# SUSTAINABLE ACOUSTICS

SUSTAINABLE ACOUSTIC SCHEME DESIGNS FROM MACH ACOUSTICS

MACH ACOUSTICS

MACH ACOUSTICS

## Tiled Contents

## 4 Sound Insulation

Subjective Evaluation, Rw and Dw

Sustainability and Sound Insulation

Performance Specifications

Light Weight and Heavy Weight Walls & Floors

Details & Services Penetrations

## 5 Room Acoustics and Reverberation

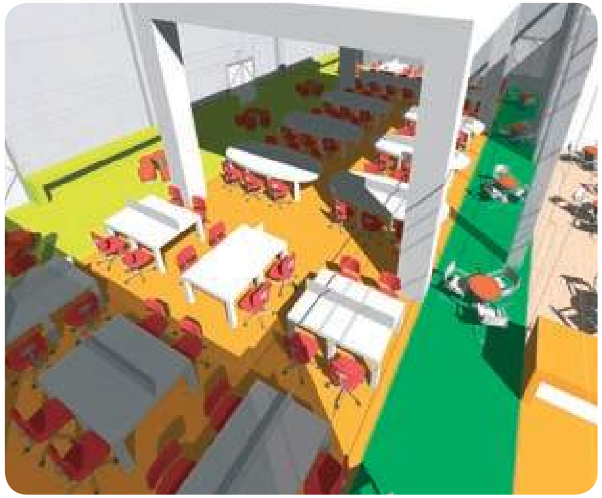
BB93, HTM, BREEAM

Estimating Levels of Room Acoustic Treatments

Class A, B and C Absorbent Finishes

Sustainable Acoustic Absorption

Thermal Mass and Acoustic Absorption



## 6 Open Plan Teaching

Poorly Laid out Plaza

Well Laid out Plaza

Distance - Didactic Teaching

The Banana

Layouts - Unsupervised Group Work

Layouts - Individual Learning

# 1 : The NAT Vent Attenuator

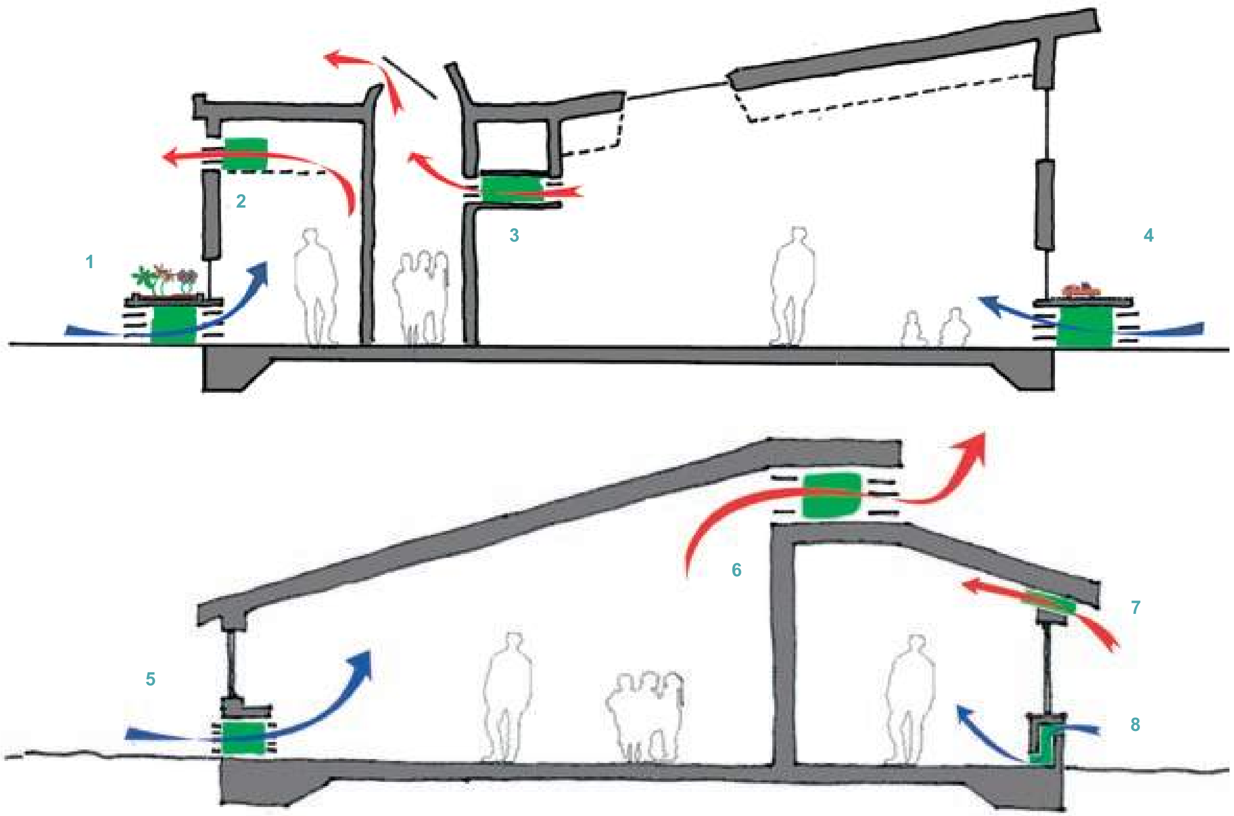
## Introduction

The NAT Vent Attenuator has been designed to overcome the conflicts between natural ventilation and acoustics. The NAT Vent Attenuator allows the flow of air into and through a building, whilst reducing the passage of sound. This product can easily be incorporated into the facade of a building, allowing for natural ventilation on all sites, irrespective of environmental noise levels. The NAT Vent Attenuator can also be used to prevent cross talk issues when implementing cross ventilation to atria and corridors. This product is flexible and can be easily customised to comply with the criteria associated with BREEAM, BCO, HTM, BB93 and other standards.

The concepts and design specifications for this product have come from MACH Acoustics consulting experience. Our experience has shown that many current products have a limited acoustic performance, are inflexible, costly, and are lacking in technical innovation. Through frustration, knowledge and insight, the NAT Vent Attenuator has been designed, developed and produced by MACH Products.

The NAT Vent Attenuator is formed from W shaped tiles manufactured from acoustic foam. These elements are then tessellated and stacked together **11**, **12** to form the NAT Vent Attenuator **13**. The result is a lightweight, simple and flexible product which can be fitted into bulk heads to allow for cross ventilation, or incorporated into the facade of a building to prevent noise break-in.

The key features of the NAT Vent Attenuator are its patented technology based around the honeycomb structure, its novel W shaped splitter arrangement and the materials from which it is made. A simple manufacturing process delivers a cost effective, lightweight product, which is exceptionally flexible and therefore can be made to fit into a wide range of spaces and locations.




The NAT Vent Attenuator is designed and manufactured bespokely for each project and tested using MACH Acoustics in-house test facilities **14** meaning that the acoustic specification of this product can meets the exact project requirements.

**1** NAT Vent located under a planter

**2** NAT Vent incorporated above a suspended ceiling, providing an air exhaust path

**3** NAT Vent used as a cross talk attenuator

**4** NAT Vent installed under a play box

**5** NAT Vent built into the building envelope

**6** NAT Vent integrated under a window and above a ceiling line

**7** NAT Vent placed under a parapet roof

**8** Dogleg NAT Vent built into the building envelope

## Acoustics and Vented Facades

When naturally ventilating a building on a noisy or moderately noisy site the acoustic design of the facade becomes fundamental. The ability to provide high levels of sound resistance within a limited depth is often a requirement for an attenuator in the facade of a building. Due to the honeycomb structure **13** and the performance of the acoustic foam, the NAT Vent Attenuator provides an exceptionally slim line attenuator with an outstanding acoustic performance. The size and depth of the NAT Vent Attenuator is dependent upon two main factors.

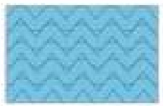
The free/open area specified by the M&E consultant/engineer. This governs the required face area of the attenuator and its percentage free area. A large face area will transmit a greater level of sound into a room, hence the attenuator can be made longer to compensate.

The second factor affecting the depth of the attenuator is the required level difference between the environmental noise and the internal noise limit. The greater the difference, the longer the attenuator.

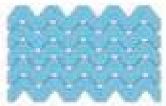
To design and test the NAT Vent Attenuator, MACH Products has an in-house test rig calibrated to BS EN ISO 7235:2003. This test facility enables MACH Acoustics to design and test a range of options at any stage of a project. The NAT Vent Attenuator is then manufactured to fit into a given location, as well as meeting the buildings ventilation and acoustic requirements.

See Chapter 2 and our website, www.machproducts.com for further details.

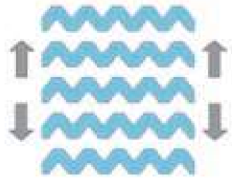
9



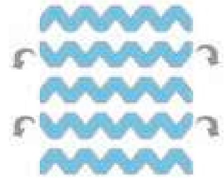
10



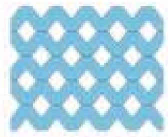
11



12



13



14

**9** Foam blocks cut using a computer controlled cutter

**10** Waste material removed

**11** NAT Vent Attenuator tiles separated

**12** Alternate NAT Vent Attenuator tiles flipped over

**13** NAT Vent Attenuator tiles stacked together

**14** MACH Acoustics test rig

MACH ACOUSTICS

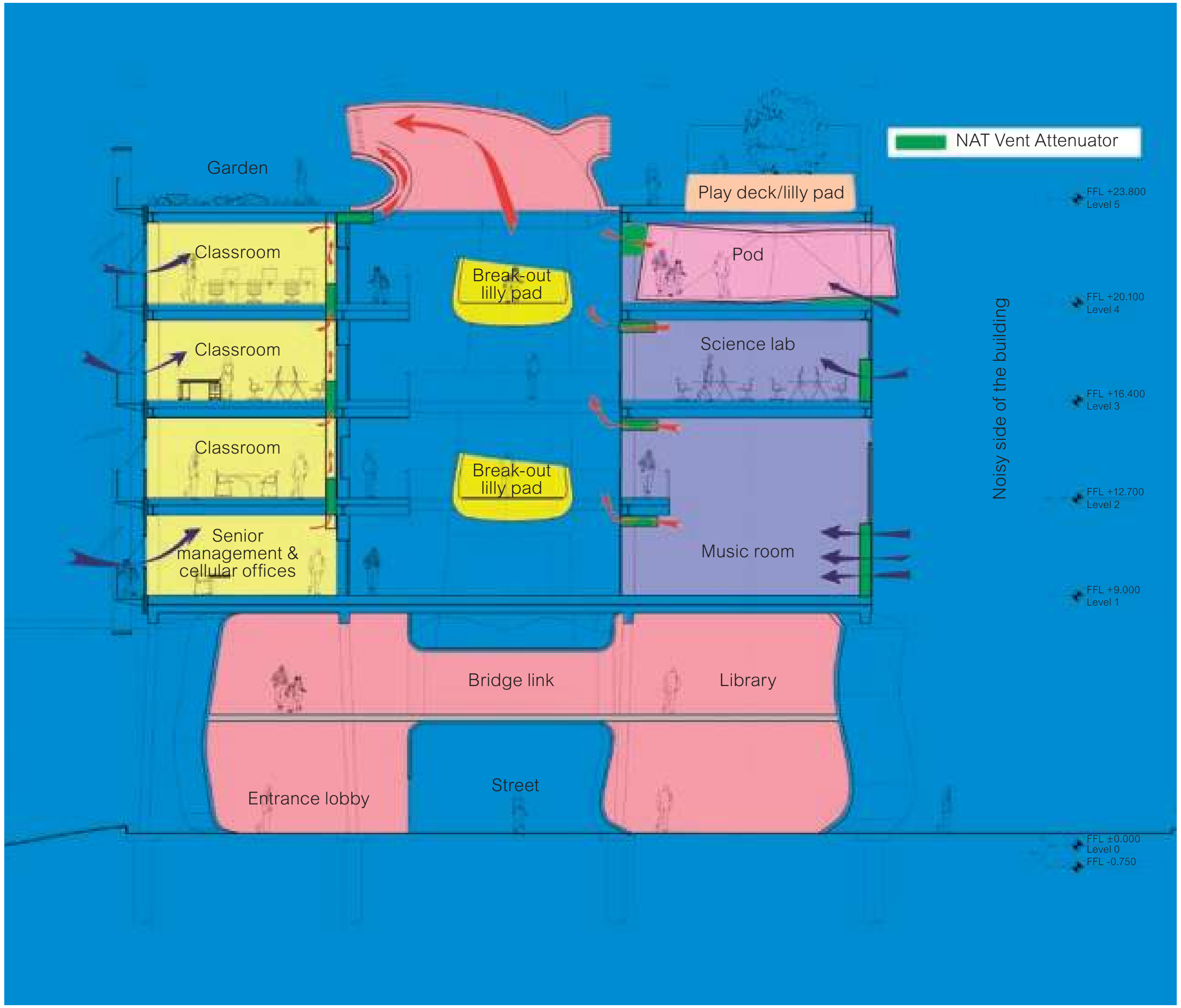
# Acoustics and Cross Ventilation

It is generally accepted that cross ventilation is the most effective form of natural ventilation. Acoustics plays a key role in the design of a cross ventilated building as air must flow freely through the building whilst maintaining privacy across partitions. To allow cross ventilation and maintain privacy, cross talk attenuators are required within partitions adjacent to circulation spaces.

One of the key design benefits of the NAT Vent Attenuator is the simple implementation of cross ventilation through a corridor wall, while still maintaining the acoustic integrity. Furthermore, this product enables cross ventilation to vertically stacked rooms, vented through a single stack. In other words, vertically stacked spaces no longer require independent chimneys to maintain the acoustic separation between rooms, resulting in a significant recovery of floor area and a considerable cost saving.

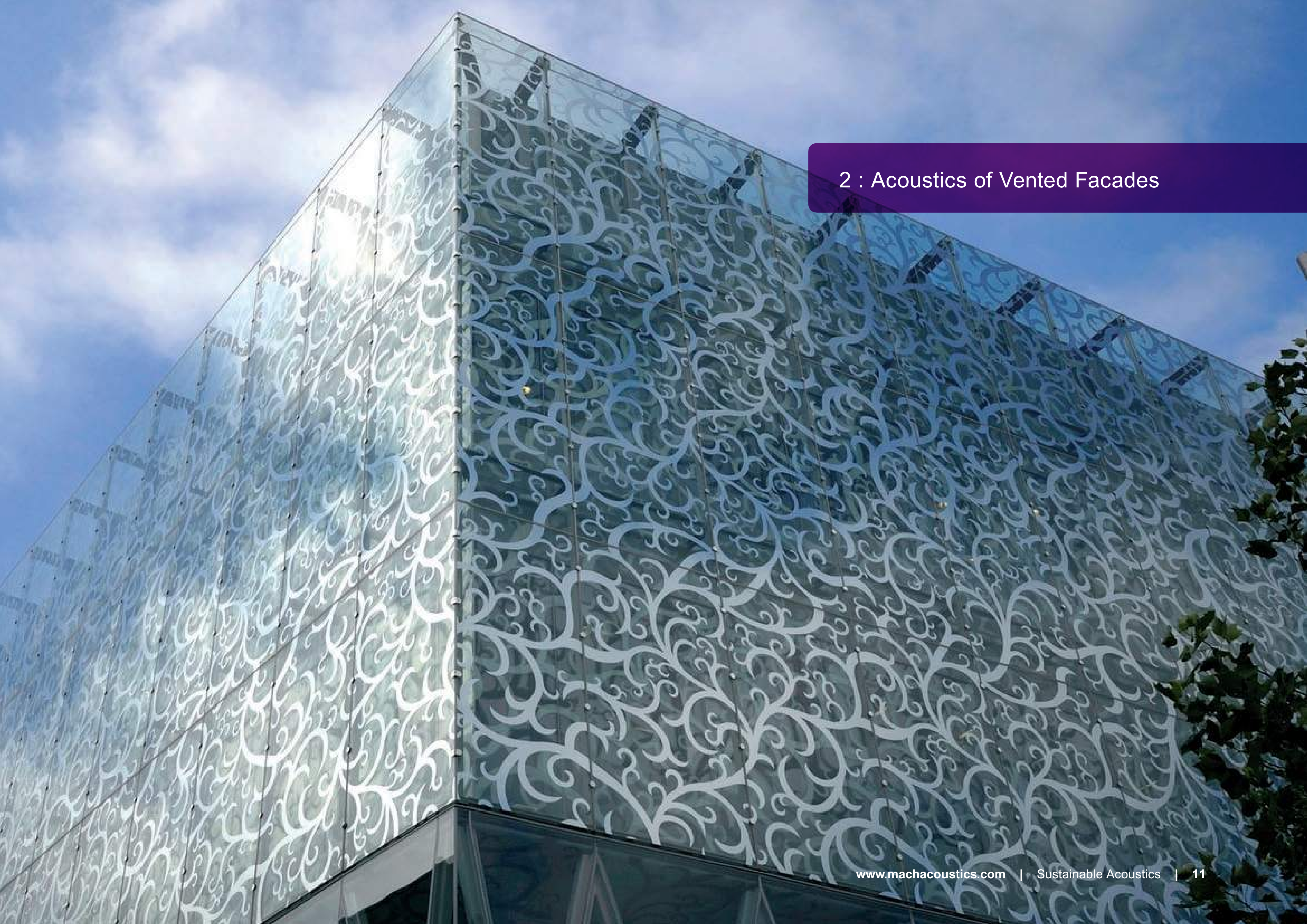
One of the drawbacks of ventilating through the corridor wall is the requirement for an exceptionally large bulk head to accommodate large, heavy attenuators. The NAT Vent has been designed to provide exceptional levels of cross talk separation. MACH Acoustics has undertaken extensive research to understand the required levels of acoustic separation across these partitions. Depending upon the air flow and the required level of acoustic separation, the NAT Vent can be as slim as 600mm deep. In some instances, this is required to be increased to 1200mm, depending on the required acoustic performance.

