desirable conditions using furniture or fittings, such as bookcases or plants.

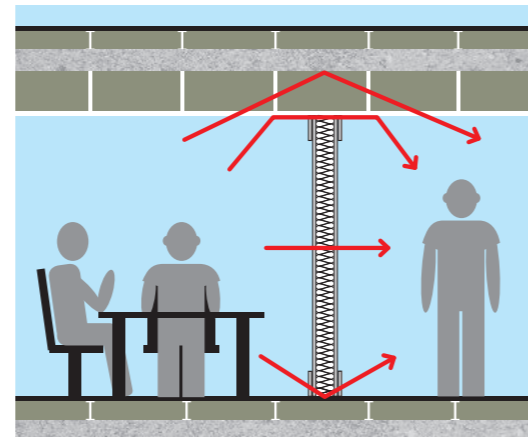
### DESIGN CONSIDERATIONS

The sound performance of any room will be affected by a number of factors, from the size and shape of the room to the elements in the room and the relationship that they have where they meet and are penetrated.

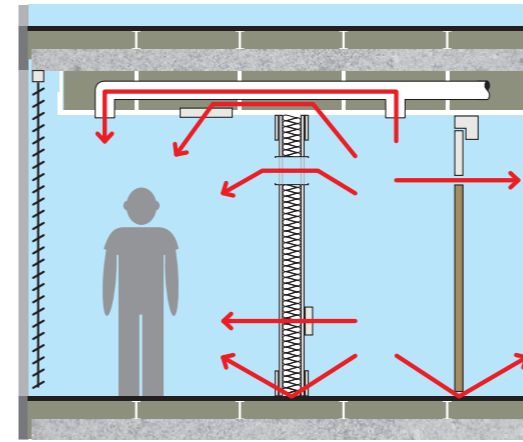
#### Flanking sound

Flanking can be defined as sound travelling around a sound resisting element as well as, or instead of, through it. In an office environment this may include:

- Transition of sound over the top of a partition - for example, where it is not sealed to the underside of the soffit.
- Sound moving underneath partitions - for example, where partitioning is built off a raised floor. This is exacerbated when there are no floor barriers or if the ventilation

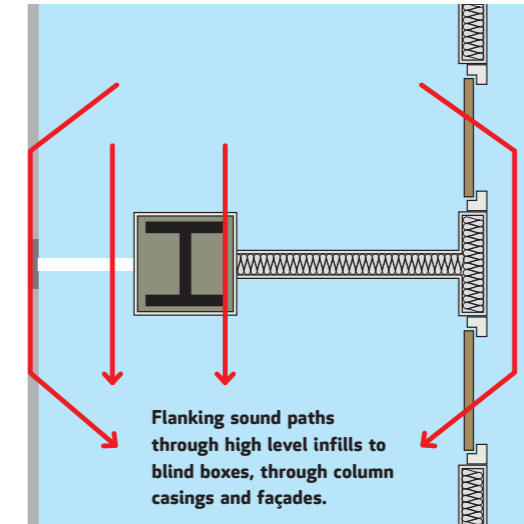


Room to room sound transmission - each flanking path will result in a discrete source of noise, and the resulting level in the receiving room will be a combination of these discrete sources.



Typical flanking paths around partitions.

- system uses the floor void as a plenum and the floor contains air diffusers.
- When butting internal partitions to external wall linings - care should be taken to ensure flanking does not occur either through the lining itself or the cavity behind.
- Where curtain walling is installed and the structural floor abuts the transom - this is a weak point. This detail should be acoustically reinforced so the sound reduction of the transom structural edge beam and any sound insulation detail are as close to that of the structural floor as possible.
- Direct flanking of sound through the continuous curtain walling sections. An effective way of controlling this is to use unitised curtain walling and to provide thermal/acoustic breaks between adjacent structural zones.
- Doors.
- Cross talk through ventilation.



- The junction of the structural and raised flooring with other building elements, specifically external walling/glazing, and structural steelwork.
- Sibilance and grazing reflections**
- In the case of large, open floorplates, consideration must be given to the reflection of sound from room surfaces. Materials with good absorptive characteristics may not have that level of absorbency at all angles of incidence. For example, a perforated material may absorb sound when the sound hits the surface directly, but at an acute angle to it the sound can be reflected. In such circumstances perforated materials may only be absorptive within a certain radius of the speaker or listener. This radius will be determined by the floor to soffit dimension and percentage of perforation of the material spacing/size of perforations.

When sound reflects from an otherwise absorptive surface, this is known as grazing reflection and can cause enhanced sibilance and exaggerated high frequency sound.

#### Ventilation (including climate control mechanisms, chilled beams/ceilings, displacement, supply and return air plenums.)

Acoustic design parameters should not be specified without balancing them against the other needs of the building's users. The holistic designer must seek to achieve the optimum balance and compromise of acoustic comfort with thermal comfort, visual comfort, sustainability and cost.

The most recent British Council for Offices standard (2009) acknowledges the need for compromise in its wholesale redress of comfort standards. The changes come in response to the pressing need to reduce the energy consumption of our buildings and will often require the building designers to compromise on acoustic standards.

**Integrating acoustic absorption into building services systems**

Certain mechanical and electrical systems can be used to support acoustic absorption panels, while allowing the thermal mass of the concrete soffit to be exposed:

1 Chilled 'beams' are often specified when refurbishing offices that have a low floor to floor dimension. These multiservice systems maximise the perceived height of the space and can allow the concrete soffit to be exposed, while housing the ventilation, lighting and other systems. Acoustic absorption surfaces can be included in the beams to help reduce reverberation, but when partitions are introduced care is needed to provide acoustic barriers in the beams at penetrations between rooms.

2 Suspended light fittings can be integrated into acoustic rafts that hang beneath the soffit. If they are very large they may reduce the effectiveness of the exposed thermal mass and detailed modelling will be required to ascertain the limiting parameters.

**Reverberation control**

The term 'reverberation time' (RT) is a useful descriptor for the environment in an enclosed space, although in large spaces, such as open plan offices, where one room dimension is significantly disproportionate to others RT may not be the most accurate method of describing the space. While RT could be used as a design target when tested in situ, it is likely that the results would vary significantly with different

**SOUND RATING AND PERFORMANCE DESCRIPTORS**

When specifying ensure that the correct descriptors are used and, if comparing products, a like for like comparison is made.

A number of acoustical descriptors are used for building elements, some of which refer to laboratory performance and others for site measurements. A summary of the most common descriptors is listed here, and can be found in the relevant BS/ICON standard. Refer to Section 6: Terminology for a full description of each descriptor.

**Descriptor relevant standard**

$R_w$	ISO 717 and 140
$R_w + C_{tr}$	ISO 717 and 140
STC	ANSI standard
$D_{nc,w}$	ISO 12354
$D_{ne,w}$	ISO 12354
$D_{nf,w}$	ISO 12354
$D_w$	ISO 717 and 140
$D_{nT,w}$	ISO 717 and 140
$D_{nT,w} + C_{tr}$	ISO 717 and 140
$D_{nT} (T_{mf,max},w)$	BB93
$R'_w$	ISO 717 and 140
$L'_{nT,w}$	ISO 717 and 140
$L'_{nT} (T_{mf,max},w)$	BB93

sources and receiver locations. So, it may be more appropriate to use the speech transmission index (STI) and other descriptors from ISO DIS 3382-3 (2012).

Speech to noise ratio or signal to noise ratio (SNR) is a critical factor in determining intelligibility. Generally, the higher the SNR, the greater the intelligibility, although the reverberant characteristics of the space are important. For example, public address announcements made at train stations or airports have a good SNR but long decay times that can render the signal unintelligible.

As a rule of thumb, an SNR of at least 10-15dB is essential for good intelligibility. That is to say that speech should be 10-15dB above the background noise to be understood.

For privacy, the SNR should be as low as possible.

**Intelligibility**

The descriptor used to define intelligibility in a room or open space is the speech transmission index (STI), which has a value range of 0 to 1.

Table 13 shows the relationship between an STI value and the perceived intelligibility of speech, as derived from research.

Speech intelligibility defines the degree of privacy in a space. The higher the intelligibility, the better for promoting communication in a space; the lower it is, the better for privacy. Intelligibility is affected by the background noise level and reverberance of a space.

Because RT is not an accurate descriptor of open plan spaces - due to the lack of a diffuse sound field, disproportionate room dimensions and lack of uniformly distributed absorption - other descriptors are used, although none has been universally adopted.

Factor	Within a working cluster	Between working clusters
Background noise level	NR40/46dBA (L <sub>90</sub> )	NR40/46dBA (L <sub>90</sub> )
STI	≥0.60	≤0.40
Absorption per m <sup>3</sup>	≥0.21	≥0.36
Physical factors	Ceiling $\alpha_w$ 0.5-0.7 across speech frequencies	Ceiling $\alpha_w$ ≥0.9 across speech frequencies
	Soft floorcovering	Absorbent screens 1.4m to 1.8m high  Soft floorcoverings  Lower ceiling height between clusters to break up skimming across ceiling

**Table 12** Performance criteria based on research and good practice, from Andrew Parkin's paper at Euronoise 2009, 'Lessons to be learnt from open plan offices and classrooms'.

Some descriptors refer to the acoustic performance of the space, others relate to the physical properties:

**Acoustic performance of the space**

- STI a measure of speech transmission quality
- DL2 the spatial decay of the A-weighted speech level per distance doubling

**Physical properties**

- $\alpha_w$  or noise reduction coefficient (NRC) of surfaces and finishes
- Amount of absorption per m<sup>2</sup> or m<sup>3</sup>

When describing the physical factors of an open plan space, refer to its absorption per volume. This can take into account not only the shell and core/Cat A finish, but also those from Cat B and internal furnishings.

**Open plan environments**

As stated, there will be varying requirements for privacy and intelligibility across an office floorplate, depending on workers' tasks.