1




**1** Example of cross vented building

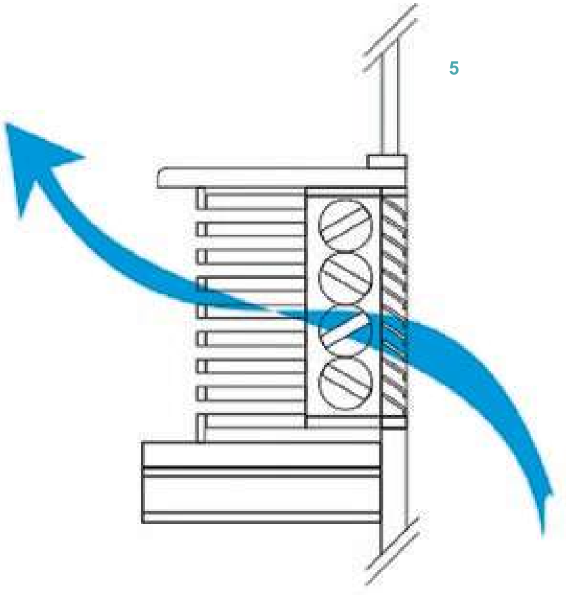
# 2 : Acoustics of Vented Facades

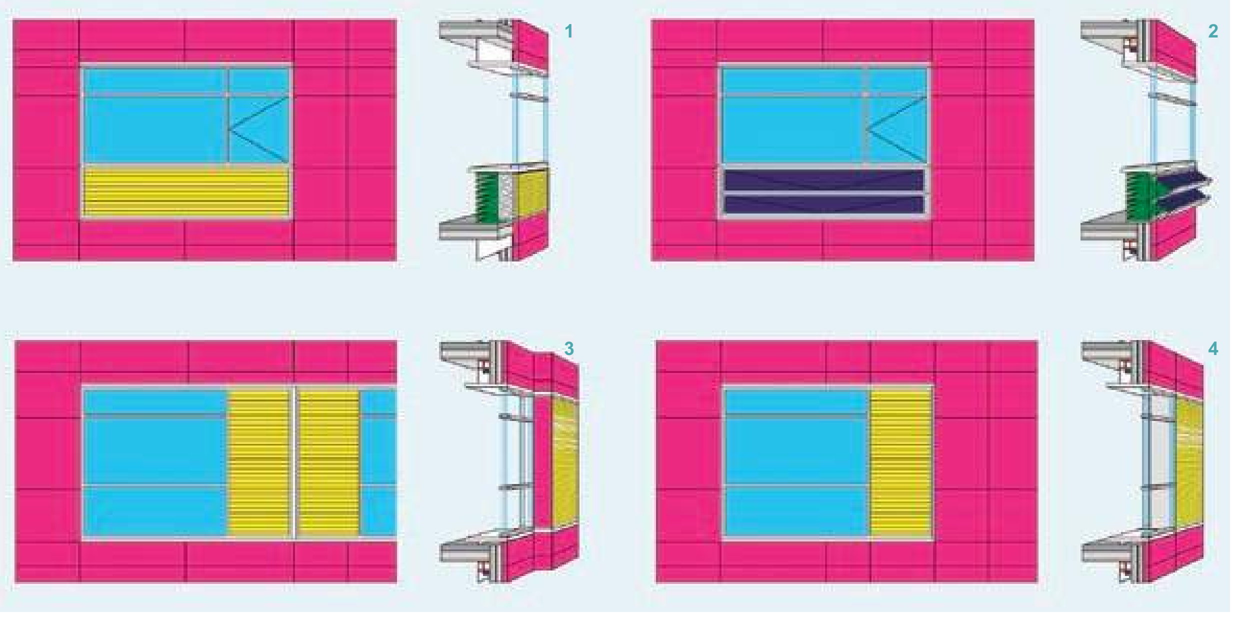


# Attenuation Incorporated Into a Facade

One of the main difficulties in designing low energy buildings can be the prevention of noise break-in via vented facades. This chapter looks at a range of options and details which can be used to reduce environmental noise break-in from the many noisy sources affecting modern buildings, including motorways, dual carriageways, trains, aeroplanes and inner city noise.

To overcome this issue, an attenuator is selected and incorporated into the facade. This attenuator is typically combined with a damper such to control the flow of air into the building, with a weather louvre being used externally to provide the weather protection. MACH Acoustics describes this combination of units as the 'NAT Vent Box'. The outline schematic of this system is shown below **5**. The damper can take the form of a thermal volume control damper, open-able vents within the facade, thermal insulated doors etc.




**1** NAT Vent Box located under a window, internal thermal damper used to control air flow

**2** NAT Vent Box located under a window, external vent used to control air flow. This is a cost effective slim design option

**3** Vertical NAT Vent Box located adjacent to window, air flow controlled by means of an internal thermal door

**4** As 3, the facade in this instance has been pushed out such to include a large attenuator. This design option is suitable for higher noise levels

**5** Section through the NAT Vent Box

## NAT Vent Box

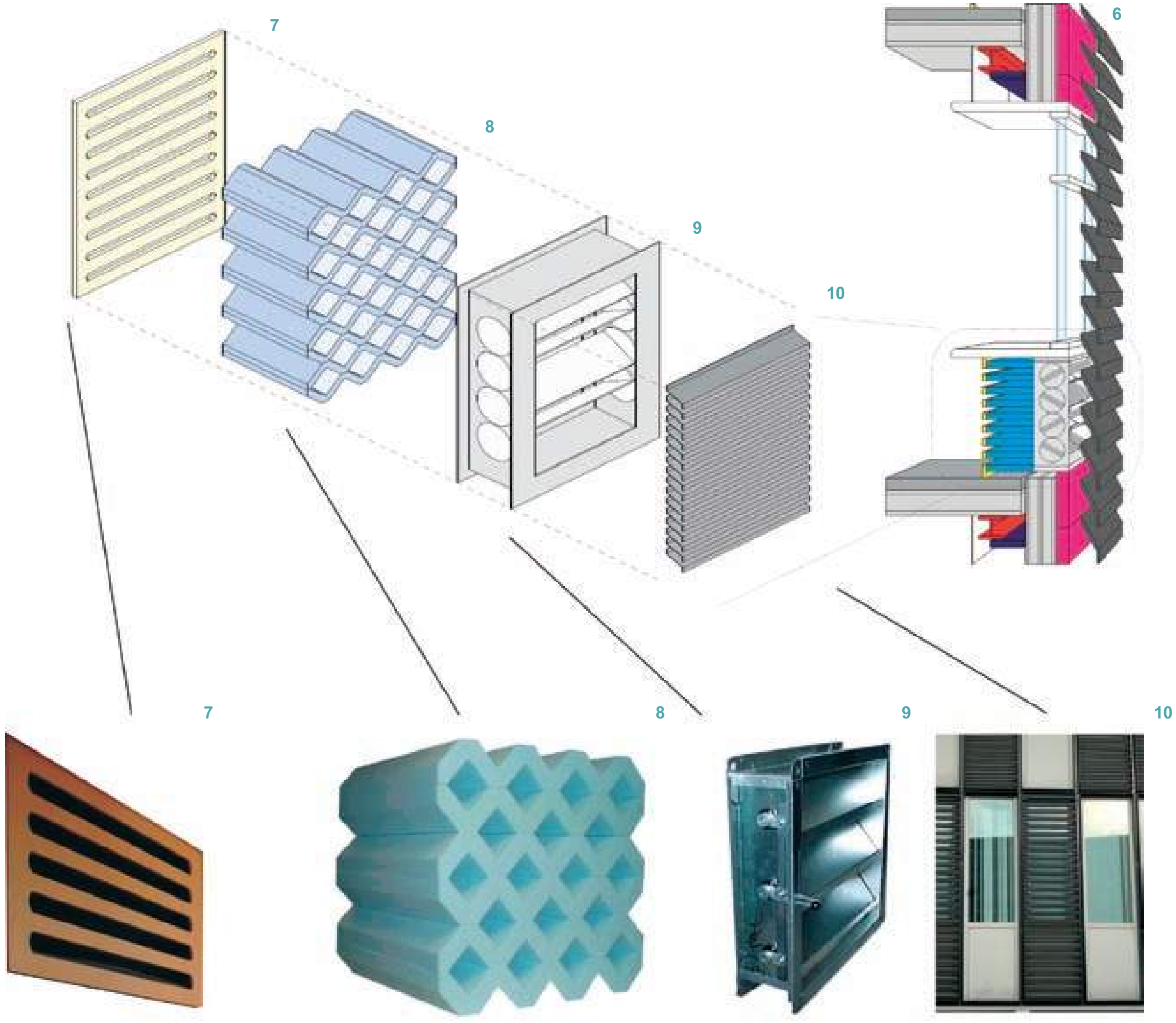
The key elements making up the Nat Vent Box are shown in the illustration to the left. Air is brought in through the external weather louvre **10**, flow is controlled with a volume control damper **9**. The volume control damper can either be used to seal the building or manage/control the flow of air into the building. This damper can be manually operated by means of a handle or Teleflex cable. Motorised thermal dampers can be used in combination with a BMS system.

A second important function of the thermal damper is to maintain the thermal line/thermal performance of the building envelope when shut.

The noise reduction across this unit is achieved through the attenuator **8**. The attenuator is incorporated between the thermal damper and an internal louvre **7**. The attenuator is formed by stacking W-shaped tiles which creates a honeycomb structure. This restricts the passage of sound whilst allowing air to flow through the central paths of the honeycomb body. The difference between the external noise levels and the required internal noise levels, governs the depth of the attenuator **8**, where a greater difference requires a deeper attenuator. The depth of the attenuator is the distance that the air travels through the unit.

Finally, the internal louvre can be manufactured from wooden slats, perforated metal, or a conventional internal louvre can be used.

**6** Attenuated Vented Facade
**7** Internal Louvre
**8** NAT Vent Attenuator
**9** Thermal Damper / Flow Damper
**10** Weather Louvre



# Locating Inlet Vents and Cross Vent as a Noise Control Measure

## Locating Air Inlet Vents

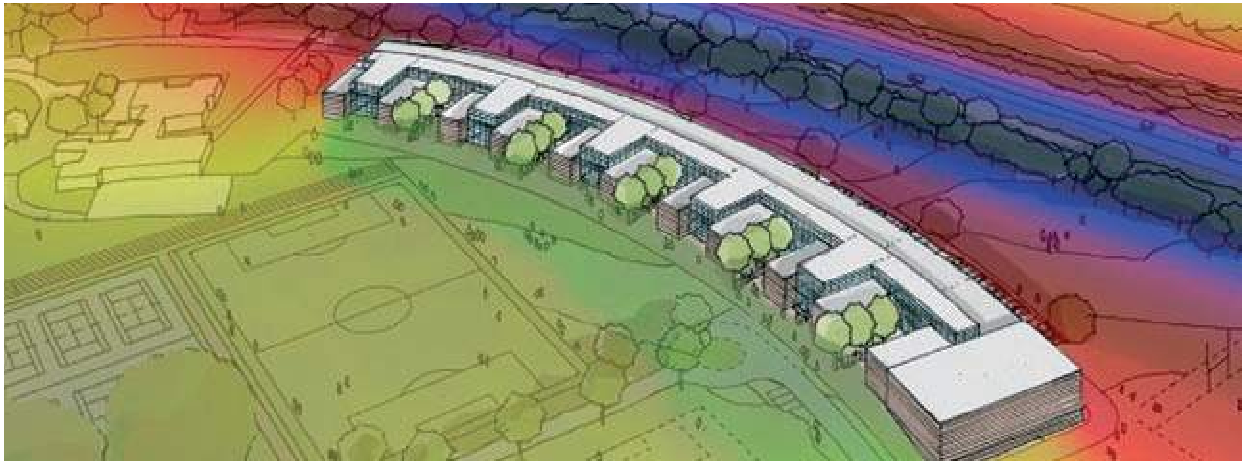
The orientation of a building has a significant impact upon noise levels at the different facades of the building. It is often the case that facades on the opposite side of a building to a significant noise source, will have considerably lower noise levels than those on the noisy side of the building.

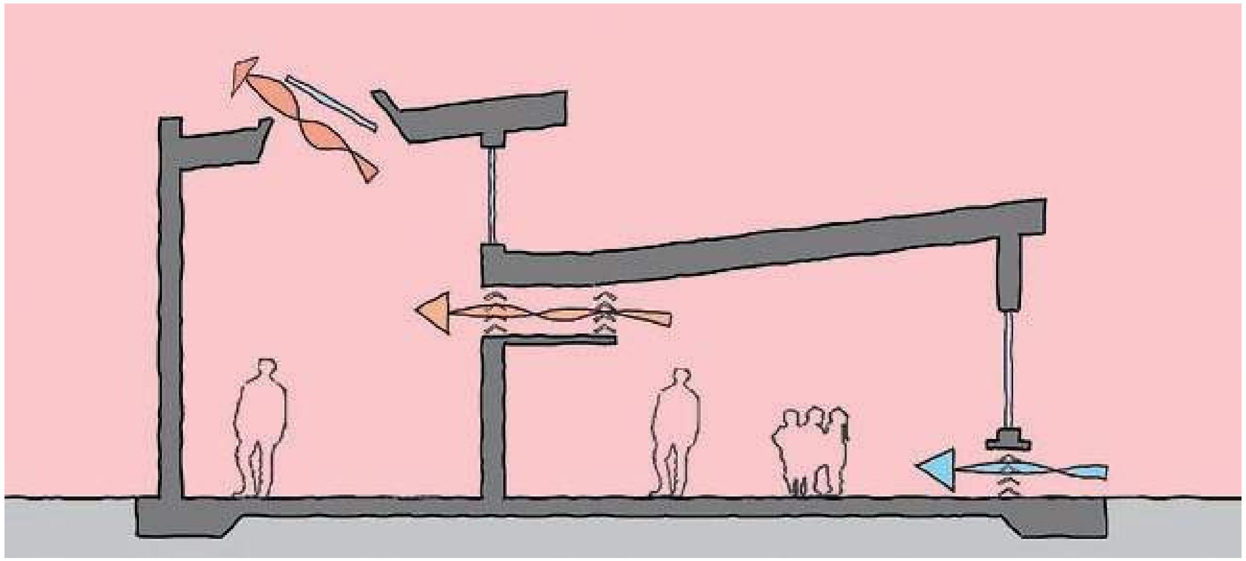
By orientating the building and by locating non-critical spaces on the noisy side of a building, it is possible to form a good acoustic buffer. In these instances, cross vent can be used where the air intake is placed on the quiet side of the building. Cross ventilation to an atrium or circulation zone is then used to provide the air extract. Alternatively, single sided ventilation could be used for sensitive spaces on the quiet side of a building.

**1** This noise map shows that screening reduces noise levels on the far side of the building from the dual carriageway sufficiently to allow natural ventilation by means of openable windows.

## Cross Vent to Assist with the Prevention of Noise Break-in

In instances where a building is located on an exceptionally noisy site, cross ventilation can improve the feasibility of natural ventilation. Cross ventilation **2** has an important advantage over single sided ventilation, in that air inlet vents can be between 25% to 75% smaller than those required for single sided ventilation. This significant reduction in vent size helps considerably in preventing noise break-in, as smaller vents restrict the passage of sound into a building.


1


2

## Bench Seating

Adding vented attenuation to the facade of a single storey building is comparatively easier than for a multi storey building. It is often possible to extend the building envelope, accommodating the additional depth of the NAT Vent Boxes within features.

In the case of single storey buildings, it is common to maintain a simple vertical thermal line, by placing the thermal damper into the line of the facade **4**. The acoustic attenuation in this instance is placed outside the building line. This design approach has been implemented by MACH Acoustics on several projects. The NAT Vent Box has been installed under bench seating, flower boxes, play boxes, small steps in the facade and other elements. These units have all been used to hide and accommodate the additional facade depth often required when naturally ventilating a building on a particularly noisy site; often without being noticed by the users!

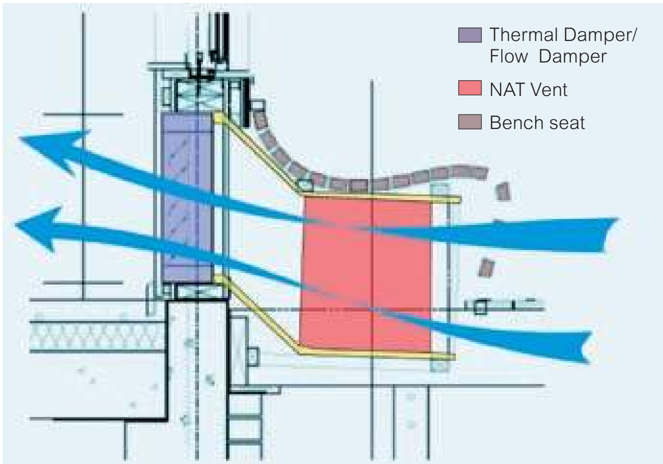
A second advantage of single storey buildings is the potential to incorporate the NAT Vent Box above or within roof lines, above corridors, over storage rooms and other areas.