Good speech intelligibility within working clusters or between groups of workers collaborating on the same task is imperative. A suitable value of STI for this zone would be ≥0.6. For a reasonable standard of privacy

STI value	Subjective description
0.0	Bad
0.1	
0.2	
0.3	Poor
0.4	
0.5	
0.6	Fair
0.7	Good
0.8	
0.9	
1.0	Excellent

**Table 13** Relationship between STI value and perceived intelligibility of speech.

between adjacent workers or groups of workers, an STI of ≤0.4 is recommended.

This will be difficult to achieve unless the area is designed for the intended end user layout and function.

Values of STI are usually predicted using specialist modelling software. An example of using modelling for open plan classrooms can be found at [www.teachernet.gov.uk/acoustics](http://www.teachernet.gov.uk/acoustics)

There are many similarities between open plan offices and classrooms, and although some sections of this resource refer to classrooms only, it is helpful in setting out many of the parameters for modelling.

Some modelling software uses ray tracing so



This artwork helps to diffuse sound and its soft felt construction helps reduce reverberation.

you can see how the sound spreads across a space to determine what happens to it from source to receiver. It is important to reflect the built environment in the model as accurately as possible, including the absorptive and reflective character of furniture and fittings and the background sound level - which would vary widely between mechanically and naturally ventilated spaces. While 0.6 is a good STI value, it may not always be possible to achieve. Table 13 overleaf shows the potential effect of achieving different STI scores. There are a number of descriptors for rating the behaviour of sound in an open plan environment, such as auditory strength, articulation class and spatial decay. Full definitions can be found in ISO 3382-3 (2012) Part 3.

**Cellular environments**

Control of reverberation in smaller enclosed spaces such as offices, meeting rooms and conference rooms must be appropriate to the use of the space - for example, discussions by telephone or between people in the same room.

Documents such as BS 8233 table 8 and BB93 table 1.5 suggest reverberation times in an unoccupied room of between 0.4 and 1 second (BS 8233 looks at the 500Hz octave band alone, whereas BB93 takes an average of 500Hz, 1000Hz and 2000Hz). It should be noted, however, that for larger rooms in which speech needs to be understood by a number of people, values <0.6 should be avoided as they may unduly deaden other sound. Measures put in place to control reverberation should be

Room volume m <sup>3</sup>	Reverberation time RT	
	Speech	Music
50	0.4	1.0
100	0.5	1.1
200	0.6	1.2
500	0.7	1.3
1,000	0.9	1.5
2,000	1.0	1.6

**Table 14**  
Guide to reverberation time RT at 500Hz in unoccupied rooms for speech, from BS 8233 table 8.

sited to control unwanted reflections from walls or soffits, for example.

**Atria**

By their very nature, atria tend to have high room volume but poor acoustic absorption capabilities. RT can be high, often up to four or five, which can lead to poor speech intelligibility and, if open to other office areas, cause distraction to workers. By connecting atria to office floor plates, the RT in the office may become extended when compared with an otherwise closed floor plate.

There is normally limited opportunity to introduce absorptive treatments to control RT in atria, but measures should be

Type of room	T <sub>mf</sub> seconds
Seminar rooms, open plan teaching areas, study rooms (individual study), audiovisual conference rooms, interview/counselling rooms	<0.8
Atria, circulation spaces used by students	<1.5
Lecture rooms for less than 50 people	<0.8
Lecture rooms for more than 50 people	<1.0
Offices, staff rooms	<1.0

**Table 15**  
Performance standards for reverberation in spaces, from BB93 table 1.5.

considered wherever possible, using the most effective absorption, such as rafts and perforated panels.

Control of RT is critical when voice alarm systems are used for building evacuation in the event of a fire or other emergency.

**Background noise**

Various factors in the base build construction allow acoustic leakage, which can make confidentiality between offices or between offices and an occupied space difficult to achieve. It is even more challenging in quiet areas of a building where low background

noise is common.

Background noise is a critical factor in the acoustic success of an office environment. It should not be so high as to disrupt concentration and communication, nor so low that it provides no masking of other office sounds. Typical sources of background noise include ventilation, external noise, office machinery and equipment, and other office users.

In 2001 studies by Banbury and Berry found that acoustic changes in pitch, timbre or tempo were the main causes of disruption rather than level. A sudden noise is more likely to disrupt than the constant level of an air handling unit.

Where background noise is very low, the apparent performance of a partition will be less notable than if the background noise level were higher.

It is often easier and more cost effective to provide a comfortable level of background noise than to increase the sound insulation of partitions. In an open plan environment the introduction of additional background noise can provide good levels of speech masking.

BS 8233: 1999 in Section 7.6.3.2 says: In open plan offices, the maximum reduction that can be expected between screened workstations 2.5m to 3.0m apart is 15dB to 25dB, but the cumulative noise of equipment and people may provide a masking background level making this adequate for general needs.

The screening should be absorbent faced and at least 1.5m high. Ceilings should be low (not exceeding about 3m) and have high sound absorption - for example, 0.9 averaged over the



Well designed booths allow privacy within noisy areas for private meetings.

frequency range 500Hz to 2,000Hz - and they may be flat. The floor would ideally be finished in carpet with good sound absorbency properties.

It should be noted that if the width of the room is small, reflections from the side walls may reduce the effectiveness of this arrangement. So, for a background noise level of 40dBA or NR35, taking a conservative value of 15dB reduction, this would have a speech privacy of 55. Values lower than this would be caused by a lack of screening and reduced absorption from the ceiling.

**Proprietary introduced sound masking**

Where background noise levels are very low - perhaps where natural ventilation is being used

and there is little sound entering the building from the surrounding area, it can be helpful to introduce 'shaped' background noise to mask sounds and block out conversations.

However this design should only be used for masking sounds below 48dBA as studies have shown that background sound levels above 48dBA can be disturbing.

Sound masking introduces unobtrusive background noise into an office to reduce interference from distracting office sounds. It can also render speech from co-workers virtually unintelligible.

Used in open and closed offices when ambient sound level is too low, it involves the electronic projection of sound, similar to softly blown air, through speakers. This sound is evenly distributed in the area being masked and can be adjusted to individual privacy requirements.

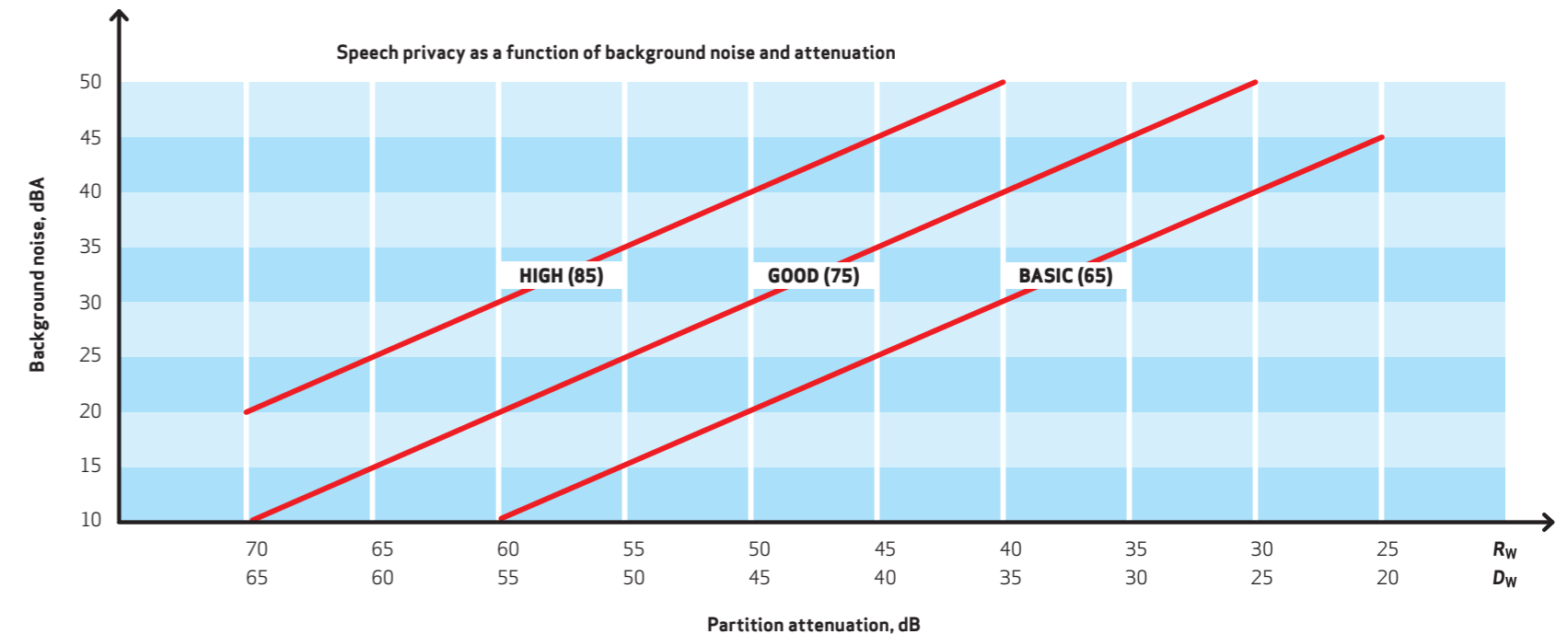
The graph below illustrates how a basic level of privacy can be achieved using a partition with a  $R_w$  figure of 30dB where the background noise level is above 40dBA, while a system offering  $R_w$  of 45dB can achieve a high level of privacy where the background noise is >40dBA.