**1** A noise map: a key tool used to assess the spread of noise around a building

**2** Cross ventilation used to enhance the feasibility of natural ventilation

**3 & 4** The NAT Vent Box in this instance is located under a bench seat running the length of a primary school classroom. Due to the fall of land around the site, the project team raised a walkway around the school. As such, the air intake was not only through the bench but also from under the raised walkway


3



4

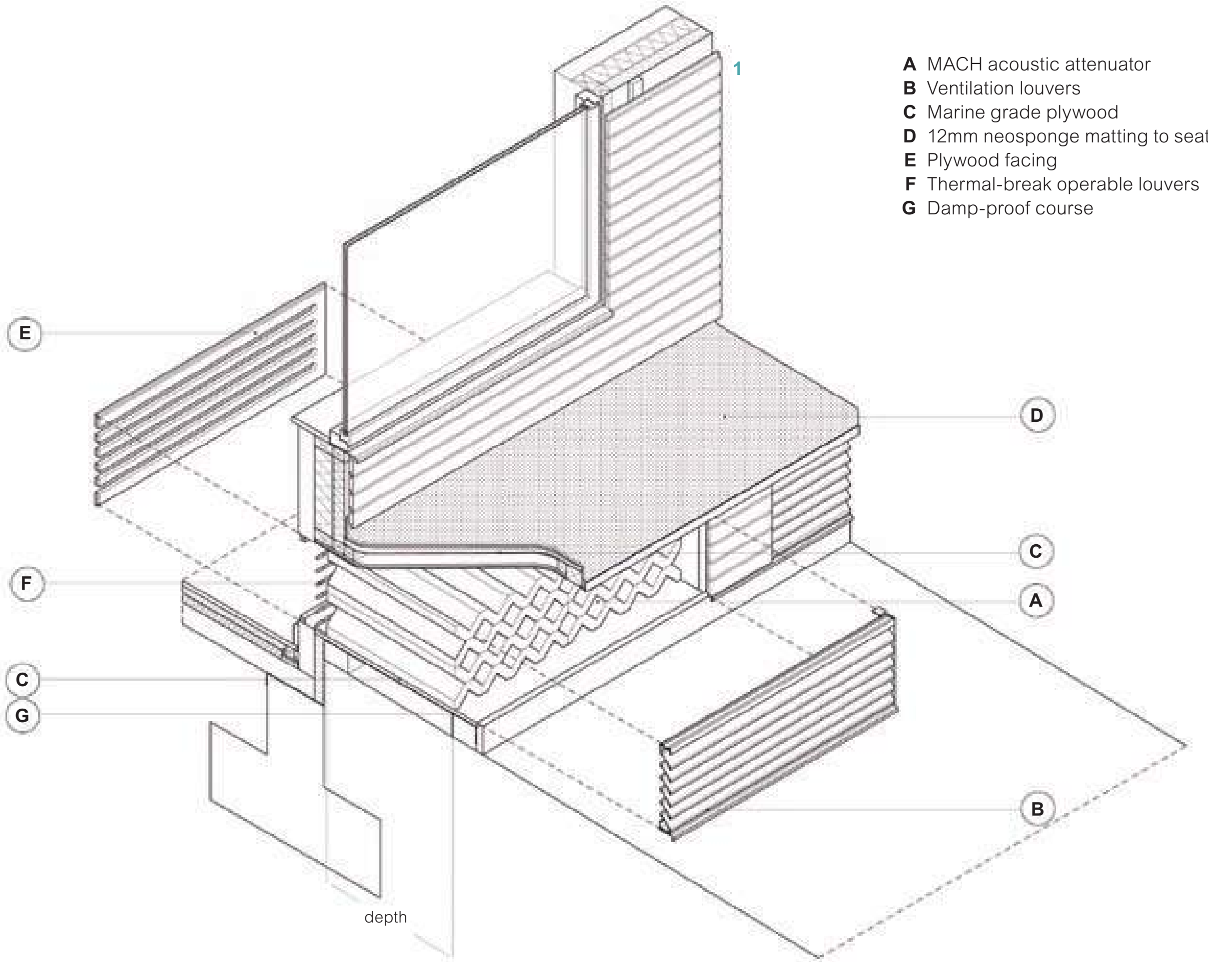
# Window Details

The details used to incorporate the attenuation box into a seat or play box are very similar to those used when incorporating the NAT Vent Box into the facades of buildings. As noted, it is often easier to extend the facade line of single storey buildings to accommodate deep attenuators. This in turn means that it is potentially possible to provide natural ventilation irrespective of how high the noise levels are. The illustration to the right was used to control noise break-in to a sensitive office space in close proximity to a major motorway.

## Installation of the Attenuator

Forming the NAT Vent Attenuator by tessellated, W-shaped foam blocks, means that this product can easily be dropped into a timber enclosure or metal duct work. The W-shaped tiles compress and can be cut to any size; hence these units are extremely easy to accommodate into the facade of a building.

2




1

**A** MACH acoustic attenuator
**B** Ventilation louvers
**C** Marine grade plywood
**D** 12mm neosponge matting to seat
**E** Plywood facing
**F** Thermal-break operable louvers
**G** Damp-proof course

**3 to 6** Example of high level air inlet
**7 & 11** Illustration of high level air inlet
**8 to 10** Different configuration of low level air inlet

## Window Systems and Curtain Walling

The thermal damper is one of the main factors affecting the cost and depth of the NAT Vent Box. Replacing the damper with an openable or motorised vent/window, eliminates both the thermal damper and weather louvre from the box make up. This typically reduces cost by around 50% and can reduce its depth by approximately 200 - 300mm.

Facade and window manufacturers can easily accommodate openable vents in curtain walling or window frames. Placing the NAT Vent Attenuator directly behind an open vent, provides a simple, cost effective design solution for preventing noise break-in.


3

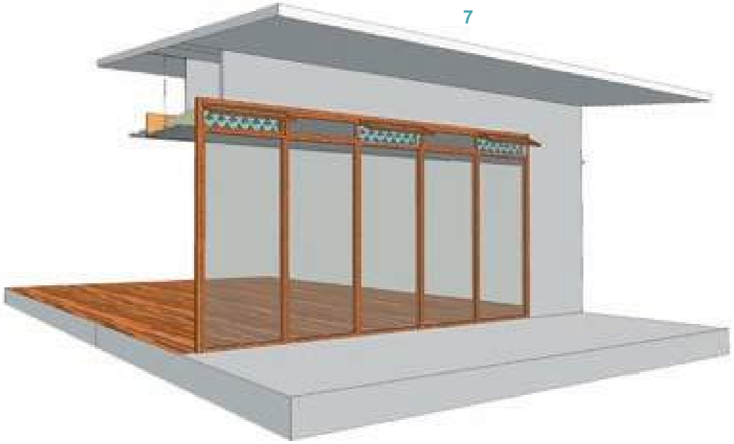

4


5


6

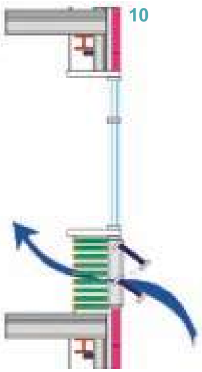
### High level air inlet

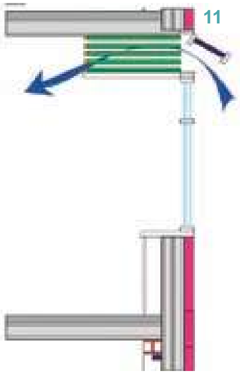
In the case where noise levels are exceptionally high, for example due to motorway noise, flight paths or inner city noise, the depth of the attenuator needs to be increased. The additional depth of the NAT Vent Box can be accommodated by using a high level bulkhead **11**.


7


8


9


10

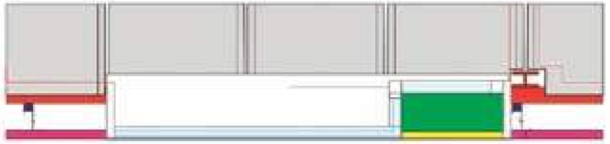

11

# Louvred Facade

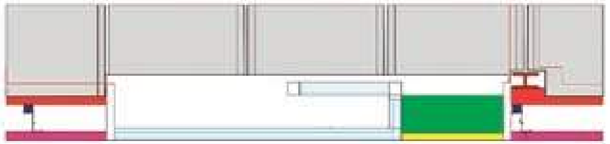
As shown below **7 - 8**, the NAT Vent Box can also be used to provide a vertical air inlet. This arrangement provides a design opportunity to provide colour and depth to a building's facade.

A second advantage is that it is often possible to place NAT Vent Boxes within the corner of a room. Here, it may be easier to incorporate a deeper Vent Box **1 - 4**. Alternatively, it may be possible to pull the facades out in certain areas such to accommodate a deeper NAT Vent Box. Both of these designs are recommended when external noise levels are particularly high.

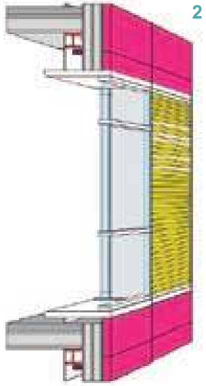
A further benefit of using a vertical louvre is the potential to incorporate acoustic attenuation into the blades. For free area reasons, this design can only be adopted if the louvres run vertically.



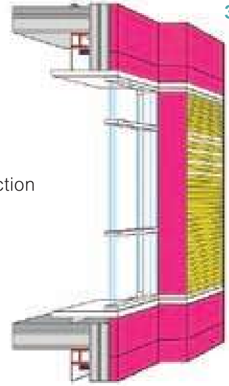
1



4


2

3D Section


3


5


6

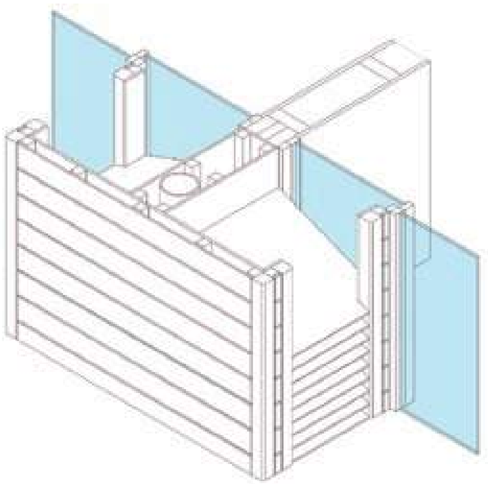

7

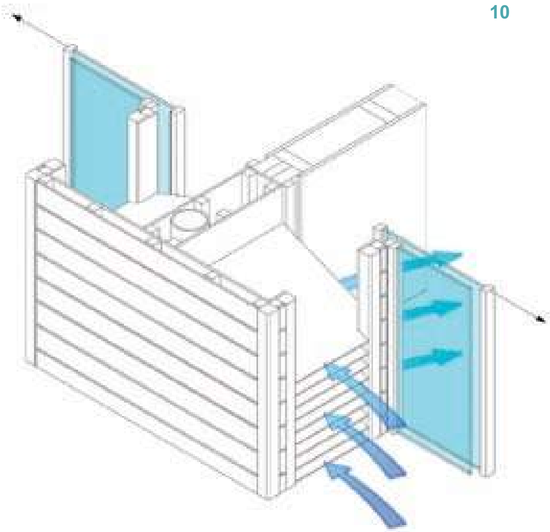

8

## Internal Sliding Doors and Windows

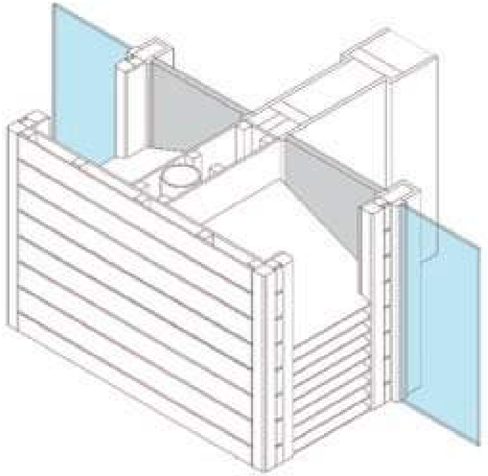
The illustrations here show some alternative arrangements **9** – **13**. In this case, the NAT Vent Attenuator is placed on the outside of a thermally insulated door or sliding window. The key advantage of this scheme is that it again eliminates the need for a thermal damper. Additionally, it can often be easier to accommodate the NAT Vent Box outside of the thermal line.

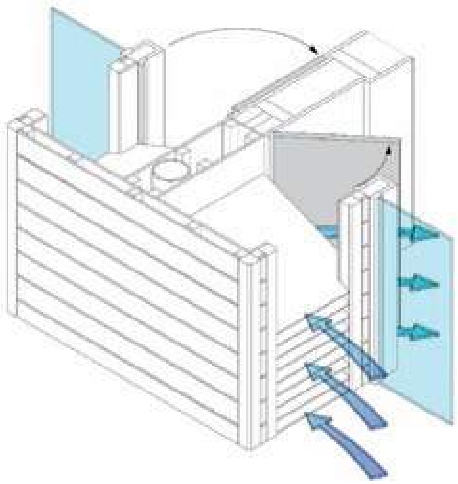
- **1 - 3** Attenuated vented facade incorporating open vents
- **2 - 4** Internal view of acoustic attenuation within a bulkhead
- **5** NAT Vent Box located over openable windows within a sliding window system
- **6** Deeper and more costly Vent Box using a thermal damper
- **7 - 8** Vent Box using external openable vents
- **9 - 10** External Vent Box and thermal internal sliding window
- **11** Facade incorporating external attenuation
- **12 - 13** External Vent Box and thermal internal sliding window


9


10

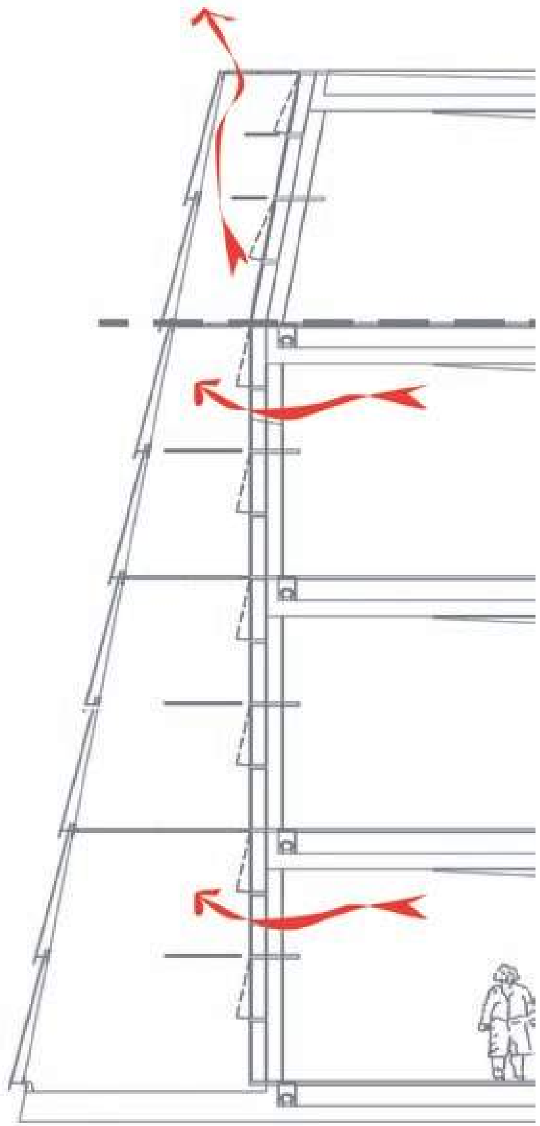

11


12


13

# Double Facades

1



2

Double facades can be used to control environmental noise break-in without the need for acoustic attenuation. When using a double facade, air enters the building through conventional open windows. The acoustic protection is achieved by acoustically screening these windows by means of a secondary facade. Air enters the void between the two facades via a gap at the bottom of the outer, secondary facade. The edges of the secondary facade are typically taken back to the primary building envelope. Attenuation may be required at the air inlet between the two facades. The advantage of this type of facade is the fact that simple openable windows can be used. It is also possible to form buildings with an interesting and unique appearance.

The drawbacks are clearly cost and space and for these reasons this type of noise control measure is less common.

It is also important to note that secondary facades can compromise the acoustic separation between two rooms when windows are open. Acoustic splitters/absorption may be required to maintain the sound insulation via two open windows.

1 Visual of a Kildare County Council building illustrating a double facade protecting against traffic noise

2 Section of double facade and ventilation path

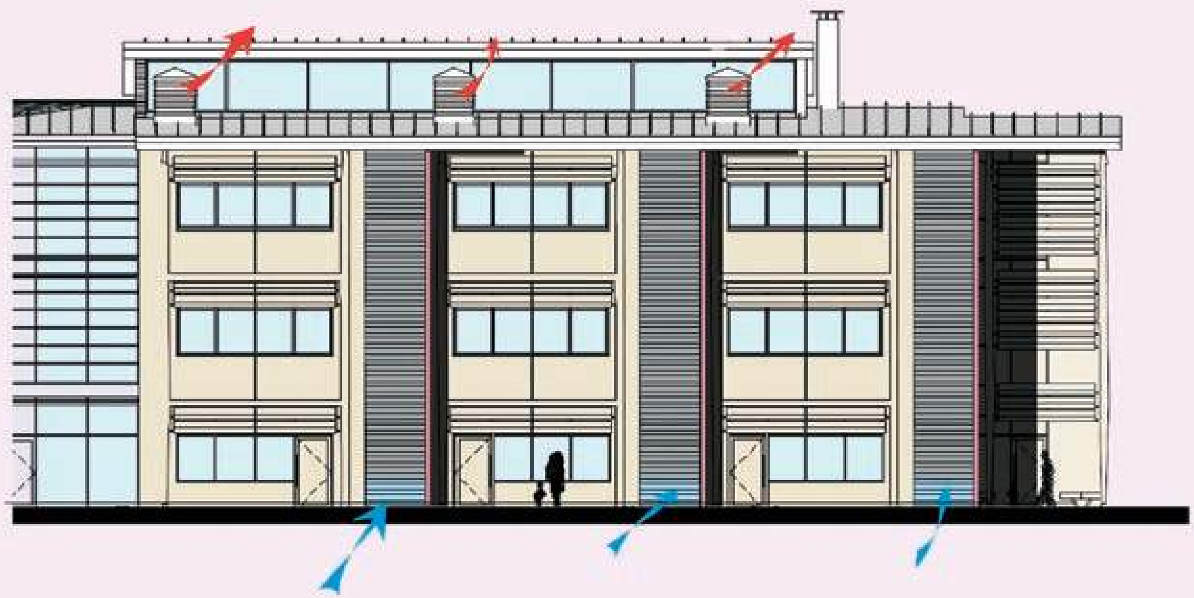
## Secondary Facades - External Ventilation Shafts

An alternative to secondary facades is to use external chimneys. This scheme uses very similar principles to that of a double facade; the difference being that the external chimneys are only used over the ventilation openings. This arrangement clearly has cost and space saving advantages over that of double facades.

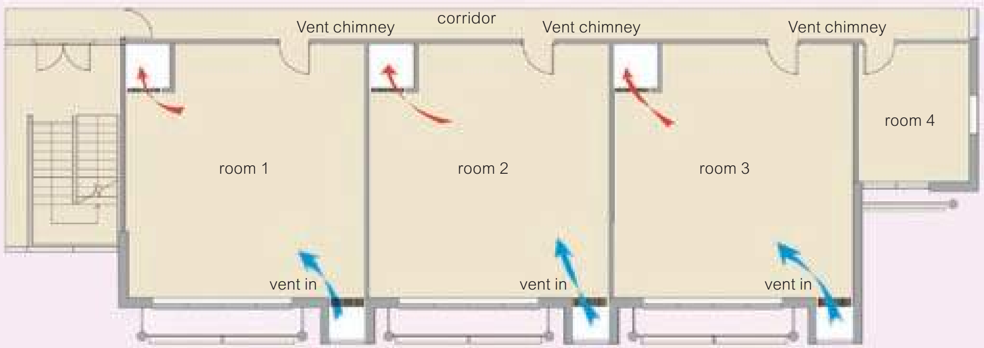
A second architectural advantage is that it is possible to provide an animated facade. Forming the chimneys from glass or other translucent materials, allows interesting designs in the form of graphics to be incorporated within the chimneys, adding further interest to the facade of the building.