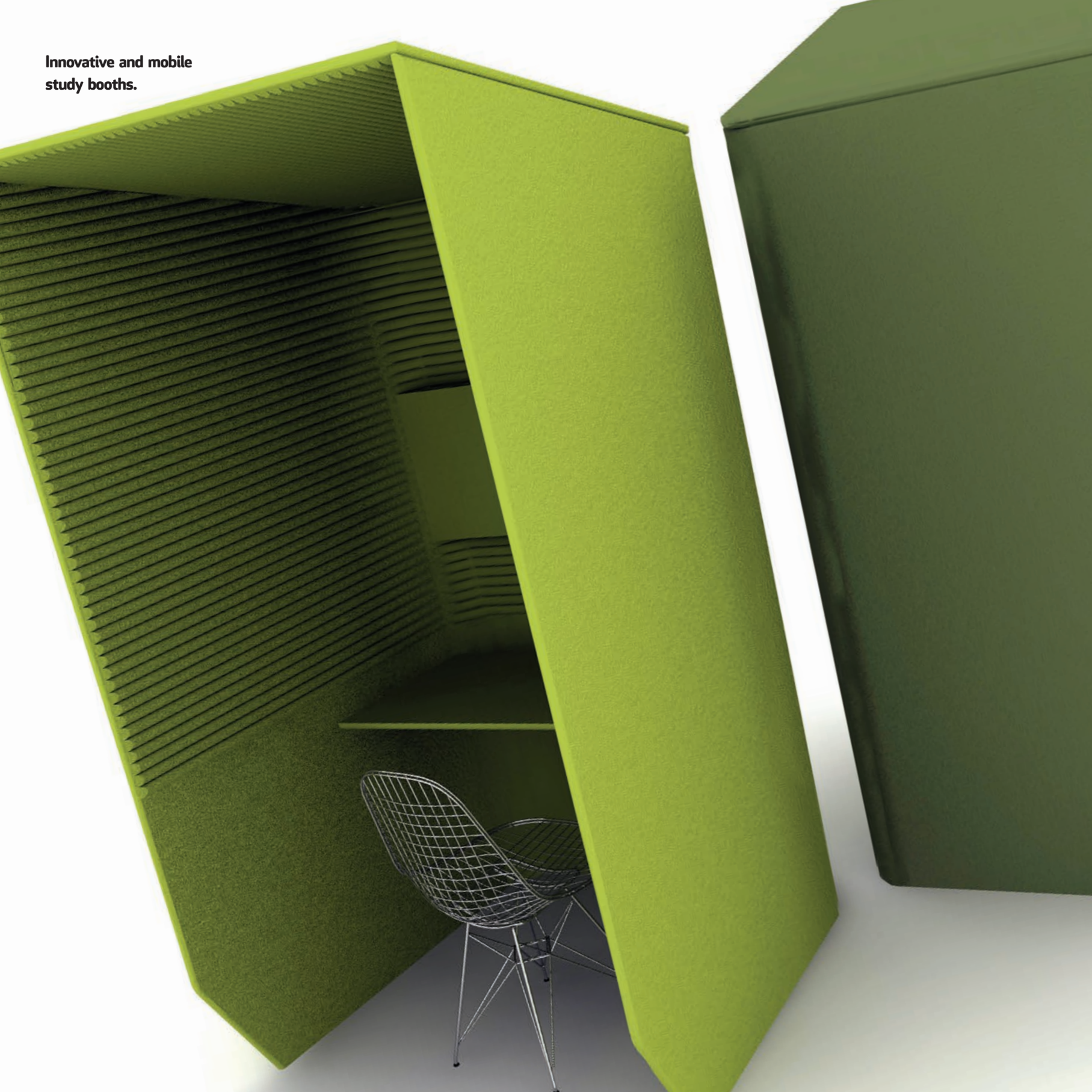
Equivalent  $D_w$  ratings are also shown.



Even though this meeting area is open, it can still provide a degree of acoustic privacy from the open area behind.

**Table 16**  
Graph showing sound radiation of partitioning in relation to background noise levels, to achieve variable rates of privacy.  $R_w$  figures assume a good standard of detailing and workmanship.





**A-weighted decibel, dBA or dB(A)**

A modification of the measured sound pressure level that approximates more closely to the response of the ear over the normal range of sound levels heard and thus correlates reasonably well to the subjective reaction to the level of sound.

**Alpha  $\alpha_w$**

See **weighted sound absorption coefficient**.

**Apparent sound reduction index,  $R'$**

A measurement of sound reduction index but in the presence of flanking sound transmission. Apparent sound reduction index can be established for laboratory or field measurements in accordance with BS EN ISO 140-3 or 140-4.

**Ceiling attenuation class, CAC**

A US based single number rating system expressed in decibels, of the laboratory measured frequency dependent room to room sound insulation of a suspended ceiling sharing a common ceiling plenum above adjacent rooms.

**Decibel, dB**

A unit of magnitude for sound pressure, sound intensity, sound power and, in relation to sound insulation, the measurement of level reduction. The dB is a logarithmic unit that compresses a wide range of values into a smaller scale.

**$D_{nT,w}$**

See **weighted standardised level difference**.

**$D_{nc}$**

See **suspended ceiling normalised level difference**.

**$D_{nc,w}$**

See **weighted suspended ceiling normalised level difference**.

**$D_{ne}$**

See **element normalised level difference**.

**$D_{ne,w}$**

See **element normalised level difference**.

**$D_{nf,w}$**

See **flanking normalised level difference**.

**$D_w$**

See **weighted sound level difference**  
- also ISO 717 and 140.

**Element normalised level difference,  $D_{ne,w}$**

From BS EN ISO 12354: 2000 - the difference in the space and time average sound pressure level produced in two rooms by a source in one, where sound transmission is only due to a small building element - for example, transfer air devices, electrical cable ducts, transit sealing systems.

$D_{ne}$  is normalised to the reference equivalent sound absorption area.

**Flanking sound**

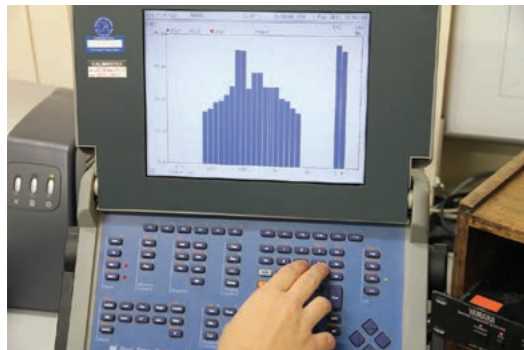
Structure borne transmission of sound between adjacent rooms or spaces but which bypasses the obvious dividing barriers. Such transmission paths may include side walls, floor slabs and ceiling slabs. The effect of flanking sound is to lower the achieved sound insulation between adjacent areas below that which would be expected from the known performance of the identified dividing barriers. Because flanking sound is always present (other than within the 'ideal' confines of an acoustics laboratory), practical site performance between 'non-isolated' constructions will be limited (typically to about  $R_w$  55dB).

**Flanking normalised level difference,  $D_{nf,w}$**

Defines the sound insulation value from room to room, where a dividing partition abuts the underside of the ceiling with a plenum (void) above. The laboratory test procedure involves use of a massive partition wall, such that the derived performance is that of the ceiling alone, with no flanking paths.

**Floating floor**

A floating floor is part of a composite floor construction whereby the upper surface membrane (possibly a concrete screed or timber deck) is independently isolated (floated) from the lower structural floor by the use of a resilient underlay or an array of flexible pads or spring isolators. This separation results in better airborne and impact sound insulation than would be achieved by an equivalent solid floor of the same overall mass, provided the 'isolation' is maintained throughout with no rigid connections between the floating and structural floor, including around the edges of the floating floor.



Dual channel real time analyser which can accommodate the majority of building and environmental acoustic tests.

**Frequency, f**

The number of cycles of pressure fluctuations within a given period of time. The human audible frequency scale extends from about 20Hz (ie cycles per second) to 20,000Hz. With such a potentially wide range of frequencies it is necessary, for practical use, to break them down into manageable groups or bands. In building acoustics, octave bands and one-third octave bands are generally used.

**Hertz, Hz**

The unit of frequency for pressure fluctuations. One cycle per second is termed one hertz.

**Impact sound**

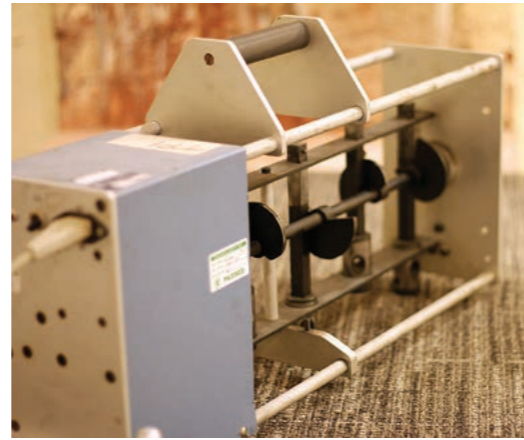
Produced when short duration sources such as footsteps, wheeled trolleys or door slams, have a direct impact on a structure. The sound will be heard as surface radiating airborne sound within the area containing the source, but it may also be transmitted as structure borne sound to re-radiate as airborne sound in more remote locations.

**Impact sound pressure level,  $L_i$** 

This is the measurement of sound pressure levels in a receiving room, when the floor/ceiling assembly is under test, including the presence of a floorcovering if applicable, is excited by a standardised tapping machine in the room above.

**Imperforate construction**

No air gaps through which noise can be transmitted.



A tapping machine is used in laboratory and field measurement for impact sound transmission tests.

 **$L'_{nTw}$** 

See **weighted standardised impact sound pressure level**.

**Mass law**

A relationship used in predicting the approximate sound reduction index (SRI) of a uniform single-skin dividing barrier based on its mass.

**Noise**

Unwanted sound resulting in distraction or disturbance, interference with speech and stress or damage to hearing. However, noise can be subjective - a noise that upsets one person may go unnoticed or be pleasing to another.

**Noise criteria curves, NC**

A US method of rating broadband sound against a set of standardised curves that broadly equate to curves of equal loudness.

**Noise rating curves, NR**

A European method of rating broadband sound against a set of standardised curves that broadly equate to curves of equal loudness. Used to describe sound from mechanical ventilation systems in buildings.

**Noise reduction coefficient, NRC**

A US single number rating for random incidence sound absorption coefficients. The term is defined in ASTM 423 (ASTM International, formerly known as the American Society for Testing and Materials (ASTM)) as the arithmetical average of the measured sound absorption coefficients for the four one-third octave band centre frequencies of 250Hz, 500Hz, 1,000Hz and 2,000Hz, which is then rounded to the nearest 0.05.