One of the drawbacks of this design is that acoustic treatment may be required within the chimneys to prevent the spread of sound along its length. This may be required to maintain the acoustic separation across floors. If the ventilation chimneys were to be made transparent, acoustic art work could be used to enhance the architecture of the building, as the acoustic material would be visible through the transparent chimneys.

3



4




**3** The floor plan of a building where the external chimneys provide the air inlet to a school. Cross vent is provided through a ventilation stack, single ventilation stacks incorporating the NAT Vent Attenuator are used to prevent cross talk between floors

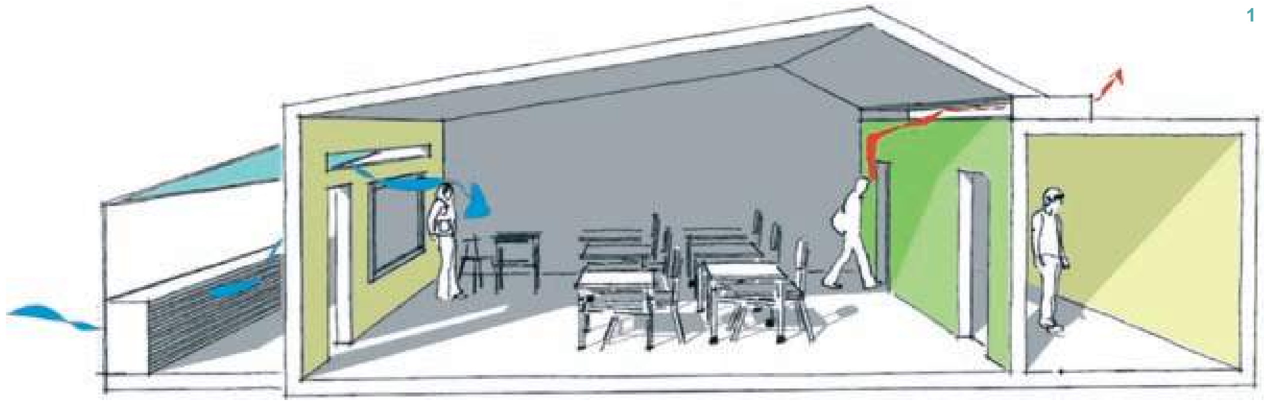
**4** Proposed elevation including external chimneys

# External Spaces as Secondary Facades

## Secondary Facade as a Functional Space

Often there is a need for spaces such as cloakrooms, changing areas, walkways, balconies and other non-acoustically sensitive spaces which need to be located adjacent to a building. By making these spaces external and unheated, i.e. open covered spaces, it is possible to use these areas as a secondary facade. If required, additional acoustic protection can be added by means of placing an attenuator within the secondary facade **1**. This attenuator could be located under benches, cupboards, shelving areas, raised areas etc. This would be an ideal way of preventing noise break-in from low flying aircraft, nearby rail lines, large main road such as a motorways as well as other sources.

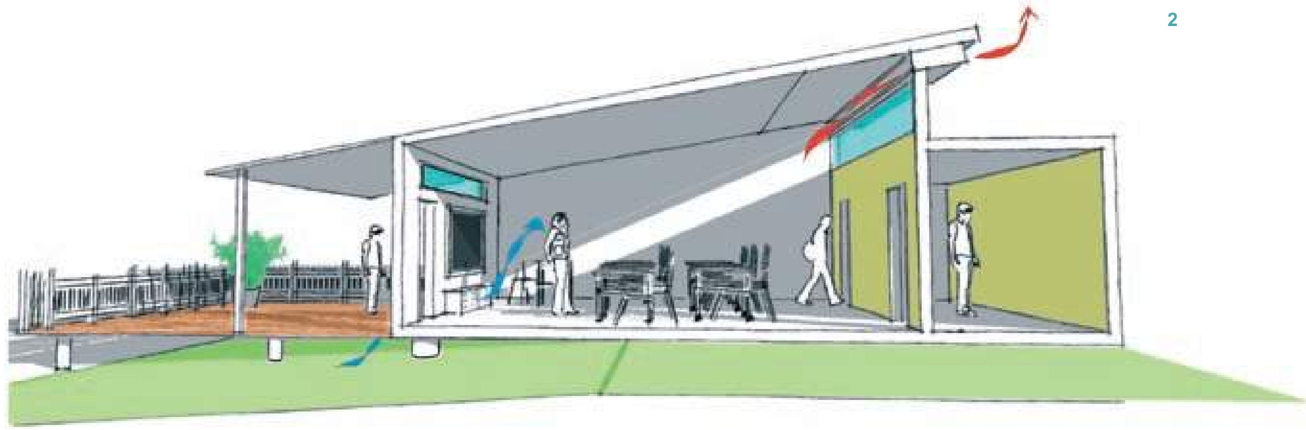
1



## Acoustic screening and ventilating from under a building

Acoustic screening is an effective method of controlling noise break-in to a building. Illustration **2** shows how a large, suspended, raised (play) area was used to accommodate the fall in the land across a school site. This play area provided a highly effective screen to aircraft noise and potentially other major noise sources. The vents under the deck have little or no visibility to the noise sources affecting the development and hence provide good attenuation. In simple terms, providing an air inlet under the building reduced noise ingress into the building.

2

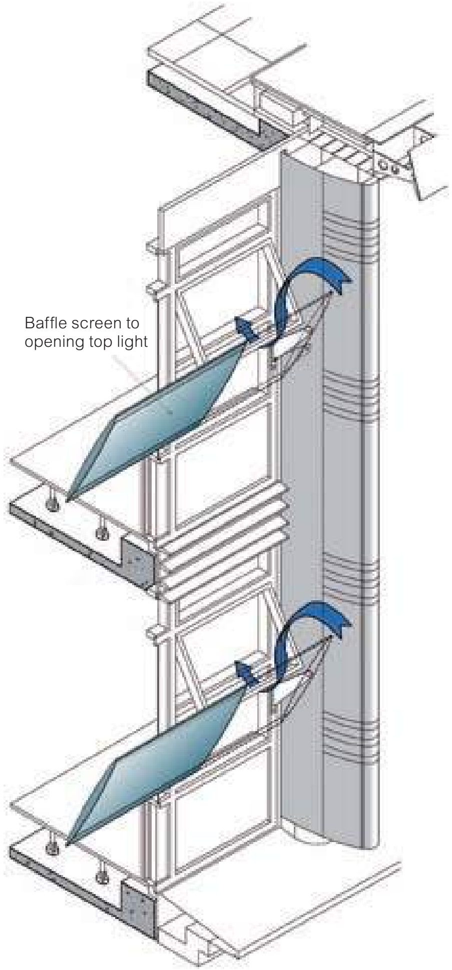


## Solar Shading and Acoustic Screening to Open Windows

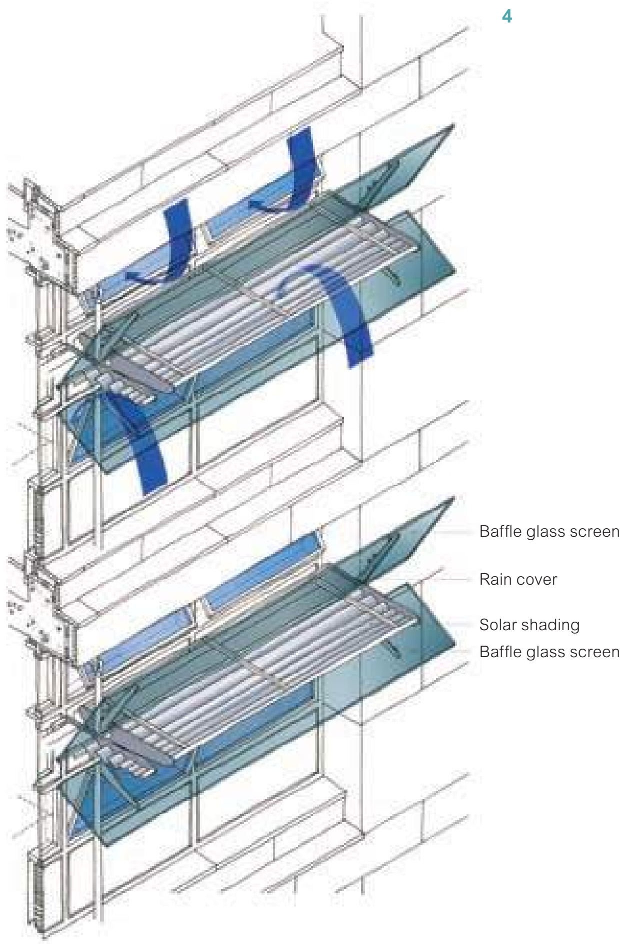
‘Acoustic Scaled Models of Vented Facades’ is a technology which has been developed by MACH Acoustics. This technology enables the effects of acoustic screens attached directly to the facade of a building to be assessed. Scaled models are typically used to assess the acoustics of auditoria during the design stages. For major concert halls, a scaled model of the auditorium is built to assess its acoustic performance and characteristics. Scaled models are used due to their practical, accurate and cost effective nature. The same principles apply to the design of screened acoustic facades. MACH Acoustics has developed a method of assessing the acoustic resistance of screens attached directly to the facade of a building by means of scaled models.

The illustration to the right shows two design options where screened facades were proposed in order to add acoustic attenuation to a vented facade of an inner city office block. This method of noise control is simple, cost effective and provides the additional acoustic resistance such to prevent inner city noise being a nuisance within the office accommodation. Screened facades are also a good method of meeting the requirements set out by BREEAM. The drawback of this system is that these screens can only enhance the performance of an open-able window by around 5 to 7 dB, meaning that these facades can only be used when external noise levels are moderately high.

3




4




**3** Simple Screened window

**4** Screened window install on solar shading unit

# Screening under overhangs and above roof

The scheme below provides three design options incorporating acoustic screens into the facade of a development. In these instances, the air inlet vents are acoustically screened by baffles which break the line of sight to a given noise source. The acoustic screens are, in this instance, created by extending parts of the facade or adding panels to the facade to cover the air inlet vents.

## Option 1 - Overlapping Facades

With a perpendicular air inlet to the facade **1** and **4**, this design provides an ideal screen to a noise source propagating from the left-hand side of the building **5**.

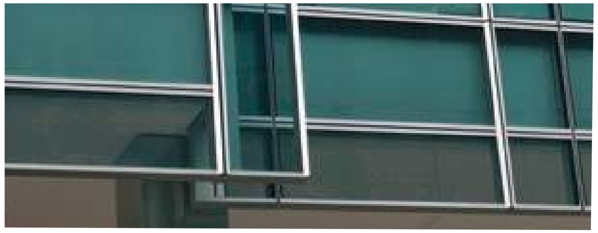
## Option 2 - Solar Shading and Acoustic Screening

Here a solid transparent screen incorporated into the solar shading **2**, provides acoustic screening to a noise source directly in front of the building **6**.

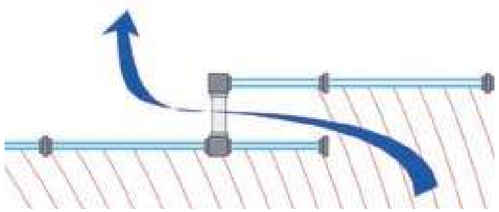
## Option 3 - Photovoltaics used as Acoustic Screens

Photovoltaics provide acoustic screens in this instance **3**. The photovoltaics are used to provide solar shading, power and acoustic attenuation, all within the building's facade. Off-setting the photovoltaics and placing the air vents directly behind these panels provide high levels of acoustic insulation **7**.

### Option 1

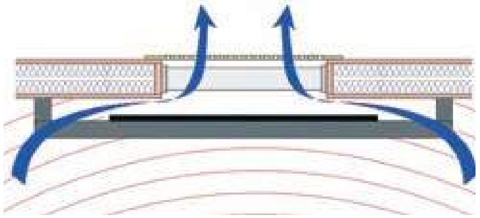

1


4


5

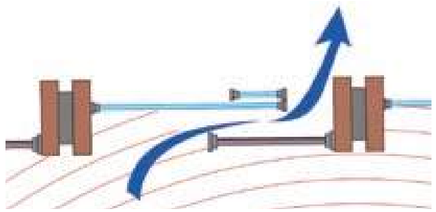
### Option 2


2


6

### Option 3


3


7

# 3 : Acoustics and Cross Ventilation

# Introduction

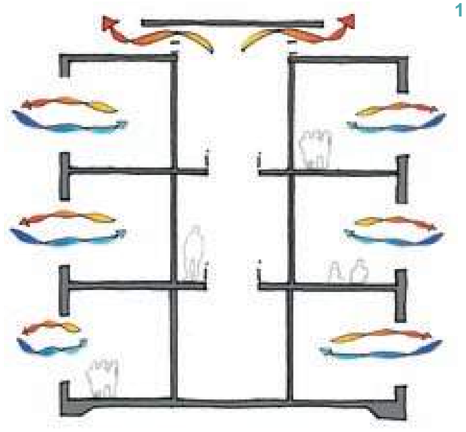
Cross ventilation is a highly effective method of ventilating a building **2**. This type of ventilation can also provide cost savings as cross ventilation requires a lower floor to ceiling height than single sided ventilation **1**. The drawback of this type of ventilation is often a reduction in floor area as a result of using multiple chimneys **3** and the risk of compromising the acoustic separation across corridor walls.

When ventilating through corridor walls, cross talk attenuators **2** are required to maintain the acoustic performance of partitions, whilst allowing the flow of air into a circulation zone. In these instances, bulkheads accommodating attenuators (600mm to 1200m deep) are required to maintain the acoustic resistance of the partitions. These figures are based upon the NAT Vent Attenuator being used.

Ventilation stacks and chimneys are an alternative to venting through corridor walls. Ventilation stacks still have drawbacks; principally the reduction of floor area when using multiple chimneys **3**. Considerable care is often required when detailing and constructing these chimneys, to ensure that these details do not compromise the acoustic performance of separating walls and floors.

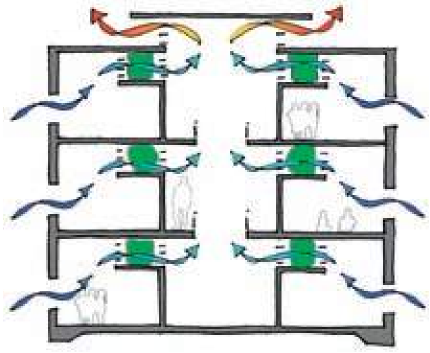
When ventilating more than one floor, independent chimneys are often used to maintain sound insulation and acoustic privacy between vertically stacked spaces. On the other hand, NAT Vent Attenuators can be placed within the ventilation stack, therefore removing the need for multiple chimneys **4**.

1



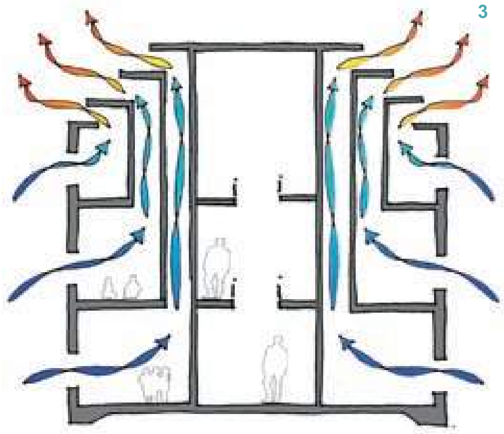
Single sided ventilation - tall, costly building

2



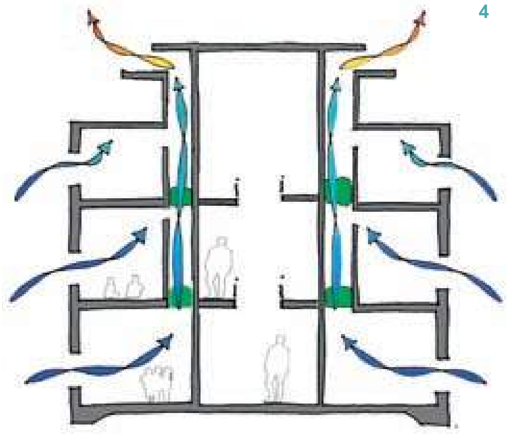
NAT Vent Attenuators in combination with cross ventilation - Improved ventilation, lower building height, reduced cost smaller openings