**Octave band**

A group of adjoining frequencies where the value of the upper limiting frequency is twice that of the lower limiting value. In building acoustics, octave bands are typically centred around 63Hz, 125Hz, 250Hz, 500Hz, 1,000Hz, 2,000Hz and 4,000Hz.

**One-third octave band**

A higher resolution version of octave bands, breaking each octave into equal thirds.

**Pink noise**

Broadband (electronically generated) noise, whose energy content is equal per frequency bandwidth, which is often used as a sound source for acoustic measurements.

**Pugging**

A loose fill material inserted into the joist cavity of a lightweight timber floor in order to improve its sound reduction properties.

Dry sand, gravel, ash or dense granular man made mineral fibre can be considered and the material is either laid onto the rear of the ceiling or supported on boards fixed between the joists. Performance increases with mass.

**Random incidence sound absorption coefficient,  $\alpha_s$** 

A measure of sound absorption derived from tests undertaken in a reverberation chamber of an acoustics laboratory, over the one-third octave frequency bands 100Hz to 5,000Hz, in accordance with BS EN 20354 or ASTM C423.

**Rating of sound insulation**

Most measurements of airborne or impact sound insulation, whether field or laboratory, are conducted over a range of frequencies to obtain a detailed picture of performance. If these are made in accordance with national or international standards, at least 18 individual one-third octave band measurements over the 100Hz to 5,000Hz range should be obtained.

For specifiers who are trying to compare the performance of alternative building products, or for suppliers of product data, such a large range

of values are cumbersome and make comparisons awkward. A single number rating (that distills the wide range of measurement results) is more appealing and easily handled.

A simple arithmetic average (adding up all the values in the range and dividing by the number in the range) has been used - see Sound Reduction Index - but the final result can be misleading in that it takes no account of the shape of the frequency spectrum. Using this method, three entirely different shaped spectra could all have the same average value.

Consequently, specific rating methods have been devised and introduced that do take into account the spread of measurements, against frequency, by comparing them with a standard curve. Further, as the standard curves adopted are chosen so as to simulate the human response to sound, the values obtained generally correlate well with the subjective impression of common internal noise sources.

BS EN ISO 717-1 and 717-2 and ASTM E413 and E989 give the rating methods and procedures.

**Reverberation**

The persistence of sound in an enclosure, due to its continued reflection or scattering from surfaces or objects, after the sound source has ceased. Reverberation is significant in determining the quality and level of sound within internal spaces.

**Reverberation time, *T* or *RT***

This is the time, in seconds, required for reverberant sound in an enclosure to decay to one-millionth (equivalent to a drop of 60dB) of its original energy level after the cessation of the sound source. It is the most common (and easily obtained) measurement or predictor of a room's potential sound quality.

The reverberation time for speech needs to be reasonably short or successive speech sounds will overlap, leading to loss of intelligibility.

***R<sub>w</sub>***

See **weighted sound reduction index** - also ISO 717 and 140.

**Sound absorption**

The loss of sound energy when striking or transmitting into a boundary surface material or obstacle or when causing a volume of air to resonate. The reduction of energy is generally due to dissipation into heat by friction but it may also be lost when sound passes into adjacent areas, or to the outside through an opening, but does not return.

Most materials absorb sound to a greater or lesser extent and the more common forms of sound absorbers can be conveniently classified into three main types - dissipative (porous), membrane (panel) and resonant (cavity).

More recently developed forms of engineered sound absorbers have become available, which use thin micro-perforated plates and films and thin non-woven porous tissues. Their performance can be optimised by selecting specific values for their flow resistance and spacing them in front of reflective surfaces.

Sound can also be absorbed within air, although this is only significant at high frequencies and depends on temperature and humidity.

Increasing the sound absorption within an enclosure will result in a reduction of the (frequency dependent) reverberant sound pressure level and reverberation time.

Conversely reducing the sound absorption will result in an increase in the reverberant sound pressure level and reverberation time.

**Sound absorption coefficient, *α***

For a given material, this is the fraction of incident sound energy absorbed at its surface.

It is expressed as a value between 1.0 (perfect absorption or no reflection) and 0 (total reflection or no absorption).

The value varies with frequency and the angle of incidence.

**Sound insulation (also known as sound attenuation)**

- 1 A term used in relation to the room to room transition of sound via a common ceiling plenum.
- 2 A general term relating to the reduction in transmission of sound pressure levels between one internal area and another.
- 3 The reduction of noise levels associated with airflow within ventilation equipment and ductwork systems.

**Sound (noise) leakage**

Airborne sound transmission via gaps or cracks around or through building elements and services that allows sound to escape from one area to an adjacent area and thus lower the element's potential sound reduction.

**Sound masking/conditioning**

Internal multi-occupancy spaces such as open plan offices or cellular offices with low sound insulation between them often suffer from poor acoustic conditions. This results in disturbance due to the persistence of fluctuating activity and speech noise between working zones. Such problems may be mitigated by the use of sound masking.

This term describes electronically generated sound, of a specified level and frequency content, which is introduced into such environments (normally by an array of loudspeakers concealed in the ceiling void) to provide masking of the fluctuating noises and to enhance speech privacy.



A number of suspended microphones to determine the special average sound pressure level of a room.

**Sound reduction index, *SRI* or *R***

The property of a dividing barrier that characterises its ability to reduce the level of sound transmitting through it.

It is determined from acoustic laboratory measurements made in accordance with BS EN ISO 140-3, when the barrier is mounted between two reverberant chambers. Since SRI is a function of frequency, it is desirable that the measurements are made over the one-third octave frequency bands 100 to 5,000Hz.



Dodecahedron speaker used in laboratory and field measurement of sound insulation and reverberation times in conjunction with a level monitoring microphone.

**Sound transmission class, *STC***

A US single number rating, expressed in decibels of the laboratory measured frequency dependent airborne sound insulation properties of a dividing barrier. The test can distort figures when compared with *R<sub>w</sub>* as a different range of frequencies is used when calculating a single figure result.

**Sound wave**

A pressure disturbance in air proceeding at a finite velocity that results from the activity of a sound source.

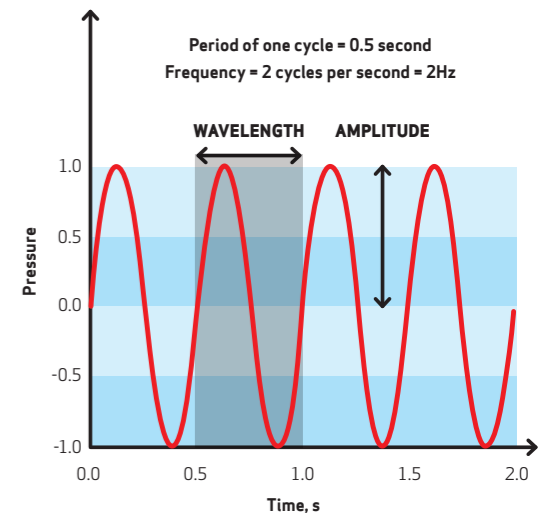


Table 17 A sound wave's cycles within a second determines its frequency.

**Speech transmission index, *STI***

Descriptor used to define intelligibility in a room or open space.



**Spectrum adaptation terms, C and C<sub>tr</sub>**

The single number rating method defined in BS EN ISO 717-1 uses a standard reference curve to determine the weighted value of airborne sound insulation. The spectrum adaptation terms **C** and **C<sub>tr</sub>** can also be evaluated to take into account different source spectra as indicated in annex A of BS EN ISO 717-1.

**C** is an A-weighted pink noise spectrum, while **C<sub>tr</sub>** is an A-weighted urban traffic noise spectrum. **C<sub>tr</sub>** can also be added to **D<sub>nT,w</sub>** or **R<sub>w</sub>** to take into account low frequency noise.

**Suspended ceiling normalised level difference, D<sub>nc</sub>**

The laboratory measured frequency dependent level difference of a suspended ceiling sharing a common ceiling plenum above adjacent rooms that is corrected to take into account the sound absorption of the receiving room.

**Tapping machine**

A portable electromechanical device used as a standardised impact sound source to rate the normalised sound pressure levels or impact noise insulation of floors.

**T<sub>mf</sub>**

The mean value of reverberation time in the octave bands 500Hz, 1kHz and 2kHz.

**UKAS**

United Kingdom Accreditation Service. Acoustic test laboratories are accredited under this scheme, which was formally the National Measurement Accreditation Service (NMAS).

**Vibration**

The oscillatory (backwards and forwards) movement of a solid body about a reference position. Movements of sufficient amplitude and frequency generate sound.

**Vibration isolation**

The use of devices such as steel springs, rubber mounts or similar resilient materials used to support a vibrating source or structure and thus minimise the transmission of its vibration energy into the surrounding structure.

**Wavelength, λ**

The distance a sound wave travels in one cycle.

**Weighted sound reduction index, R<sub>w</sub>**

Laboratory measurement of sound reduction performance of a building element - there is no flanking (indirect) loss, so only the element under test needs to be considered. **R<sub>w</sub>** is used to compare one building element with another.

**Weighted apparent sound reduction index, R'<sub>w</sub>**

A single number rating, expressed in decibels. This is a field measurement of airborne sound insulation between rooms - but unlike **D<sub>nT,w</sub>** it will give the performance of the building element under test and not the performance of the whole room.

This test is used when the area of the separating wall (and volumes of the rooms, cinemas, leisure centres and so on) are large, as this means the flanking transmission conditions do not come into play.

**Weighted sound level difference, D<sub>w</sub>**

This term is not defined in BS EN ISO 717-1: 1997, even though it is used as the descriptor for sound insulation in BB93 (and is likely to be implemented in the revision of BB93). **D<sub>w</sub>** can be defined as a **D<sub>nT,w</sub>** where T = T<sub>0</sub>, ie reverberation corrections are cancelled out and therefore not counted.