3



Multiple chimneys - reduced floor area

4



NAT Vent Attenuators and single chimneys increase floor area

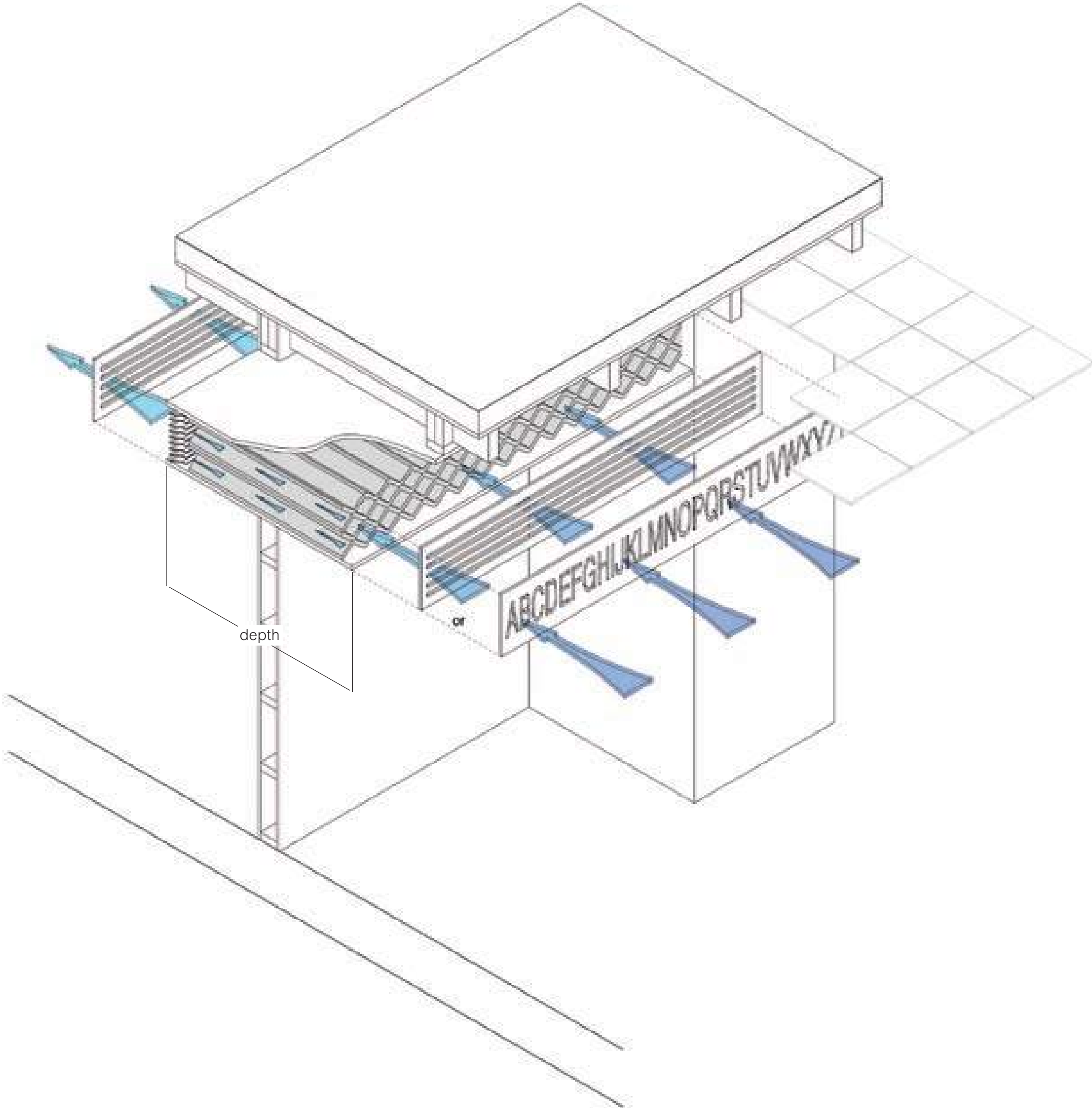
## Size and Acoustic Performance Requirements

The depth of the NAT Vent Attenuator is a function of the acoustic performance required and the free area requirements for ventilation. If a large free area is needed, the depth of the cross talk attenuator will need to be increased. This increase in depth is required to balance against the increase in sound transmission as a result of a larger face area.

The free area of the NAT Vent Attenuator is typically between 20% and 50%. The calculated pressure drop through this product is minimal due the low air speed experienced with natural ventilation. 20% free area attenuators are used in cases where there is a limited depth for the attenuator. The drawback of this configuration is that a large face area is required to maintain the same free area specified by the M&E engineer. In this instance, the cross talk attenuator typically runs the width of the classroom, office or medical room.

The acoustic performance of the NAT Vent Attenuator is rated between 34 dB $D_{ne,w}$ and 39 dB $D_{ne,w}$. Through research, it is seen that cross talk attenuators with an acoustic resistance of 34 dB $D_{ne,w}$ provide an equal performance to that of a solid partition containing an acoustically rated door (30 dB $R_w$). BB93 requires 39 dB $D_{ne,w}$ across a vent within a corridor wall, due to this limitation of the door this is seen as an over specification.

5




**5** 3D section of the NAT Vent installed into a classroom corridor wall. The depth of the NAT Vent Attenuator is 900mm and its performance meets BB93's requirement of 39 dB Dne,w

# Location and Cross Talk Depths

When installing cross talk attenuators, there are numerous locations and arrangements which can be used. Some of these arrangements have been illustrated in **2** to **9**. As shown, the sizing, depth and height of the attenuators is typically proportional to the free area of the unit, **1**.

**Options 2**, If a deep attenuator is feasible, 50% free area units are recommended, which results in a longer unit but reduces cross sectional area.

**Option 3**, one of the most popular methods is to install the NAT Vent Attenuator within a bulkhead. The bulkhead is either located in the cellular spaces or under a walkway within a circulation zone, or a combination of the two. The depth of the bulkhead is proportional to the free area of the unit, 50% free area units may require a depth of 1200mm with a height of around 250mm. 20% free area attenuators will only need to be 600mm deep, in turn this unit will require a height of 625mm.

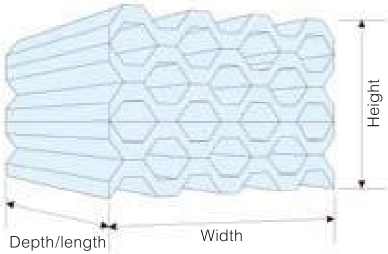
**Option 4**, an alternative to option **3**. In this instance, the bulkhead is only 900mm deep, a 37% free area unit has been used with a height of 340mm

**Option 5**, a second alternative to option **3**, 600mm deep bulkhead, attenuator 30% free area, height of 625mm

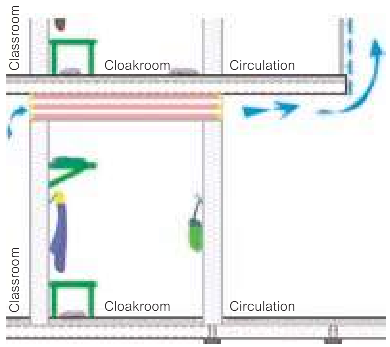
**Option 6** a further variation on option **3**, the NAT Vent Attenuator has been split to allow the passage of services.

**Option 7 to 9**, Smaller rooms such as cellular offices/medical rooms require a significantly smaller unit due to reduced air flow rates. A wide range of options are therefore available.

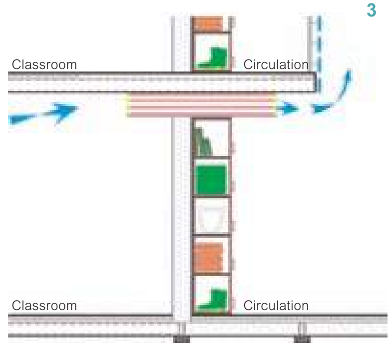
1



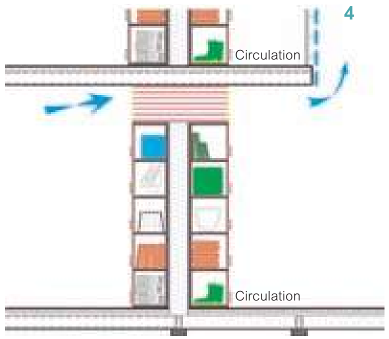

2



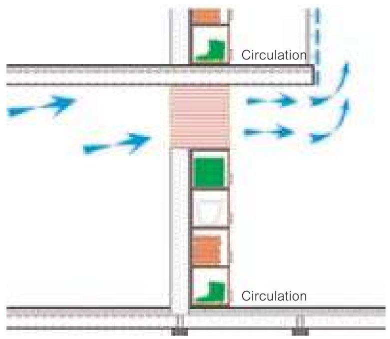

3



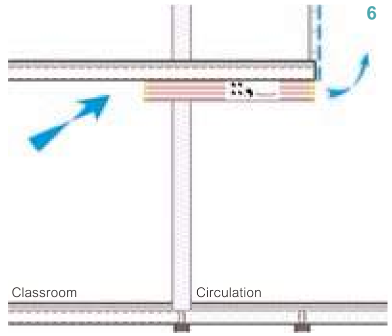

4



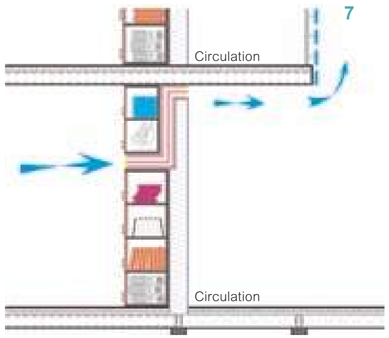

5



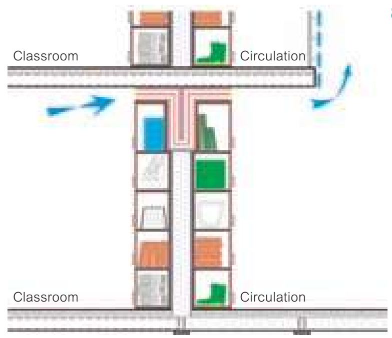

6



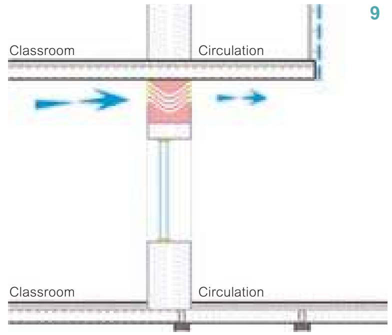

7




8




9



# Fire and Air Return Paths

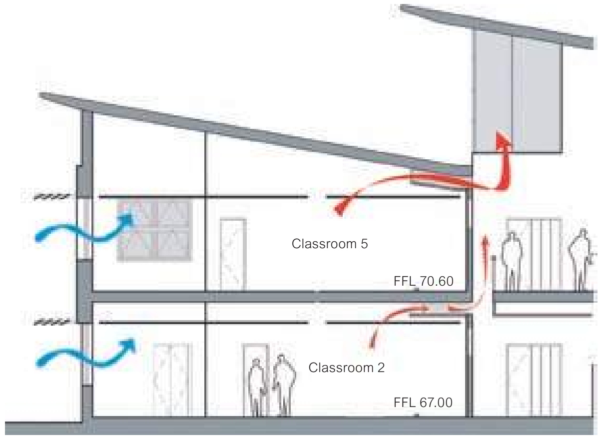
## Fire Separation

The spread of fire is an important consideration; as such the NAT Vent Attenuator can be made from Class O Foam. Additionally, it is common to install either an intumescent fire damper **13** or smoke damper into the corridor wall adjacent to the NAT Vent Attenuator. The requirement for fire/smoke dampers is dependent on the level of fire compartmentalisation of the building.

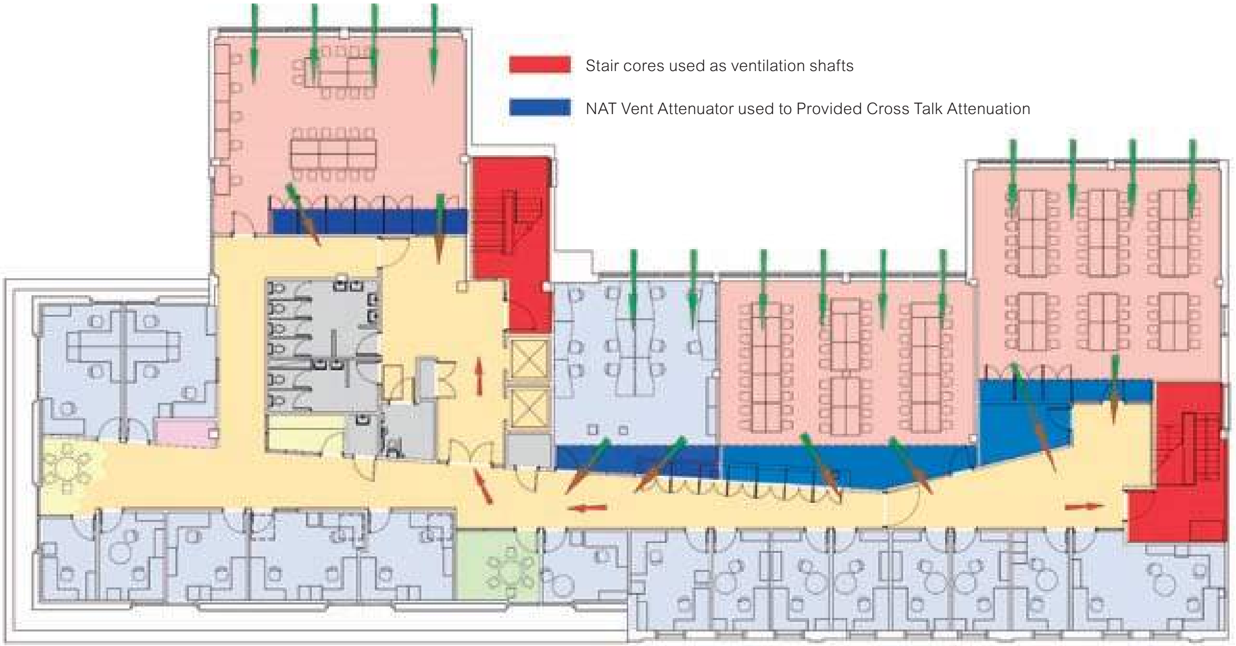
## Air Return Path

Several methods can be used to provide air return paths. These include atria **11**, light shafts **10**, ventilation shafts and stair cores. Stair cores were successfully used as an air return path as part of the ventilation scheme for the refurbishment of a Bristol University Education Building **12**. In this development, smoke dampers were proposed to be incorporated within the walls to the stair cores. A cost saving was provided by allowing the flow of air through fire doors held back on magnetic holders. In the case of a fire, the magnet released the fire door, providing the required protection to the stair cores.


10



11



12


13

# The NAT Vent – Installation

The NAT Vent Attenuator is an attenuator specifically designed for low energy buildings. This product allows for cross ventilation through a partition without downgrading its acoustic performance beyond the negative contribution from the door. To meet the acoustic and ventilation requirements, MACH Acoustics design and test attenuator configurations, using our in-house test facility to meet the individual needs of a sparticular building.

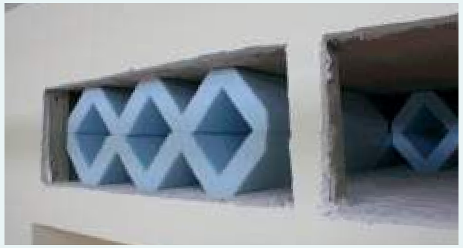
The NAT Vent Attenuator is constructed using foam blocks which tessellate together to form the product. A range of raw materials can be selected to adjust its acoustic performance. In addition, materials can be selected to the meet fire (Class O) requirements of recycled content. To control air flow and prevent the spread of fire, the NAT Vent Attenuator is often combined with volume control and fire dampers.

The installation of the NAT Vent Attenuator is exceptionally simple; the foam wedges are pushed into a bulkhead formed from timber or metal. Timber bulkheads can be lined with plasterboard if required. If the NAT Vent Attenuator is supplied in a metal duct, it can be simply supported on uni-struts to hold it in place.


1


2


3


4


5

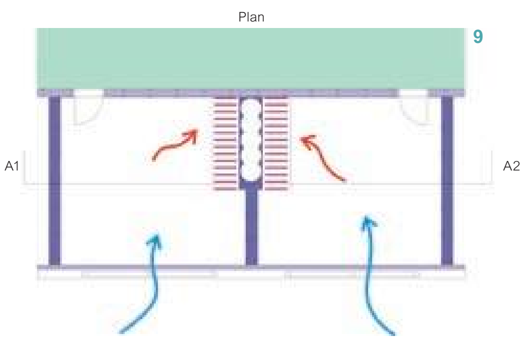

6


7

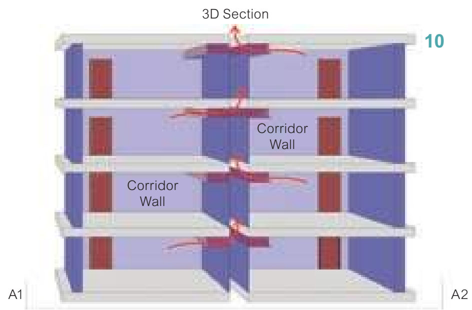

8

**1** NAT Vent Attenuator supplied in bags
**2 & 3** Plywood bulkhead
**4** W-shaped wedges installed into the bulkhead
**5** W-shaped wedges being pushed into the bulkhead
**6** NAT Vent Attenuator fully installed
**7** Letter shaped timber louvre - classroom side
**8** Vent finished within a slotted timber louvre, corridor side

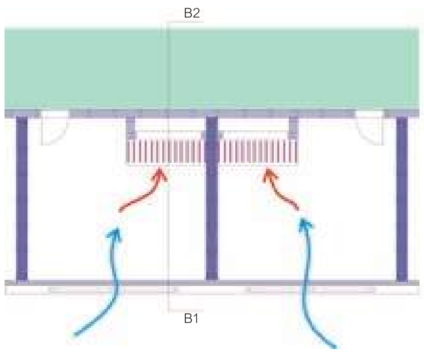
# Cross Vent Using Single Ventilation Stack



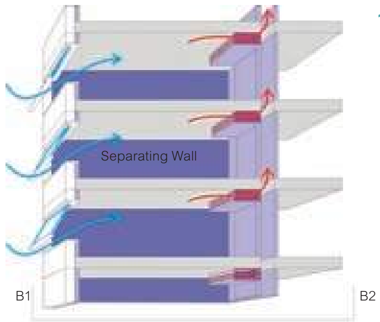

9



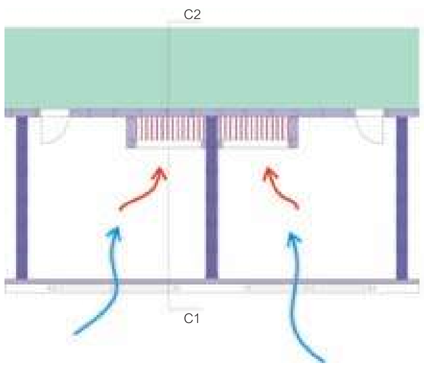

10



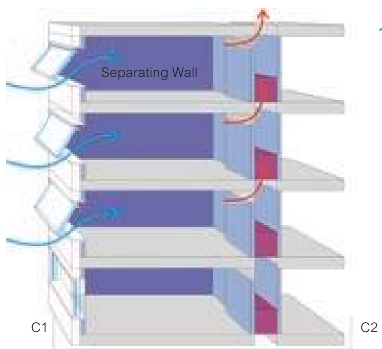

11




12




13




14

Ventilation chimneys provide an alternative to venting through corridor walls. When ventilating vertically stacked spaces, it is common to use multiple chimneys, one per floor, so as not to acoustically link vertically stacked spaces. This arrangement is disadvantaged by the floor area taken up by the ventilation stacks. Illustrations **9** to **14** overcome this issue by combining multiple vent stacks into one by means of using NAT Vent attenuator.

### Vent Stacks within Separating Walls

The ventilation chimney is located within the separating wall between two cellular spaces **9**. Cross talk attenuators are required within each cellular space. The 3D section of the building **10**, shows the NAT Vent located in a bulkhead within each cellular space. In this instance, the approximate length of the attenuator is in the order of 1200mm.

### NAT Vent Attenuator in Bulkhead

This is a relatively conventional approach where air and sound passes through cross talk attenuators prior to entering the ventilation stack **11**. The attenuators are located within a bulkhead. The NAT Vent Attenuator depth in this instance will be in the order of 600mm.

### NAT Vent Attenuator inside the Ventilation Stack

This is a similar approach to above, although the cross talk attenuator in this instance is located within the Ventilation stack itself **14**, resulting in a deeper shaft but no bulkhead.

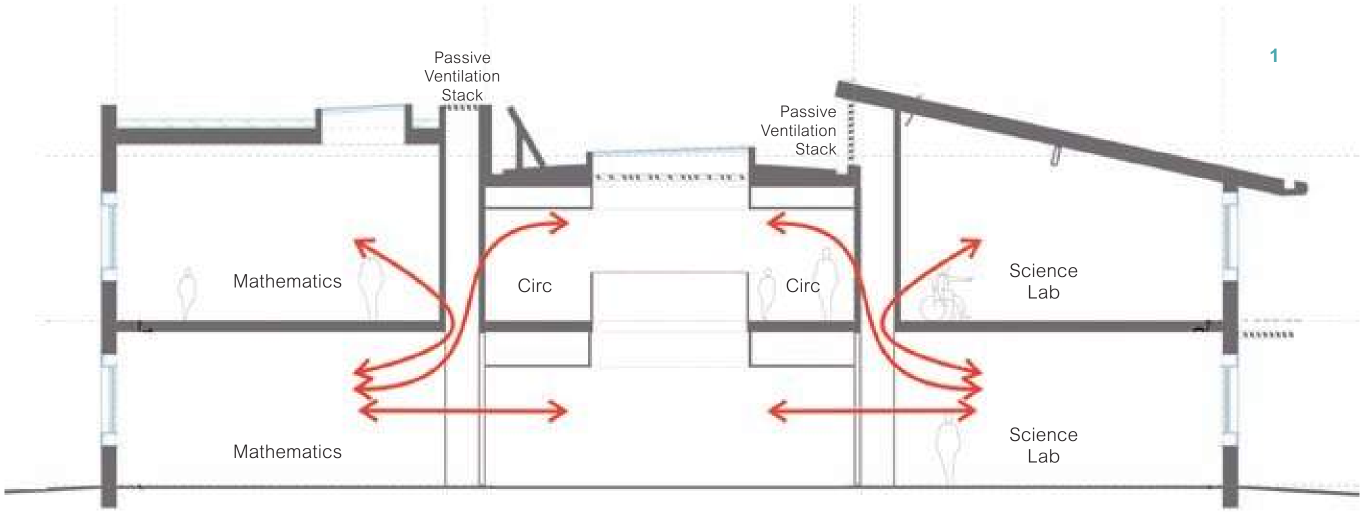
# Details Required When Using Chimneys

When using ventilation chimneys, considerable care is required with respect to detailing. Illustration **1** shows how, if not properly detailed, the use of ventilation chimneys can seriously compromise the sound insulation between multiple spaces.

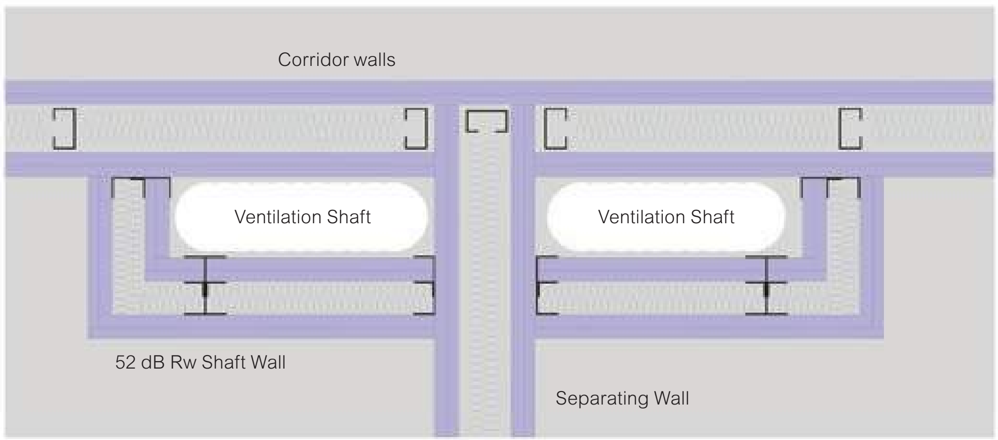
When using chimneys it is also important to consider build-ability. Simple stud walls cannot be used, since it is not possible to build the inner skin of the shaft. The walls to the shaft must contain two leafs such to maintain the sound insulation across the shaft. The solution is to use a Shaft Wall system with an acoustic rating of 50 dB $R_w$+ or to form the shaft using dense 140mm block work. Note that a 50 dB $R_w$ wall may not be appropriate in all instances.

The positioning of the ventilation shaft is also important; care must be taken not to breach the acoustic performance of separating walls and floors. Illustration **2** provides the recommended detail; here the separating wall and corridor wall are built first. It can also be seen that each shaft is formed from two separate penetrations within the floor slab. Once the corridor wall and separating walls are built, the walls forming the shaft can be built. This detail should ensure the horizontal and vertical sound insulation between cellular spaces.

1




2



# 4 : Sound Insulation

# Subjective Evaluation and Conversion between $R_w$ and $D_w$

## Sound Insulation

Sound insulation describes the reduction in sound across a partition. The sound insulation across a good conventional, lightweight, office to office construction is typically in the order of 45 dB $D_w$. This means that if the sound level in the source room is around 65 dB, (a typical level for speech) the sound level in the adjacent room, the receiver room, will be approximately 20 dB (barely audible). If sound levels are increased in the source room to 75 dB (raised voice), sound levels within the adjacent room will also increase to around 30 dB (audible). Sound insulation therefore describes the level of sound lost across a partition and not the level of sound within a adjacent room.

## Privacy

Privacy describes the perceived sound reduction across a wall. Privacy is a function of both sound insulation and background noise. Background noise is made up of services noise and environmental noise sources breaking in through the facade or open windows, vents etc.

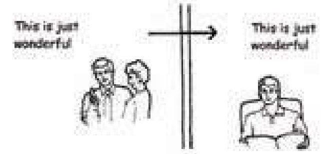
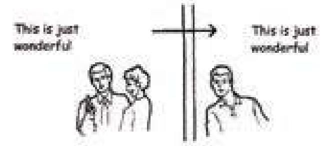
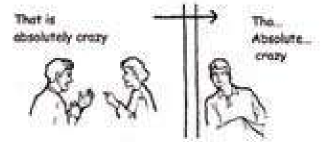
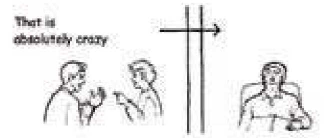
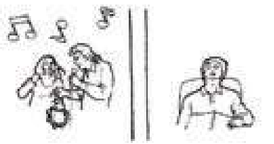
If the background noise within a room is increased by 5 to 10 dB, the perceived level of privacy across a partition is also increased by 5 to 10 dB. Therefore, when looking at required sound insulation levels on-site, it is important to consider both the background noise in the receiver room and the sound insulation across the partition.

## Subjective Description of Sound Insulation

The table to the right provides an illustrative representation of privacy. This table specifies two $D_w$ levels for a partition, Column **1**. Two levels are provided in this column, one for background noise levels in the receiver room of 35 dBA [1], and the second for background noise levels of 40 dBA [2]. Please see the text above for an explanation.

## $R_w$ (Lab Tested Sound Reduction Index) and $D_w$ (On SIte Sound Reduction Index)

Two parameters are used to describe the sound insulation of a partition, $D_w$ and $R_w$. $D_w$ represents the sound insulation between rooms on-site. Since these figures describe the final site requirements, $D_w$ levels are specified by clients and Building Regulations. $R_w$ represents the lab tested sound insulation of an element making up a partition wall/floor type. Due to flanking and other factors, lab rated sound reduction levels will not be achieved on-site. Conventionally, there is a 5 to 10 dB reduction between a $R_w$ lab tested figure and an on-site $D_w$ figure. The conversion between $D_w$ and $R_w$ is relatively complex and takes into consideration receiver room volume, receiver room reverberation times and the area of the separating partition. The conversion between Rw and Dw should always be calculated.

| Dw | Subjective Description | |
|---|---|---|
| 30dB[1]<br>25dB[2] |   | Most sentences clearly understood |
| 40dB[1]<br>35dB[2] |   | Speech can be heard with some effort. Individual words and occasional phrases heard |
| 50dB[1]<br>45dB[2] |   | Loud speech can be heard with some effort. Music easily heard |
| 60dB[1]<br>55dB[2] |   | Loud speech essentially inaudible. Music heard faintly; base note disturbing |
| 70dB[1]<br>65dB[2] |  | Loud music heard faintly, which could be a problem if the adjoining space is highly sensitive to sound intrusion, such as a recording studio, concert hall, etc |
| 75dB[1]<br>70dB[2]<br>and above |  | Most noises effectively blocked |

# Sustainability and Sound Insulation

## Introduction

Sound insulation is not a subject often considered an influential factor during the design stage of green and sustainable buildings. Sound insulation can significantly impact upon the levels of embodied energy in a given building. It is therefore important to have a clear understanding of how sound insulation can affect the levels of embodied energy.

## Refurbishment

The most effective method of reducing the embodied energy is to re-use an existing building. Demolition and rebuilding is often justified on the grounds of flexibility and acoustics. Our experience across large and complex refurbishment projects shows that most problems can be overcome and resolved in a cost effective manner. The key to refurbishments is in understanding the performance of the existing building fabric by means of early up front acoustic testing. Having established the existing performance and understood the limitations and restrictions of a given building frame, design teams can work their way around these restrictions.

## Lightweight versus Mass

Heavy/high mass buildings are often favoured on the grounds of enhanced acoustics; however timber and other lightweight framed buildings can often offer equal or better performance. The advantage of timber/lightweight framed buildings is the considerable reduction in embodied energy with a sustainable building frame and reduced levels of flanking between spaces.

Comparing the acoustic performance of lightweight stud to block work, it is seen that both of these systems have a similar performance. Block work does have a better low frequency performance but this is easily overcome hence low frequencies are rarely problematic. Timber studs tend to offer lower levels of sound insulation than metal studs, as timber studs are less flexible. This limitation can be overcome by means of using a resilient bar within the partition make up. For comparison, the acoustic performance of walls and floor types are covered over the next two pages.

## Mineral Wool within Partitions

Acoustic dampening within stud walls is a cost effective and sustainable method of enhancing the performance of a partition. Mineral wool is conventionally used within partitions. This is a quarried product and one which requires considerable heat to turn rock into wool. Damping within partitions can be achieved by most forms of lightweight fibrous or fluffy materials. This means that a wide range of recycled / sustainable materials can be used: NaturePro – fine wood fibre, Non-itch insulation - recycled plastic bottles, Jean fibre - recycled jeans, Thermo fleece - sheeps wool, hemp, Warmcell - recycled newspapers, etc.

## Performance

As a theoretical rule of thumb, a ±6 dB change in sound insulation equates to a halving or doubling of mass of a given construction. Over specifying acoustic parameters can therefore have a significant impact upon waste.

It is often the case that performance standards are copied from one project to another, particularly in the case of office developments. Performance standards are repeatedly misunderstood and hence over specification occurs. Planning conditions are another type of performance requirement that are rarely challenged, which again can lead to over specification. All of these factors result in waste and unnecessary levels of raw materials being used. When designing green buildings it is fundamental to ensure that the correct and most suitable performance requirements are used.

It is important to note that small reductions in acoustic performance levels are often not perceived. A small variation or reduction in performance levels can however considerably reduce the required levels of acoustic treatment, remembering the 6dB rule. It is therefore sometimes worth considering downgrading the performance levels of the floors and walls on the grounds of sustainability.

An important rule is that a partition should only exceed the performance of the weakest link by no more than 10 dB. As an example, it is unnecessary to have a partition rated above 40 dB $R_w$ if it contains a 30 dB $R_w$ door.

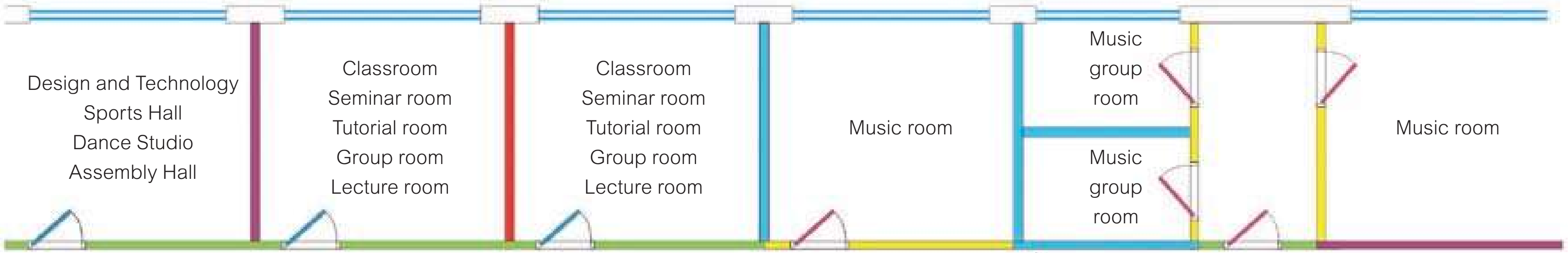
By having tight, accurate performance requirements, waste can be considerably reduced. Hence, it is always worth consulting with an acoustic engineer when considering performance specification.

## Specification Design Tolerances & Early Testing

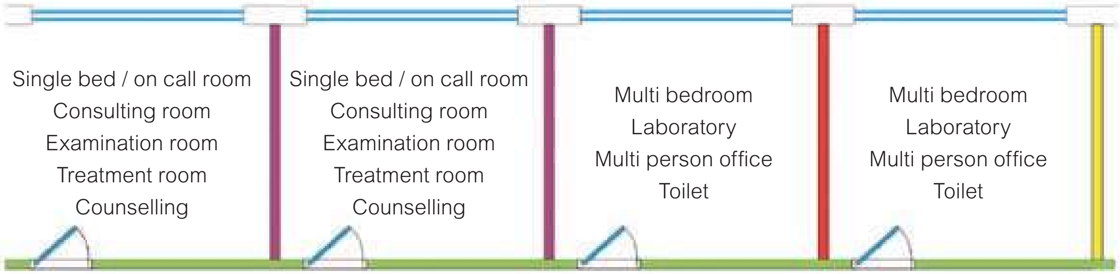
When designing a building, an acoustic consultant will conventionally use significant design tolerances, often to account for workmanship. One way to reduce the effects of these tolerances is to carry out a programme of early acoustic testing. This is a very good method of ensuring that designs are sufficient, that the construction quality is high and, providing enough time is given to make the required changes on site,, significant cost savings can be made. This method therefore ensures that performance requirements are met, with the benefit of accurate designs, less waste, less embodied energy and less cost to the client.

# Performance Specifications

## BB93 - Schools

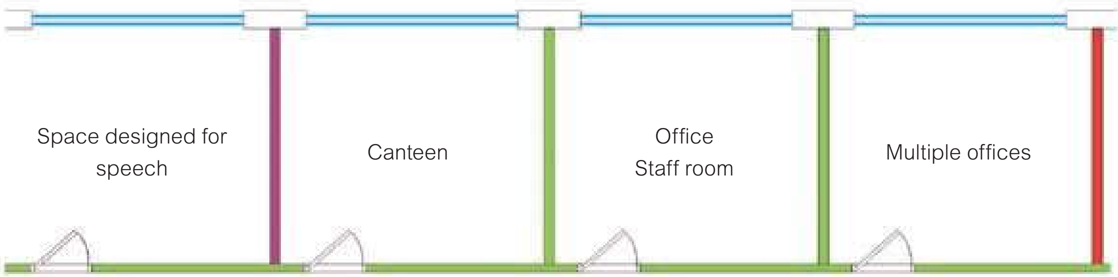



## HTM 08 - 01 Health Care





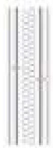
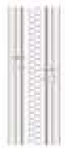
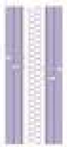
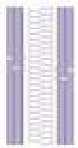
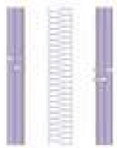
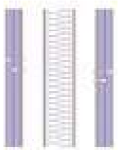
## BREEAM Offices

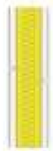
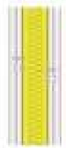
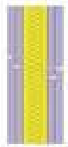
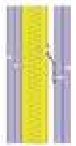
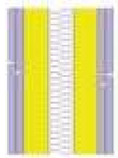


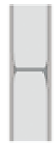
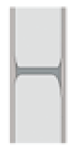
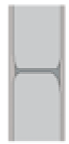
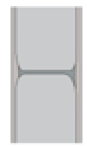
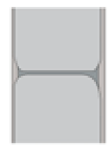

This illustration presents the typical performance standards for partitions to meet BB93, HTM and BREEAM office requirements for a range of cellular spaces.

The provided performance targets are given in terms of the $R_w$ levels to achieve appropriate $D_w$. Assumptions relating to room sizes, floor to ceiling height, room acoustic finishes and other factors have been made during the conversion between $R_w$ and $D_w$ levels specified BB93, HTM and BREEAM. These assumptions do not apply to all developments; hence this information should be used as guidance only. Please consult with an acoustic consultant for accurate levels.