**Weighted standardised level difference, D<sub>nT,w</sub>**

This is the level difference achieved from one room to another, normalised to a standard reverberation time T<sub>0</sub> and weighted to provide a single figure value. The most common value of T<sub>0</sub> is 0.5 seconds, as used in Building Regulations (Part E). This is a field measurement of airborne sound reduction between one room and another - there will be flanking transmission, so the whole room needs to be considered because the element under test, such as the separating wall, may not be the weakest path. **D<sub>nT,w</sub>** is used in the Building Regulations and will provide an overall performance of the building element being tested in a 'real' environment.

**Weighted standardised level L<sub>nT,w</sub>**

This field test value measures the reduction between one room and another (floor/floor) - there will be flanking transmission loss, so the whole room needs to be considered because the element under test, such as the separating floor, may not be the weakest path. **L<sub>nT,w</sub>** is used in the Building Regulations to provide the overall performance of the building element (floor) being tested in a 'real' environment.

**Weighted normalised impact sound pressure level, L<sub>nw</sub>**

Laboratory measurement of sound performance of a building element (floor) - there is no flanking (indirect) transmission loss, so only the element under test needs to be considered.

**Weighted sound absorption coefficient, α<sub>w</sub>**

A European single number rating for random incidence sound absorption coefficients as calculated by reference to BS EN ISO 11654: 1997.

Weighted sound absorption coefficient is also a method for converting a wide frequency based range of sound absorption coefficient values into a single number. This is done using a curve fitting process. Although more complex to derive, **α<sub>w</sub>** is considered more representative of how the human ear interprets sound.

The method is fully described in BS EN ISO 11654: 1997 and at the time of writing is the preferred European unit for making a simple and rapid comparison of sound absorption performance. The single figure rating can have a modifier added to indicate if the spectral shape is dominated by a particular frequency range:

- L** Absorption is predominantly in the low frequency region.
- M** Absorption is predominantly in the mid frequency region.
- H** Absorption is predominantly in the high frequency region.

The absence of a letter following the rating indicates that the absorber has no distinct area of sound absorption and has an essentially flat spectral shape.

**Weighted standardised impact sound pressure level L'<sub>nT,w</sub>**

ISO 717 and 140 BS 8233 weighted standardised impact sound pressure level. Single number used to characterise the impact sound insulation of floors over a range of frequencies.

**Weighted suspended ceiling normalised level difference, D<sub>nc,w</sub>**

A single number rating, expressed in decibels, of the laboratory measured, frequency dependent room-to-room sound attenuation of a suspended ceiling sharing a common ceiling plenum above adjacent rooms. The calculation is normalised to a reference value for the absorption of the room rather than reverberation time, as is the case with **D<sub>nT,w</sub>**.

**D<sub>nc,w</sub>** is used by specifiers to compare one suspended ceiling with another.

NB: this is now superseded by **D<sub>nf,w</sub>** - see ISO 12354.

**White noise**

Broadband (often electronically generated) noise, but can also be attributed to running water, air movement and other random sounds.

This acoustic ceiling includes hidden acoustic fleece to improve performance in this large open space, whilst perimeter bulk heads are also covered with perforated board to aid sound absorption.



## CASE STUDIES

Project: Ordnance Survey, Southampton  
Architect: Broadway Malyan

7

### Background

In December 2010, Ordnance Survey moved into its purpose built, three storey, 10,000m<sup>2</sup> offices in Southampton. Awarded a BREEAM Excellent rating, the building uses the latest environmental technology to maximise natural resources and minimise carbon emissions.

Designed to be as environmentally friendly as possible, as well as cost effective to maintain, the building is naturally ventilated with computer controlled windows, has the UK's largest ground source heat pumps and includes rainwater harvesting.

For the interior, the client's brief was for an open plan office to create a high quality, professional environment which would allow staff to work more efficiently and effectively, encourage co-operation between teams and better facilitate the sharing of information.

Having experienced difficulty in communicating in its existing offices, due to dead acoustic space where excessive absorption had been installed, the acoustic performance of the new environment was particularly important.

### Acoustic requirements and constraints

The building's interior is designed around a central atrium, with four 'fingers' housing the open plan offices and meeting rooms. The atrium is a hub for a range of activities including a restaurant, informal meeting space for collaborative work, and regular 'state of the nation addresses' to the 1,000 strong workforce - all of which have very different acoustic requirements.



These semi elliptical pods are clad in slatted wood, which assists in diffusing the sound and narrowing the opening to each floor plate.

A key feature in the original design of the atrium was an acoustically neutral brick feature wall. It was important that the noise from the nearby dual carriageway was reduced to avoid distraction within the building, so an acoustic wall made of over 95,000 bricks was designed to surround the building, and then cut through the atrium to form the feature wall. However, the design of the feature wall was changed to a plaster finish as part of the value engineering process. This caused an issue as highly reflective surfaces negatively impact on reverberation times.

As part of the building's ecofriendly functions, heat from the computer hardware

housed in the building is extracted to one of 18 underground chambers to store until it is required for heating the office environment. Exposed concrete slabs are used to cool the building. There is no other source of heating or cooling.

However, using such an ecofriendly system has one draw back - noise. With limited quantities of soft internal finishes, the potential for increased noise levels was high, as people compete with the effect of long reverberation times.

Also, one of the consequences of natural ventilation is a reduction in background noise generated from the air handling units, which is

used in calculating speech privacy potential (SPP) for meeting rooms.

It was also clear that as staff would be coming from a conventional cellularised environment to open plan, this would require the team being able to manage their aspirations, and introduce new etiquette into everyday worklife.

### Solutions

'The exposed soffits and hard plaster used in the feature wall increased reverberation times from the expected  $\leq 2.0$  which, along with the possibility of increased noise levels leaking into the four open plan fingers and range of uses in the space, proved to be a challenge,' said Tony Balmbra, the lead architect at Broadway Malyan.

Sound Research Laboratories (SRL), which was employed by the main contractor to ensure that the clients requirements could be met within the tender price, modelled the effects of changes in finish to ensure that design targets were met.

'The changes to the finished face of the large feature wall had the effect of increasing the reverberation times in the central multi functional atria, and the modelling indicated that the result would be an increasing noise level,' Balmbra said. 'It was anticipated that during the lunchtime period people would raise their voices above the reverberant background noise created by the hard surfaces and the general lunchtime activity would raise the noise levels even further to an unacceptable level. Another concern was that this increased noise

level may also occur outside of the lunch period, which could disturb the staff in the office fingers which opened on to the atria'.

To deal with the increased reverberation times caused by the plaster feature wall, additional absorption was specified in the bulkheads between the floors, and an upgraded acoustic ceiling was added.

Ray tracing done by SRL indicated that omitting the brick wall had reduced the amount of diffusion, which would have spread the sound rather than directly reflecting it, so additional absorption at ceiling level at the entrance to each floor plate from the atria, together with soft flooring, was specified to reduce the noise entering the open floors.

Specialist software allowed SRL to ensure that the correct materials were specified in advance of the contract starting, to ensure that expensive retrofit would not be necessary when the building was occupied. Ian Harley of SRL said: 'It is important at the specification stage that we fully understand the acoustic performance of products, so it is essential that manufacturers provided us with good technical information across a range of frequencies, and not just a single NRC figure - although that is useful in the initial investigation.'

In conjunction with the fit out contractor, perforated lined gypsum board, known for its unique patterns and sound absorbing properties ( $\alpha_w$  of 0.55 NR .65), was specified for the bulkheads around the perimeter of the building. To provide continuity between the bulkheads and the ceiling an acoustic metal suspended ceiling, designed to provide the

same appearance as plasterboard but with the advantage of providing easy access to the ceiling void and the service contained therein, was installed. The ceiling was lined with an acoustic fleece to provide further sound insulation.

In line with the architects design, the ceiling was set out 3°15' from the grid line, which ran north to south, to reflect the true magnetic north which is a feature of all OS maps.

Full height toilet pods delineate the entrance to each of the fingers from the atria. These semi elliptical pods are clad in slatted wood, which assists in diffusing the sound and narrowing the opening to each floor plate, effectively and practically reducing the noise created in the atria transferring to the office fingers.

The key requirements for the performance of the partitioning and doors were set using laboratory test figures at 45dB  $R_w$  for the sensitive or noise producing rooms, such as printer rooms, and 38dB  $R_w$  for the other rooms. Doors were rated at 35dB  $R_w$ .

'As well as the design of building and the interior finish, it was also important that staff expectations were managed,' Balmbra concludes. 'To ensure a smooth transition to the new building, the client visited recently completed projects to understand how to manage the culture changes required for this new, flexible and vibrant environment.'

The end result - a very happy client with a state of the art, stunning, ecofriendly building and an equally satisfied staff with a superb working environment.



The perforated pattern in the steel tiles was selected to complement the perforations in the plasterboard upstands.

**Background**

Ropemaker Place is a state of the art commercial development with 80,844m<sup>2</sup> of gross floor space including retail units on the ground floor and 20 levels of office accommodation above. The building has impressive sustainability credentials, including expansive garden roof terraces with stunning city views, rainwater harvesting, and use of a double glazed tilted façade to reduce heat gain.

Ropemaker Place was the first building in Europe to achieve pre-certification for LEED platinum rating. It has also received a BREEAM 'excellent' rating and a B-rated energy performance certificate.

**Acoustic requirements and constraints**

The entrance foyer to Ropemaker Place is 10.5m tall, so with such a large open atrium it was necessary to provide high levels of acoustic absorption.

Bespoke metalwork comprising of a striking waveform shaped ceiling was designed by architects Arup Associates to feature in the construction of the building. The bespoke wave ceilings were installed in the atrium, main reception area, lift lobbies and main external canopy.

Simon Anson, architect at Arup Associates comments: 'The purpose of the ceiling was to provide the 10.5m tall entrance foyer with an acoustic performance, and create a lighting source providing both uplight and downlight. It also needed to provide the entrance foyer with visual impact from views of City Point Plaza, Ropemaker Street and The City.'