# Acoustic Performance – Light Weight and Heavy Weight Walls

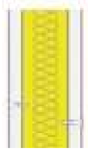
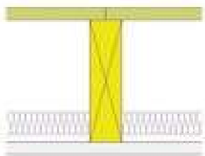
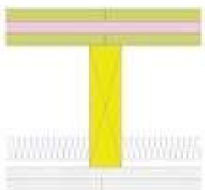
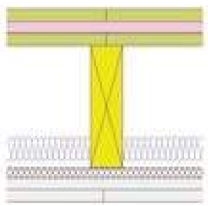
| $R_w$ | Illustration | Description (Metal Stud) |
|---|---|---|
| 42 dB |  | One 12.5mm WallBoard, a 48mm 'C' stud at 600mm centres, 25mm Isowool Width - 73mm |
| 51 dB |  | Two 12.5mm WallBoard, a 48mm 'C' stud at 600mm centres, 25mm Isowool Width - 98mm |
| 56 dB |  | Two 15mm SoundBloc, a 48mm 'C' stud at 600mm centres, 25mm Isowool Width - 108mm |
| 58 dB |  | Two 15mm SoundBloc, a 70mm 'C' stud at 600mm centres, 50mm Isowool Width - 130mm |
| 60 dB |  | Two 15mm SoundBloc, a 146mm 'C' studs at 600mm centres. 50mm Isowool Width - 206mm |
| 65 dB |  | Two 15mm SoundBloc, twin stud, void 155mm, Studs at 600mm centres. 50mm Isowool Width - 215mm |

| $R_w$ | Illustration | Description (Timbers Stud) |
|---|---|---|
| 39 dB |  | One 12.5mm WallBoard, a 50mm timber stud at 600mm centres, 25mm Isowool Width - 75mm |
| 47 dB |  | Two 12.5mm WallBoard, a 50mm timber stud at 600mm centres, 25mm Isowool Width - 100mm |
| 51 dB |  | Two 15mm SoundBloc, a 50mm timber stud at 600mm centres, 25mm Isowool Width - 100mm |
| 58 dB |  | Two 15mm SoundBloc, a 50mm timber stud + res bar, 25mm Isowool Width - 126mm |
| 60 dB |  | Two 15mm SoundBloc, a 120mm timber stud + res bar, 50mm Isowool Width - 196mm |
| 65 dB |  | Two 15mm SoundBloc, twin stud, void 155mm, Studs at 600mm centres. 50mm Isowool Width - 215mm |

| $R_w$ | Illustration of construction | Description (Block wall) |
|---|---|---|
| Fair faced: 39 dB Plastered: 45 dB |  | Width: 75mm Density: 1475 Kg/m³ |
| Fair faced: 46 dB Plastered: 48dB |  | Width: 100mm Density: 1475 Kg/m³ |
| Fair faced: 37 dB Plastered: 52dB |  | Width: 100mm Density: 2000 Kg/m³ |
| Fair faced: 47 dB Plastered: 56dB |  | Width: 140mm Density: 2000 Kg/m³ |
| Fair faced: 56 dB Plastered: 57dB |  | Width: 200mm Density: 2000 Kg/m³ |
| Fair faced: 57 dB Plastered: 58dB |  | Width: 215mm Density: 2000 Kg/m³ |

**Indicative Sound Insulation Levels - Based on INSUL Composite Sound Insulation Calculations**

# Acoustic Performance– Light Weight and Heavy Weight Floor

| $R_w$ | Timber Floor | Description |
|---|---|---|
| 39 dB |  | 18mm T&G board,<br>250mm Joist,<br>12.5mm Wall Board,<br>50mm Iso Wool<br>Thickness: 280mm |
| 42 dB |  | 18mm T&G board,<br>250mm Joist, 2*12.5mm Wall Board,<br>50mm Iso Wool<br>Thickness: 293mm |
| 49 dB |  | 2*18mm T&G board,<br>19mm plan,<br>250mm Joist,<br>2*12.5mm Wall Board,<br>50mm Iso Wool<br>Thickness: 330mm |
| 62 dB |  | 2*18mm T&G board,<br>19mm plan,<br>250mm Joist,<br>Res Bar,<br>2*12.5mm Wall Board,<br>50mm Iso Wool<br>Thickness: 346mm |

| $R_w$ | Light weight Concrete Floor | Description |
|---|---|---|
| 44 dB |  | Density: 1400 Kg/m$^3$<br>Mass: 140 Kg/m$^2$<br>Thickness: 100mm |
| 54 dB |  | Slab as above<br>50mm void,<br>25mm mineral wool,<br>one 12.5 Wall Boad on MF system<br>Thickness: 162.5mm |
| 59 dB |  | Slab as above<br>50mm void,<br>25mm mineral wool,<br>two 12.5 Wall Boad on MF system<br>Thickness: 150mm |
| 63 dB |  | Slab as above<br>100mm void,<br>25mm mineral wool,<br>two 12.5 SoundBloc on MF system<br>Thickness: 150mm |

| $R_w$ | High Mass Floor | Description |
|---|---|---|
| 49 dB |  | Density: 2200 Kg/m$^3$<br>Mass: 220 Kg/m$^2$<br>Thickness: 100mm |
| 55 dB |  | Density: 2200 Kg/m$^3$<br>Mass: 330 Kg/m$^2$<br>Thickness: 150mm |
| 59 dB |  | Density: 2200 Kg/m$^3$<br>Mass: 440 Kg/m$^2$<br>Thickness: 200mm |
| 63 dB |  | Density: 2200 Kg/m$^3$<br>Mass: 550 Kg/m$^2$<br>Thickness: 250mm |

**Indicative Sound Insulation Levels - Based on INSUL Composite Sound Insulation Calculations**

## Sound Insulation Details & Services Penetrations

One of the key factors affecting the acoustic performance of separating elements is the acoustic performance of details, flanking elements and services penetrations. It is vital that these elements are addressed carefully.

**Flanking and Junctions** – Flanking is an important point to consider during the design stages. For high performance buildings, an acoustic consultant should be appointed. Pages 40-43 provides a range of details.

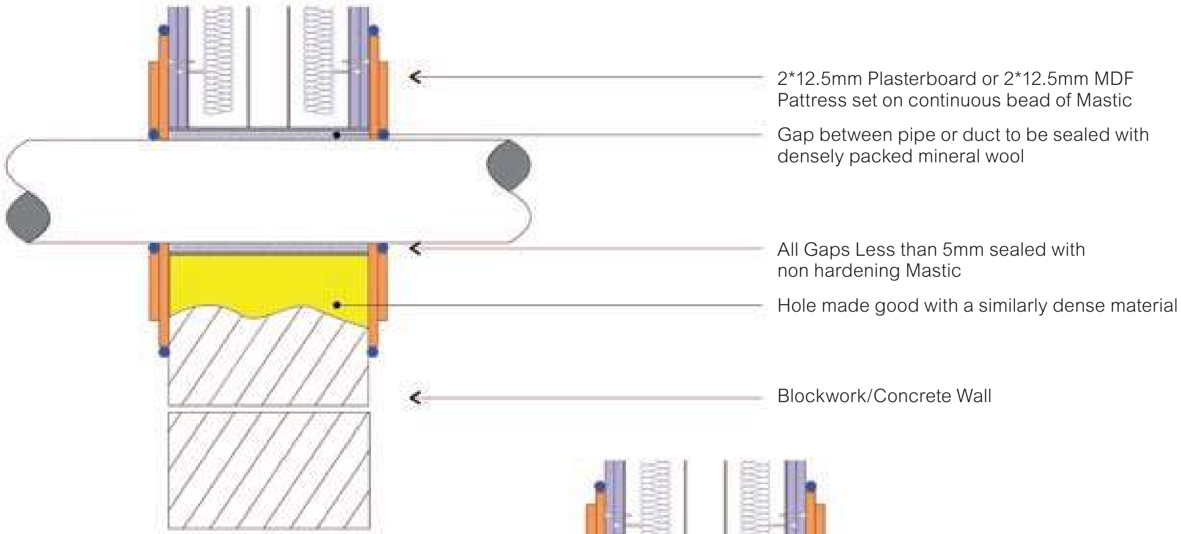
**Sealing junctions** - As a rule of thumb, all junctions and joints should be sealed with non-hardening mastic. Any holes smaller than 5mm can be sealed with mastic. Large holes should be sealed with plasterboard or mortar as appropriate.

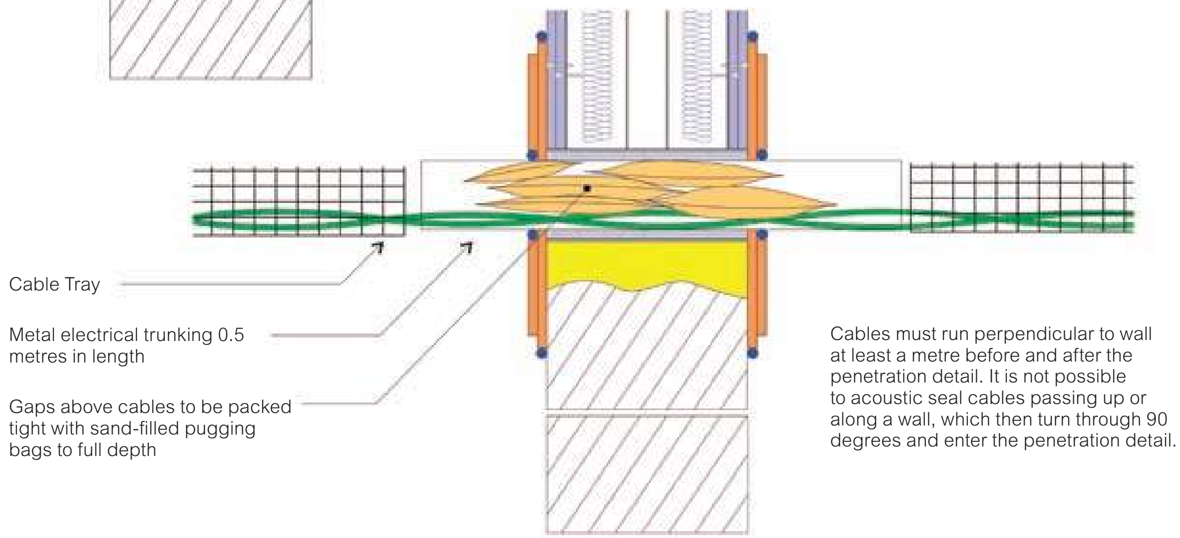
**Resilient bars** are a useful method of boosting the performance of stud walls. Care must be taken to ensure that the flexibility of the resilient bar is not breached; by long screens for example. See pages 41 & 43.

**Services** are one of the major reasons for short falls in sound insulation and this is usually due to the poor layout of services during the design stages. It is vital to consider service runs, location of crosstalk attenuators and penetration details. See pages 42 and 43.

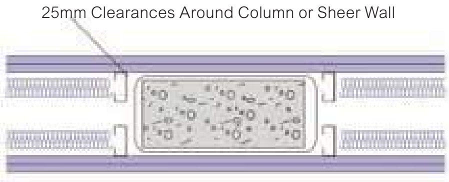
**Structures** are often overlooked during the design stage. If not considered, details around partitions can become difficult to make good.

**Site Construction Details** - Having worked across many sites, there are many common faults which have been observed. Most issues relate to services, see pages 42 and 43.

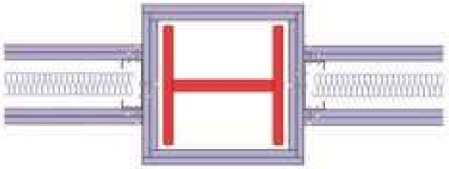


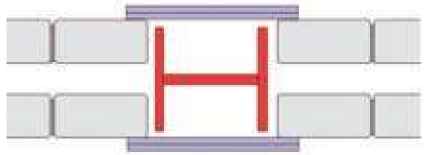
# Sound Insulation Details - Junction and Penetrations



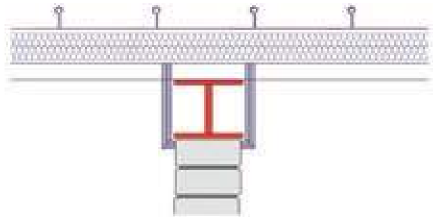

When enclosing a concrete column, the plasterboard should not be conventionally connected to the column.



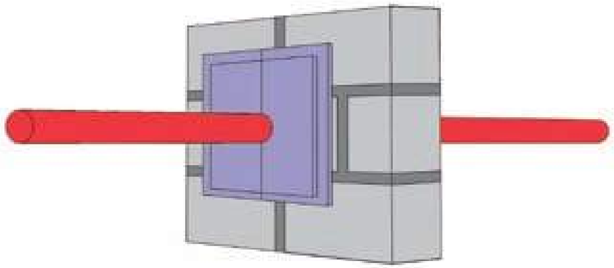
The boxing around steels should equal that of the partition type.



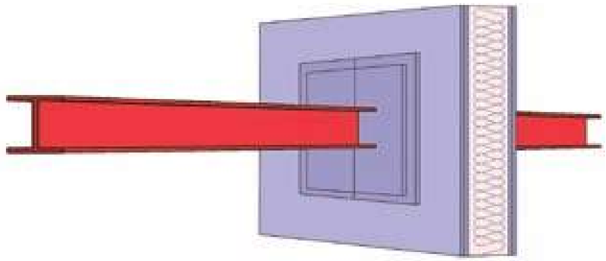
Steels should not make contact with cavity walls in any way.



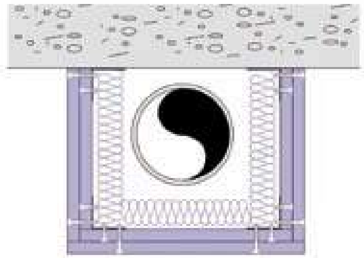
Steels above block walls are always advised to be enclosed with plasterboard.



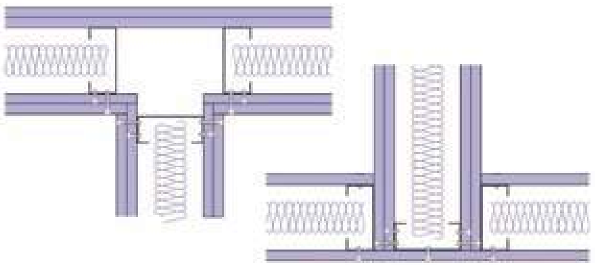
Steels passing through a separating block wall should be sealed with two layers of plasterboard and all joints sealed with mastic.



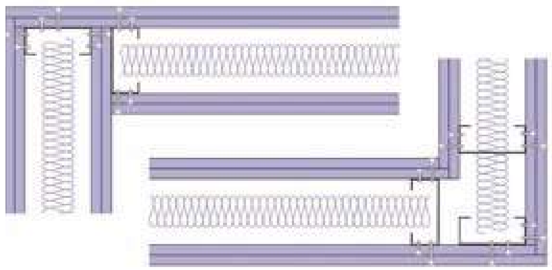
Steels passing through a separating stud wall, should be sealed with two layers of plasterboard and all joints sealed with mastic.



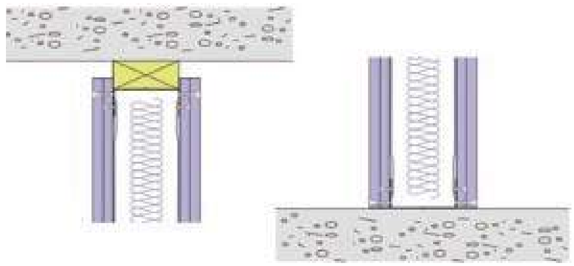
All waste pipes within sensitive rooms are recommended to be enclosed with two layers of plasterboard.



Two equally performing T-junctions. For corridor walls formed using 1 layer of plasterboard, the right hand detail must be used.

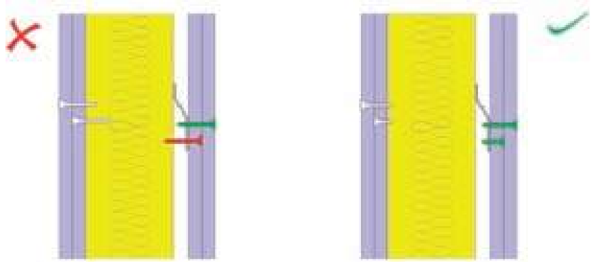


Two equally performing details. The selection of this detail is down to build-ability.

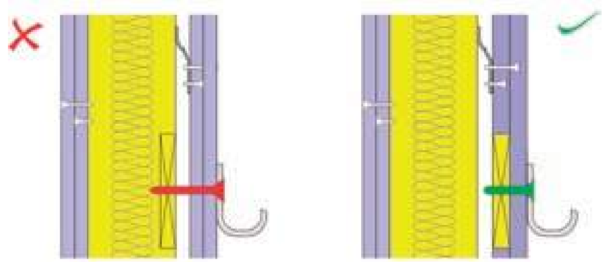


Base and head deflection details, note that all joints and junctions are required to be sealed with mastic.

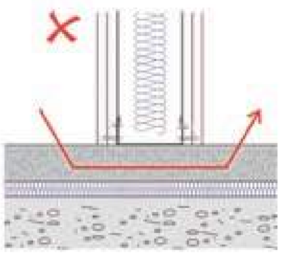
## Sound Insulation Details - Resilient Bars and Flanking



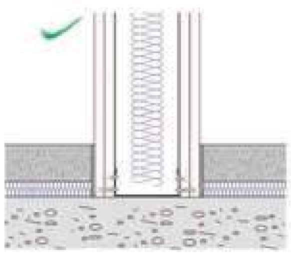
Left side - screws to long, as such the resilient bar is seriously compromised. This is likely to down grade the partition by 5 to 10 dB.



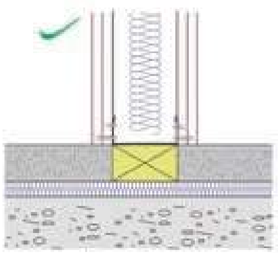
Left side - Resilient bar is seriously compromised by a fixing detail. This is likely to down grade the partition by 3 to 7 dB.



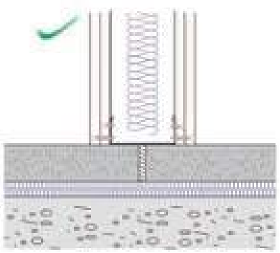
Flanking through a floating screed breaching the sound insulation of the wall



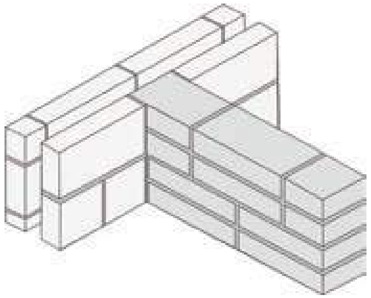
Flanking through a floating screed prevented by building the partition off the floor slab.