Acoustic waveform panels with integrating lighting detail

The acoustic waveform panel, although elegant in appearance, also required strength to support the light fitting. The complex design required all fixings to be concealed, as a large proportion of the face and rear of the waveform tiles are visible. Consideration also had to be allowed for on site installation of the electric cables through the waveform panel to cater for the light fitting, with meticulous finish, as all fixings were to remain hidden.

The design team worked closely from an early stage to ensure a total understanding of the design criteria and that expectations of the various ceiling products specified by Arup Associates were achieved to meet the client's design brief.

**Solutions**

The panels on the waveform ceiling were perforated allowing sound to pass through the face of the metal panel and be absorbed by acoustic pads to the rear.

In addition to the waveform ceiling an acoustic accessible metal ceiling system and panels were also installed within the lift lobby areas comprising of modular hook-on tiles in a concealed grid format. Providing sound absorption, the system was specified with perimeter acoustic baffles which were used in the external and internal atrium areas to create a closure bulkhead section between the waveform and flat perimeter ceiling panels.

The vaulted waveform ceiling design provides an aesthetically appealing yet practical ceiling as it combines acoustic performance qualities with integration requirements. This bespoke design manages acoustics with reverberation times reduced.

'The appearance of the ceiling is that of a series of illuminated vaulted waves flowing into the interior, the volume of the space perceptually expanded by the uplit waveform surfaces,' says Anson. 'The vaulted ceiling with its flowing contours provides a visually stunning focal point as well as a practical solution to the acoustic requirements of the interior of the building.'

Bespoke metal waveform ceiling provides both acoustic absorption and the visual impact required.





Acoustic wall panels with digitally printed fabric covering.

### Background

When Greenfields Community Housing commissioned a new purpose built office development it turned to Richards Partington Architects to create a civilised and uplifting working environment in which to house its office functions, community rooms and meeting spaces.

Richards Partington Architects is committed to minimising the environmental impact of its buildings. Its sustainability strategy combines natural ventilation, exposed concrete soffits and ground source heat pumps, to create a building that achieved a BREEAM 'very good' rating. Creating these types of buildings though does lead to some acoustic problems which need to be addressed.

### Acoustic requirements and constraints

The interior design of the building called for a

combination of open plan spaces, private meeting rooms, a high vaulted reception area, staff canteen and some areas for public use. The exposed concrete soffits, highly reflective surfaces and floor to ceiling windows specified by the architect combine to create a highly reverberant environment. Additional hard surfaces such as glass partitioning, desks, and kitchen units further increase the reverberant sound. Too much reverberation causes workers to raise their voices to make themselves heard, which increases the noise levels for all workers, causing discomfort and fatigue.

### Solutions

Traditional acoustic solutions, such as desk screens and blinds, were deployed in the open plan offices to help control reverberation times and perforated plasterboard ceiling areas,

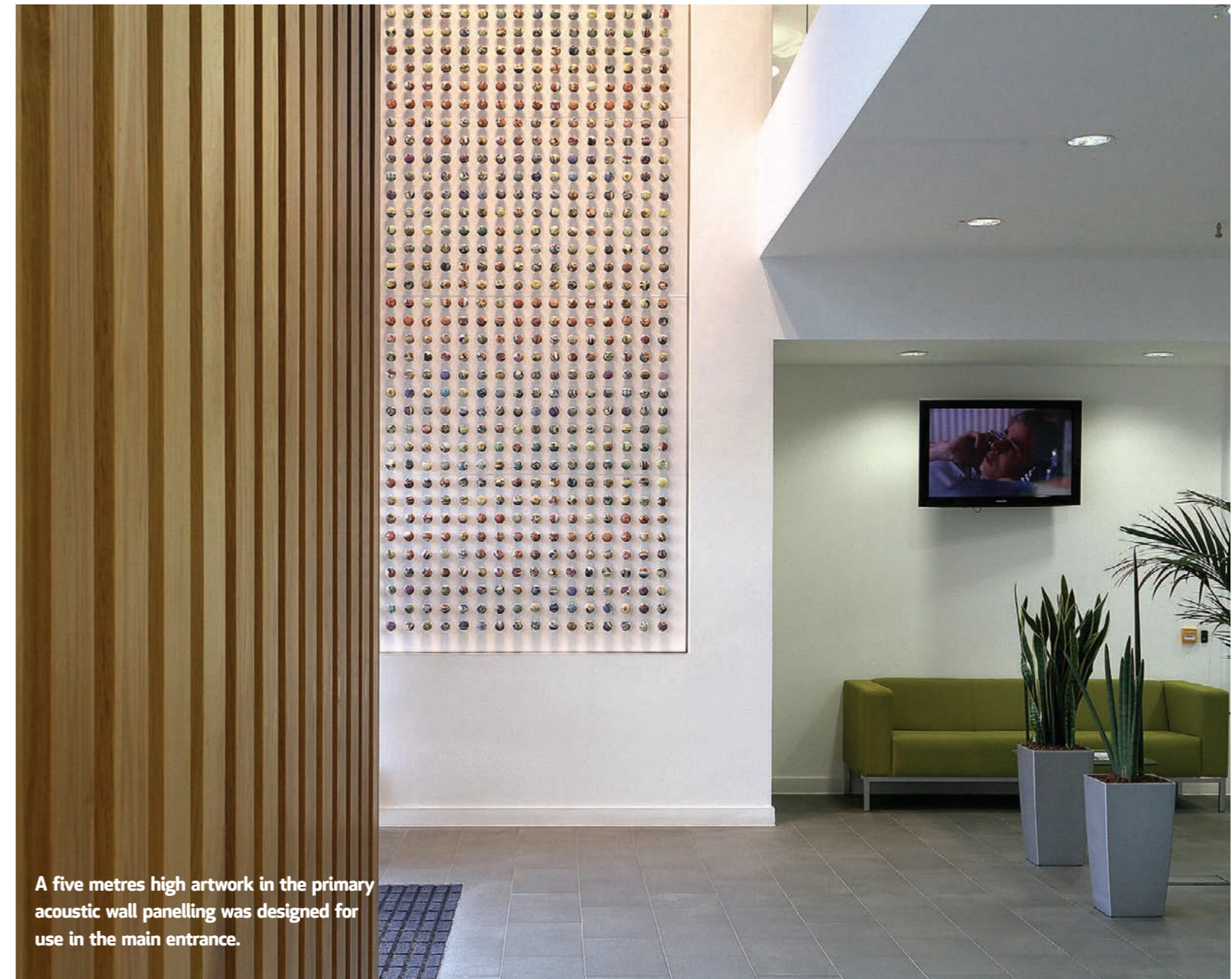
backed by insulation, were installed in the reception and public areas. However, following the client's brief, the architect pursued a unique acoustic solution which would celebrate the diversity and heritage of the local community, whilst adding to the acoustic performance of the building.

It was agreed to use acoustic wall panels with digitally printed fabric covering in some areas, with more traditional acoustic panels in others, along with specially commissioned artwork in the foyer. The piece of artwork, over five metres high, built into the primary acoustic wall panelling, was designed for use in the main entrance to make a unique and eye catching feature, whilst reducing reverberation in this large, reflective main foyer.

Bespoke images were selected by the architect and client to make the acoustic wall panelling unique to the project. The areas of absorption required were calculated and the necessary sized panels produced to fit the site, with artwork being prepared to span five panels and cover an area of 6m x 3m.

The finished products performed as expected, with overall reverberation times reduced to the required levels. The offices are quiet and afford staff good acoustic comfort with pleasing aesthetic design.

Richards Partington Architects state 'We are passionate about good detailing. Elegant detailing and good workmanship lift the spirit and create an impression of quality, whatever the budget.' This is certainly true of this project.



A five metres high artwork in the primary acoustic wall panelling was designed for use in the main entrance.

**Background**

After almost ten years of careful design and planning, the extraordinary seven storey headquarters for accounting firm KPMG in Langerhuize, Amstelveen is a triumph of form and function.

Architect Marcel van der Schalk worked closely with the client to meet some testing objectives: this 62,000m<sup>2</sup> building must stimulate communication, integrate transparency, incorporate flexible layouts, and meet very demanding sustainability requirements.

At the heart of the building's elongated, curved shape and large glass towers, two open atria soar to the full seven storey height, bathing the building in natural daylight. Yet despite its vast size, the building still manages to retain a surprisingly human scale inside, creating comfortable workspaces and a welcoming atmosphere.

**Acoustic requirements and constraints**

The walls of the offices follow the flowing lines of the façade on one side and border internal walkways on the other. These generously proportioned walkways allow the floor plans to be fluid, adapting areas to suit multiple uses such as kitchens, hot desking and meeting places.

While these fluid open spaces are perfect for encouraging internal staff communication and impromptu meetings they could lead to increased noise levels which, if left untreated, would make the space unusable. This is alleviated in part by the use of movable walls



**Two open atria, vital for light, provide intriguing acoustical challenges.**

designed to connect to the ceiling system, maintaining the flexibility of the workspaces while ensuring acoustic integrity.

The KPMG headquarters is remarkably quiet even in large spaces such as the atria and restaurant. This has been achieved through imposing demanding specifications on the materials used in the interior. All ceiling tiles used in the building satisfy class A sound absorption (according to EN ISO 11654), which offers the highest sound absorption.

**Solutions**

Several ceiling systems are used in the building. In the restaurant, a section of the ceiling is fitted with bamboo panels that were specifically manufactured for this project. A razor-fine curved line separates these panels

from the rigid white ceiling with a concealed suspension system. The virtually seamless white surfaces look almost like a plastered ceiling, while high sound absorption of these panels makes the space comfortable, even when large groups of people are enjoying lunch together.

In the traffic zone, ceiling panels are used with a concealed suspension system. The result is the same as the rigid and smooth ceiling surface in the restaurant. However, a system with a visible bandraster is used in the flexible workspaces. The bandraster profile allows for different layouts because partition walls can be easily placed underneath. When the walls are attached to these profiles, stability and optimal sound insulation can be guaranteed.

These acoustic ceilings not only meet the technical and aesthetic demands placed on them, but work with other building elements to provide a pleasant atmosphere which is welcoming for both employees and visitors.

**Virtually seamless white surfaces look like a plastered ceiling, and high sound absorption of these panels makes the space comfortable.**



**Background**

For years, Severn Trent Water operated from a series of outdated buildings inherited from state owned water authorities. So, when it embarked on a company wide modernisation programme, an inspiring new headquarters was central to its plans. As well as office space, the 24,332m<sup>2</sup> new building comprises conference rooms, exhibition areas, a restaurant, canteen, kitchen and a stunning reception area.

'We wanted the new HQ to help change the culture of our organisation and create an environment which would encourage staff to interact and co-operate,' says Bryan Hemmings, Severn Trent's service delivery manager. But there was a catch. 'Our customers, the people paying their water bills, want to see value for money,' says Hemmings. 'So we needed it to look good, be a great place to work, but not be expensive.'

**Acoustic requirements and constraints**

The interior created by architects Webb Grey is striking, with exposed concrete soffits and expanses of plasterboard and coloured plaster curved walls and the overall atmosphere is of an open, almost minimalist environment. However, the use of hard floors and the spray painted concrete ceiling surfaces and walls would have created a highly reverberant environment. Such spaces can be noisy and uncomfortable to occupy, making it difficult to hold conversations and to work in.

To counter the reflective surfaces and reduce the sound energy within the room, the designers needed to introduce materials that

absorb sound. The introduction of sound absorbing materials has to be balanced as too much absorption will create a very dead environment which is an equally difficult space to work within.

**Solutions**

Central to the acoustic design of the building are large, wave shape rafts suspended from the ceilings. Created from perforated gypsum boards backed with acoustic tissue material, they provide acoustic control and make a feature of the ceilings at the same time. The rafts also house additional lighting and smoke detectors.

**Perforated gypsum ceiling rafts control a highly reverberant environment.**



Hemmings explains: 'The rafts are made of sound absorbing material. They also keep to our brief. They look good and perform the noise attenuation function - but they are not expensive.'

So has Severn Trent got the HQ it wanted? Hemmings is extremely positive: 'We wanted to make every pound count and I think we got what we wanted by working through the detail. The acoustic rafts perform to specification as well as looking great. People are extremely happy with the new environment and we can already see a real positive change in the way staff are interacting and working.'



Severn Trent's Coventry HQ boasts sound absorbing ceiling rafts.

Random perforations in a gypsum ceiling help to reduce reverberation.

## STANDARDS

8

The design and construction industry works to agreed standards. The following list concerns acoustics in the non-domestic built environment and construction standards for partitioning and suspended ceilings:

### British standards

**BS EN ISO 140** Acoustics: Measurement of sound insulation in buildings and of building elements.

**BS EN ISO 140-3: 1995** Laboratory measurement of airborne sound insulation of building elements.

**BS EN ISO 140-4: 1998** Field measurements of airborne sound insulation between rooms.

**BS EN ISO 717** Acoustics: Rating of sound insulation in buildings and of building elements.

**BS EN 717-1: 1997** Airborne sound insulation.

**BS EN 717-2: 1997** Impact sound insulation.

**BS 5234** Partitions (including matching linings).

**Part 1: 1992** Code of practice for design and installation.

**Part 2: 1992** Specification for performance requirements for strength and robustness, including methods of test.

**BS 8233: 1999** Sound insulation and noise reduction for buildings - code of practice, see page 67 for summary.

**BS EN ISO 11654** Acoustics: Sound absorbers for use in buildings. Rating of sound absorption.

**BS EN 12354** Building acoustics: Estimation of acoustic performance in buildings from the performance of elements.

**BS EN 13964** Suspended ceilings: Requirements and test methods.

**BS EN ISO 10140-4: 2010** Acoustics: Laboratory measurement of sound insulation of building elements.

### Building Bulletin for Schools

**BB93** Building Bulletin 93: Acoustic design for schools.

### BRE Environmental Assessment Method

BREEAM scheme document SD5055-BREEAM Offices 2008.

### Health Technical Memoranda (HTM)

**HTM 08.01** Method of determining level of sound insulation required between adjacent spaces in hospitals.

**HTM 56** Partitioning in hospitals.

**HTM 57** Internal glazing in hospitals.

**HTM 58** Internal door sets in hospitals.

**HTM 60** Ceilings in hospitals.

**HTM 2045** Replaced by HTM 08.01

### International standards that apply

**ISO 354:2003** Acoustics: Measurement of sound absorption in a reverberation room.

**ISO / DIS 3382-3 (2012)** - for open plan offices.

These standards are subject to revision and alteration at any time. Readers should ensure they use the latest and most relevant standard.

### European Accreditation bodies

<http://db.european-accreditation.org>

Accredited bodies from 10 EA Accreditation Bodies signatories to the EA MLA Multilateral Agreement: CAI, Czech Republic; COFRAC, France; DANAK, Denmark; DAR-AKB, Germany; ENAC, Spain; FINAS, Finland; INAB, Ireland; IPAC, Portugal; SNAS, Slovakia; UKAS, UK; European Test Centres

### Individual products are tested in the UK at UKAS accredited test centres...

0444 Sound Research Laboratories Ltd, Holbrook House, Little Waldingfield, Sudbury, Suffolk, United Kingdom, CO10 0TH  
+44 (0)1787 247595

0578 BRE Global Ltd Incorporating LPC Testing, BRE Testing, Bucknalls Lane, Garston, Watford, United Kingdom, WD25 9XX  
+44 (0)1923 664334

0296 The Building Test Centre, British Gypsum Ltd, East Leake, Loughborough, Leicestershire, United Kingdom, LE12 6NP  
+44 (0)115 945 1564

0483 Acoustical Investigation & Research Organisation Ltd (AIRO), Duxons Turn, Maylands Avenue, Hemel Hempstead, Hertfordshire, United Kingdom, HP2 4SB  
+44 (0)1442 247146

1262 University of Salford, School of Computing, Science & Engineering, Newton Building, The Crescent, Salford, Manchester, United Kingdom, M5 4WT  
+44 (0)161 295 4615

**Further reading** BREEAM



These tiles provide visual interest and help reduce reverberation in this meeting room.

To underpin this guide FIS commissioned a review of available research on office acoustics, which was carried out by Professor Bridget Shield, professor of Acoustics in the Faculty of Engineering, Science and Built Environment at London South Bank University. Here is a summary of her findings...

Research over the past 50 years has suggested guidelines for the acoustic conditions of open plan offices. The results, which are in general agreement, include the following main points:

- Fluctuating noise in offices is much more annoying than steady noise.
- The preferred level of ambient/masking noise is 45dBA, with a maximum limit of 48dBA.
- An articulation index of less than 0.05 or speech intelligibility index (SII) of less than 0.10 is required for confidential speech privacy.
- An articulation index of 0.15 or SII of 0.20 is a practical design goal.
- The ceiling is the surface that has the biggest impact on speech privacy and should be as absorbent as possible.
- Screens should be at least 1.7m high.
- Workstation floor area should be at least 3m x 3m.
- Flat luminaires degrade speech privacy.
- To achieve good speech privacy all room design parameters must be close to their optimum values.
- The speech transmission index (STI) should be less than 0.20 to give good speech privacy or less than 0.50 to prevent distraction by speech.

Design factor	Summary of effect / importance
Ceiling absorption	Ceiling is the most important reflecting surface in open plan offices; it should be as absorbent as possible.
Screen/panel height	Screens must be high enough to 'block' direct path of speech from one workstation to another, so that sound diffracted over them is sufficiently reduced to allow acceptable speech privacy. However, above a height of 1.7m further increases in height do not affect SII.
Screen/panel absorption	Panels must be sound absorbing but increasing absorption from medium (eg 0.6m) to high (eg 0.9m) does not significantly affect speech privacy.
Workstation plan size	SII values decrease as workstation plan size is increased. Smaller than 3m x 3m does not meet acceptable speech privacy criterion.
Floor absorption	The floor should be carpeted although thickness of carpet is insignificant. Use of carpets also reduces noise of footsteps and moving furniture, and minimises sound propagation through gaps at the bottom of screens.
Screen transmission loss	Minimum STC of 20 is required - increasing from 21 to 25 makes negligible improvement in SII.
Ceiling height	Increasing height to 3.5m has a negligible effect on SII but reducing it from 2.7m to 2.4m decreases it to a little above 'acceptable'. Therefore particularly low ceilings should be avoided.
Light fittings	Open grille light fittings are best.
Speech level	Office etiquette of low voice levels should be promoted; meetings in which discussions are necessary should be held in closed rooms.
Masking noise	Masking noise of 45dBA to 48dBA is necessary.

**Table 18**  
Importance of office design parameters (Bradley, 2003).

- Horizontal absorption, provided by the floor and screens in addition to the ceiling, is necessary to attenuate speech across an office.
- New acoustic parameters related to the attenuation of speech have been proposed to describe acoustic conditions in open plan offices.
- A new classification system for open plan offices has been proposed.

**Conclusions**

This report has presented a review of research published over the past 40 to 50 years on office acoustics. The subjects covered include annoyance and disturbance caused by noise; effects of noise on performance; and the development of new parameters and guidelines on the acoustic design of offices. The research reviewed dates from the 1960s, the majority of papers having been published since open plan offices have been in vogue - during the 1970s and in the past 15 years.

There is remarkable consistency between the results of the various studies, which lead to similar conclusions concerning the detrimental impacts of office noise and potential design solutions.

It was apparent from the early subjective studies of the office environment that noise was the main cause of dissatisfaction, particularly in open plan offices. Recent studies show the same result, indicating that the problem of how to reduce annoyance and disturbance caused by office noise has still not been resolved.

RASTI	Speech intelligibility	Speech privacy	Examples in offices
0.00 – 0.05	Very bad	Confidential	Between two single person rooms, high sound insulation.
0.05 – 0.20	Bad	Good	Between two single person rooms, normal sound insulation.
0.20 – 0.40	Poor	Reasonable	Between two workstations in a high level open plan office. Between two single person rooms, doors open.
0.40 – 0.60	Fair	Poor	Between desks in a well designed open plan office.
0.60 – 0.75	Good	Very poor	Between desks in an open plan office with reasonable acoustic design.
0.75 – 0.99	Excellent	None	Face to face discussion, good meeting rooms. Between desks in an open plan office, no acoustical design.

**Table 19**  
Subjective rating of RASTI in offices (Hongisto et al, 2004).

Criterion	Typical situations	Design range LAeq,T dB	
		Good	Reasonable
Reasonable conditions for study and work requiring concentration.	Library, cellular office, museum	40	50
	Staff room	35	45
	Meeting room, executive office	35	40

**Table 20**  
Indoor ambient noise levels in spaces when they are unoccupied (from BS 8233).

In an attempt to more fully understand the disruptive nature of office noise, recent research investigating the impact of noise on performance of office tasks has focused on the disruptive effects of speech on various cognitive processes. It has become clear that the intelligibility of speech is a major factor, and therefore speech intelligibility and speech privacy are regarded as critical issues in the design of open plan offices.

Progress in acoustic modelling has enabled detailed studies to be made of the relative importance of various office design parameters in minimising the detrimental effects of noise. Optimal values of acoustic design parameters and a new acoustic classification system for open plan offices have been proposed.

Professor Bridget Shield, May 2009

**USEFUL INFORMATION**

BS 8233: 1999 Sound insulation and noise reduction for buildings - code of practice replaced the 1987 edition and incorporated significant revisions that took account of changes in legislation and official guidance, including changes in the guidance provided by the World Health Organisation (WHO) on noise targets for residential accommodation.

The document includes useful background acoustical information, including noise spectra for road traffic, civil jet aircraft and railways, and definitions for a number of acoustical terms.

Table 5 of BS 8233 sets out maximum ambient noise level targets for spaces within

buildings when unoccupied - that is, in the absence of noise from the occupants of these spaces - with the aim of providing an appropriate level of acoustic comfort in commercial premises and suitable conditions for resting and sleeping in residential accommodation.

Table 6 of BS 8233 sets out minimum ambient noise level targets for spaces within buildings when unoccupied - that is, in the absence of noise from the occupants of these spaces - with the aim of providing an appropriate level of acoustic privacy in spaces such as restaurants and open plan offices.

**Absorption classes**

The ability of the sound absorber is measured in line with the international standard EN ISO 354 and is classified according to the international standard EN ISO 11654 on the basis of its absorption factor - its ability to absorb sound according to classes A, B, C, D and E, where A is the best absorber.

**Classification of sound absorbers**

The classification system of this annex is primarily intended to be used for broadband applications. The single number value  $\mu_w$  is used to calculate the sound absorption class according to Table B.1 of EN ISO 11654.

The different classes are illustrated in Table 3 (page 22).

**Sound absorption class  $\alpha_w$**

- A 0,90; 0,95; 1,00
- B 0,80; 0,85
- C 0,60; 0,65; 0,70; 0,75
- D 0,30; 0,35; 0,40; 0,45; 0,50; 0,55
- E 0,25; 0,20; 0,15
- Not classified 0,10; 0,05; 0,00

**Existing building stock**

Existing office buildings do not generally meet the exacting energy targets of future sustainability requirements. One study indicated that the median office building in England achieves an Energy Performance Certificate (EPC) rating of E. However, 2010 Building Regulations Part L requires most offices to achieve an EPC rating of B and by 2019 they must achieve an EPC zero or A+ rating. This shift in sustainability targets is introducing enormous challenges for acoustic designers, architects and building services engineers.

Typically, offices designed in previous years had lightweight finishes, low suspended ceilings concealing extensive building services and sealed windows. To meet the new sustainability challenges, new offices may require heavyweight finishes, exposed concrete soffits, windows that can be opened and open atria.

Each of these introduces demanding acoustic challenges, to which we must rise if we are to play our part in meeting one of the largest challenges in the 21<sup>st</sup> century.

**British Council for Offices specification**

Traditional energy intensive forms of servicing buildings are no longer acceptable. The British Council for Offices (BCO) is promoting a change to loose, adaptable buildings, with the 2009 BCO specification accepting and promoting a trend towards mixed mode and naturally ventilated buildings with openable windows.

**Exposed soffits and heavyweight finishes**

The new BCO standard increased the maximum temperature from 22°C to 24°C to allow a greater swing in the interior thermal environment, thus saving energy. However to maintain thermal comfort when air temperatures are higher, it is often desirable to lower the radiant temperature of exposed surfaces such as the ceiling or soffit.

Thermal comfort is a complex science that depends on both the air temperature and the radiant temperature - the temperature of the surfaces facing the individual, including the ceiling, walls, windows and floor (as well as clothing, activity rate, air velocity and humidity).

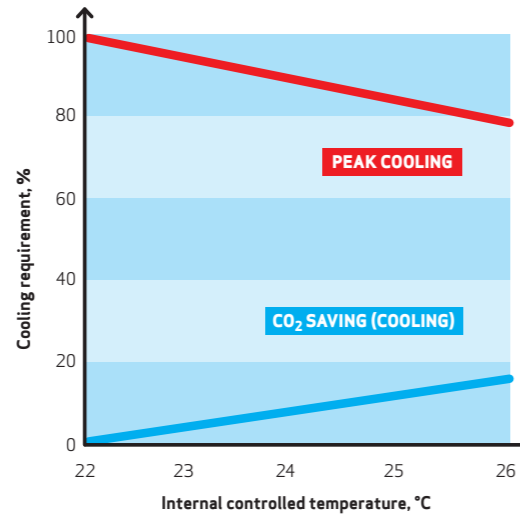


Table 21  
Typical office cooling requirements.

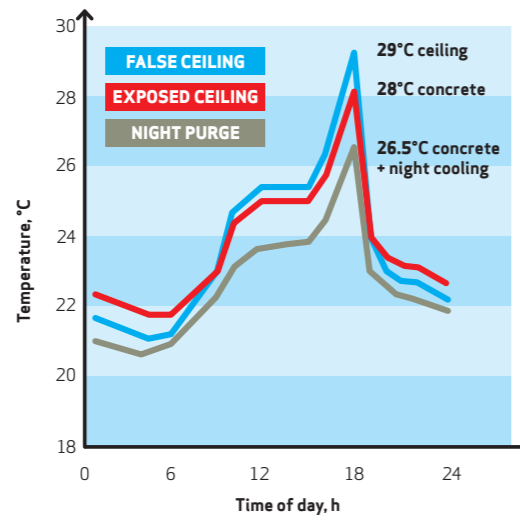


Table 22  
Typical summertime radiant temperature in the room.

The most common means of reducing the radiant temperature of an office are:

- 1 Chill the ceilings using chilled water pipes attached to the rear of the ceiling panels. This can be combined with acoustic absorptive ceilings.
- 2 Remove the ceiling and expose the concrete soffit. The concrete acts as thermal mass, storing 'coolth' from the cooler part of the day or previous night and taking considerably longer than lightweight finishes to raise its temperature. This avoids the mechanical cooling system but may limit the opportunity for acoustic absorptive ceiling tiles.
- 3 A combination of the two above - embedding chilled water pipes within the concrete soffit to cool it during the day.
- 4 Compromise solutions include floating raft ceilings suspended below the soffit (but not extending the full width of the room), or narrow linear acoustic slats suspended close to the soffit but separated by wide gaps so that a high proportion of the concrete soffit is exposed. For example one system comprising of perforated aluminium acoustic slats spaced 30mm apart and covering 50% of the soffit is reported to reduce the cooling effect of the concrete soffit by only 25%.

**Increased floor to ceiling heights**

Taller spaces without ceilings can be more energy efficient than spaces with low suspended ceilings for a number of reasons:

- 1 Daylight penetrates deeper into tall spaces with tall windows and helps minimise electrical lighting loads.
  - 2 Natural ventilation can penetrate deeper into tall spaces, helping to avoid air conditioning and mechanical loads.
  - 3 Efficient mechanical ventilation systems such as displacement ventilation can work in tall spaces while more energy intensive air conditioning systems may be needed in spaces with low ceilings.
  - 4 Efficient electrical lighting systems can be suspended within the space, which have a higher efficacy than traditional recessed office light fittings.
- However, increasing the height of office spaces can lead to challenges for the acoustic designer to reduce reverberation times for the space and introduce absorption in other locations such as on down-stand baffles within the space.

**Open plan spaces and open atria**

Low energy office designers attempting to minimise the use of mechanical ventilation and maximise the availability of natural light will generally prefer narrow plan spaces. However, to achieve the maximum value and larger floor plates, it is often necessary to design deeper-plan spaces.

Minimising energy consumption in deep plan spaces often requires compromises to acoustic ambitions:

- 1 Unobstructed open plan areas are required to allow double sided natural ventilation, but this can lead to noise transmission through the space.
- 2 Linking open plan spaces to open light wells or atria not only lets valuable daylight into the space but also creates a path for air to rise. However, noise transmission from one floor to another via atria can present acoustic challenges.

**Opening windows**

Natural ventilation and mixed mode (combined air conditioned and naturally ventilated) strategies require openable windows. Open windows allow noise in from outside, which can provide a difficult challenge for the designer.

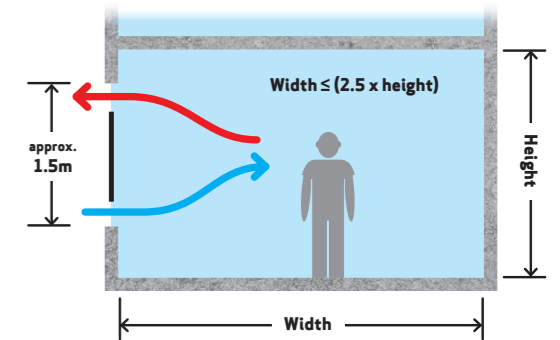


Table 23  
Exposed concrete soffits can reduce peak temperatures within the space and help avoid air conditioning.

Soft felt provides texture as well as absorption.



### FINISHES & INTERIORS SECTOR

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