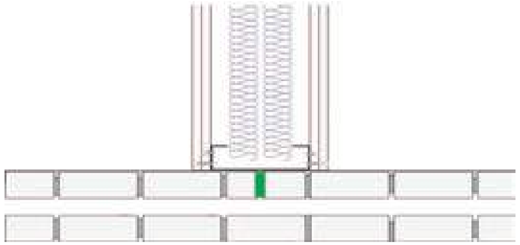
Flanking through a floating screed prevented by timber sole plate.



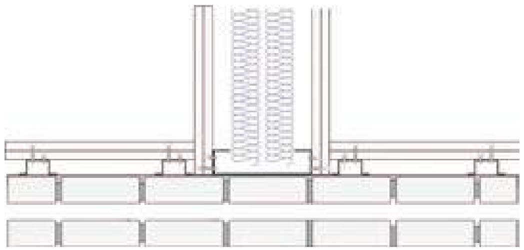
Flanking through a floating screed prevented by saw cut in screed.



Separating wall must be built into the inner skin of the facades

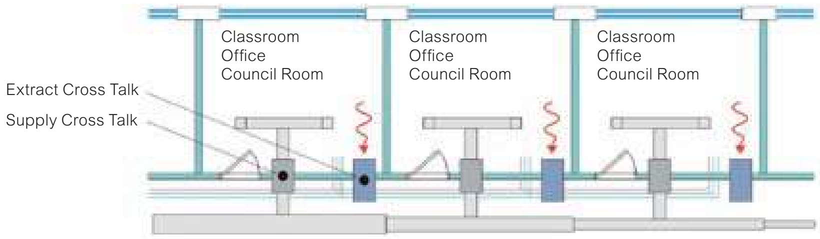


Stud work separating walls - block work inner skin of facade. Resilient gap or expansion joint required to prevent flanking.

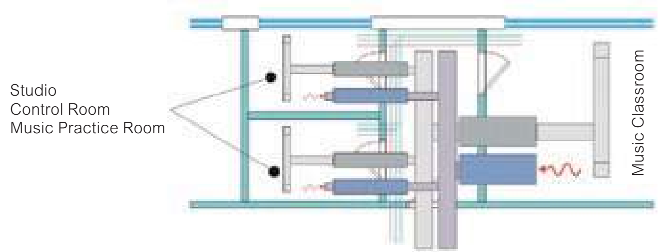


Alternative detail, where flanking is prevented by an independent wall lining.

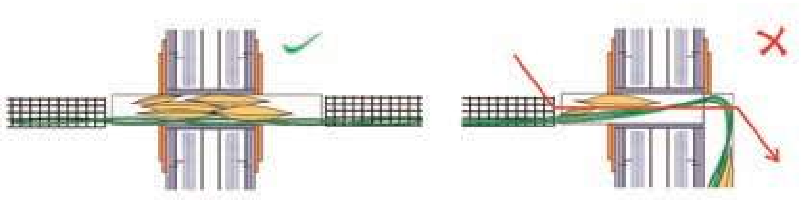
# Sound Insulation Details - Services and Structure



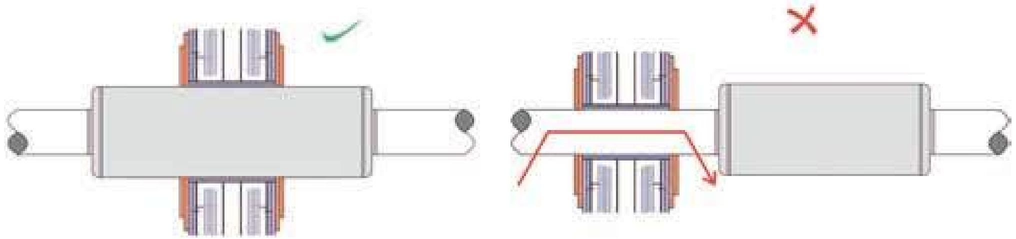

Electrical services should always run down the circulation zones and enter sensitive spaces though the corridor wall. This prevents penetration within high performance walls.




This detail provides a preferred method of servicing high performance spaces such as music rooms.



When sealing electrical cables, the cables must run perpendicular to walls at least half a metre before and after the wall penetration



Cross talk attenuators are required to straddle partitions as shown in the left hand image. There is a risk of sound entering the duct-work and beaching the performance of the partition in the right hand image.

Badly thought out services runs are a main reason for failures on site. The above detail is too congested to enable the correct level of acoustic sealing to take place.

Steels and other building structures are often overlooked during the design stages. The bracing point above could have been moved by 300mm, making the above detail easier to seal.

## Sound Insulation Details - Poor Site Details

Electrical trunking not packed with sand bags, large gaps around the penetration point, no patressing

Cable tray passing through separating walls. This is impossible to acoustically seal.

Pipe work hidden by raised floor, no patressing or sealing of any sort. Fails to meet acoustic requirements.

No patressing around cross talk attenuator, the cross talk should also straddle the partition, rather than installed on one side only.

Back to back electrical sockets breaching the performance of the separating wall.

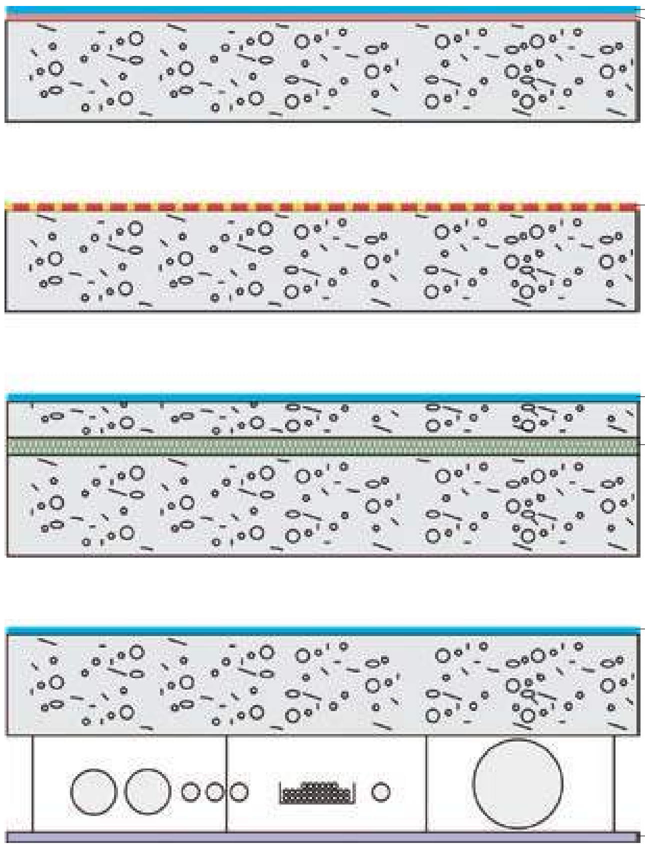
Acoustic putty poorly installed, still a large gap around the electrical socket.

The sealing between different constructions needs to be considered carefully. Image of junction between mullion and floor slab.

Gaps principally at the head and facade of partition interface. A major reason for on site shortfalls in sound insulation levels.

Incorrect screw size breaching the flexibility of the resilient bar and hence compromising the performance of this partition.

# Impact Isolation




Impact isolation is the prevention of foot-fall noise, chair scrapes and the transmission of other noise sources as a result of direct impact into the building structure.

It is more often the case that the mass of the building (even concrete framed buildings) does not provide adequate acoustic protection to mitigate against impact noise. The solution is to add a resilient layer within the floor make up. The resilient layer in most instances can be carpet or acoustic lino (depending on performance requirements). Alternatively, a polyurethane or isolation sheet is located under a floor finish or screed. With this method of isolation, it is important to ensure that the floating layer or screed does not make contact at any point with the building structure. It is therefore essential to install the correct edge detail and follow all other requirements specified by the resilient layer manufacturer.

# 5 : Room Acoustics and Reverberation

# Introduction

Room acoustics/reverberation affects the way a space sounds. A high reverberation time can make a room sound loud and noisy. Speech intelligibility is also a function of reverberation, a high reverberation time causes speech to sound muffled and muddy. Rooms designed for speech therefore typically have a low reverberation time: ≤1 second.

A high reverberation time can enhance a music hall by adding richness, depth and warmth to music. A higher level of reverberation within a concert hall is therefore critical. Illustration **2** provides indicative reverberation times for a range of building types and room volumes.

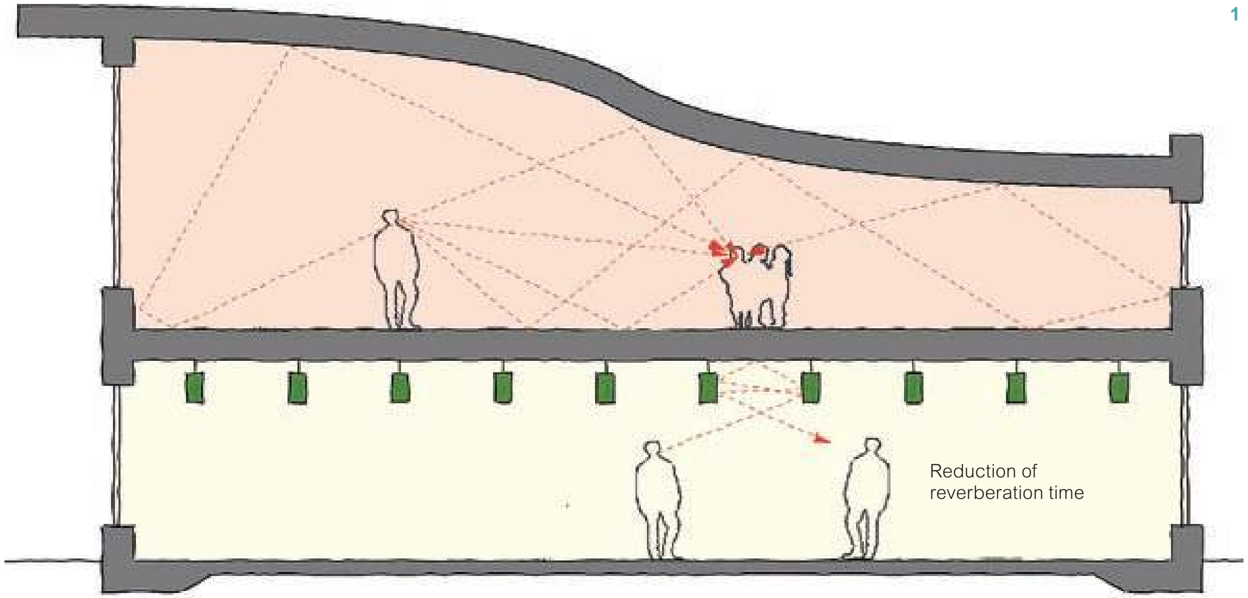
The reverberation time of a room is defined as the time it takes for sound to decay by 60 dB after an abrupt termination. The reverberation time of a room is linked to the total quantity of soft treatments and the volume of the room by the Sabine equation;

$$RT = \frac{\text{Volume} \times 0.161}{\text{Total Acoustic Absorption}}$$

## Acoustic Properties of Materials

To control reverberation time, acoustic absorption is used. Absorbent materials conventionally take two forms; fibrous materials or open celled foam, **3**. Fibrous materials absorb sound, since sound waves force the fibres to bend and this bending of the fibres generates heat. The conversion of acoustic energy into heat energy results in the sound effectively being absorbed. In the case of open celled foam, the air movement resulting from sound waves pushes the air particles through the small narrow passages which in turn generate a viscous loss along with heat.

1




Architecturally, fibrous materials and open celled foams are not particularly attractive or robust. It is therefore common to cover these materials with an acoustically transparent finish such as a tissue, cloth, slatted wood, perforated materials; wood, metal, plasterboard and so on.

The thickness of a given material along with properties such as its fibrousity governs the acoustic performance of a product. Finishes within a space are therefore defined in terms of their absorption coefficient. This is a number between 0.0 (100% reflective) for example stone, tiles, concrete and 1.0 (100% absorbent), products with this rating include high performance acoustic ceiling tiles, slabs of mineral wool, etc.

Products such as carpets typically have an absorption coefficient between 0.1 and 0.3 depending on their thickness. Perforated plasterboard generally provides around 0.6 to 0.7.

It is also common to classify absorbent materials in categories, A to E, where A is highly absorbent and E is almost fully reflective.

**1** first floor: reverberant room without acoustic treatment.
ground floor: less reverberant room with acoustic treatment.

# Performance Standards – BB93, HTM and BREEAM

### Performance Requirements

The function of a space governs its acoustics requirements. Spaces which need to be quiet and where speech intelligibility is important require a low reverberation time.

### BB93 'Acoustics Design for Schools'

Table 1.5 of BB93 provides a comprehensive list of performance requirements for educational spaces. This table is used as a benchmark for many buildings including multi-functional buildings and higher educational facilities.

| Rooms | RT Seconds |
|---|---|
| Classrooms for the hearing impaired | <0.4 |
| Nursery and Primary school classrooms | <0.6 |
| Secondary school classroom | <0.8 |
| Science, Workshops, Art rooms | <0.8 |
| Drama studios, Offices | <1.0 |
| Multi-purpose halls | <1.2 |
| Sports halls | <1.5 |
| Music rooms - See BB93 | |

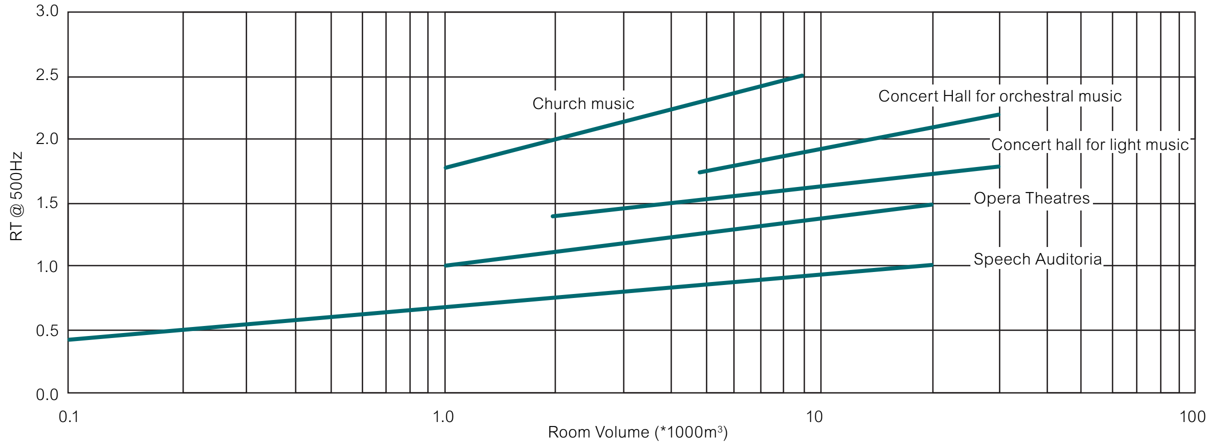
### BREEAM Offices

At this present time BREEAM Offices does not provide performance requirements with respect to room acoustics, therefore the 1 second BB93 requirement for offices is commonly used.

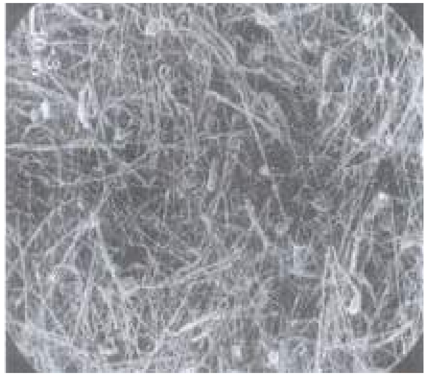
### HTM - Health Technical Memorandum Acoustics

HTM states that 'Sound-absorbent treatment should be provided in all areas (including all corridors), except acoustically unimportant rooms (storerooms etc), where cleaning, infection-control, patient-safety, clinical and maintenance requirements allow.

2

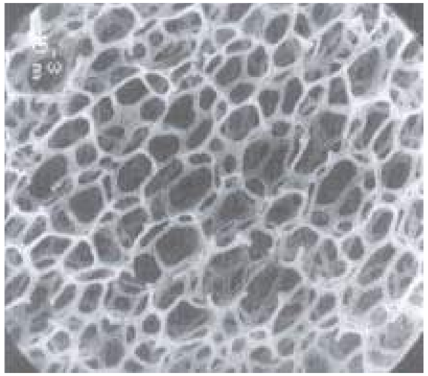



3



Magnified Image of Fibrous Acoustics Absorption

4



Magnified Image of Open Celled Foam, Acoustics

Acoustically-absorbent materials should have a minimum absorption area equivalent to a Class C absorber (as defined in BS EN ISO 11654:1997) covering at least 80% of the area of the floor, in addition to the absorption that may be provided by the building materials normally used. If a Class A or B absorbent material is used, less surface area is needed.

Acoustic absorption is likely to be needed in large open spaces such as atria, particularly in localised areas.

MACH Acoustics advises that an acoustic consultant should be appointed to undertake a detailed assessment if an alternative to ceiling tiles is to be used.

# Estimating Levels of Room Acoustic Treatments

The key to understanding the required level of room acoustic treatments is to study the Sabine equation on page 46. To implement this equation, MACH Acoustics provide an excel spreadsheet **1** which can be acquired by email from ze@machacoustics.com. This spreadsheet can be used to find the required amount of room acoustic treatments.

### Estimating Levels of Room Acoustics Treatments

Such to approximate the required level of soft treatment, four factors need to be considered:

1 Required reverberation time

2 The average ceiling height **2**

3 The floor finish **2**

4 Added acoustic treatment **2** (acoustic ceiling tiles, acoustic ceiling panels, acoustic wall panels...)

The tables on the far page present the amount of total absorption required **3** to **5** as a percentage of the floor area, to control the reverberation time based on the four factors above.

The three different tables are provided for hard floor finishes, industrial carpet and an industrial carpet placed on an industrial underlay.

1

**Reverberation Time Calculation**

**Music Drama**

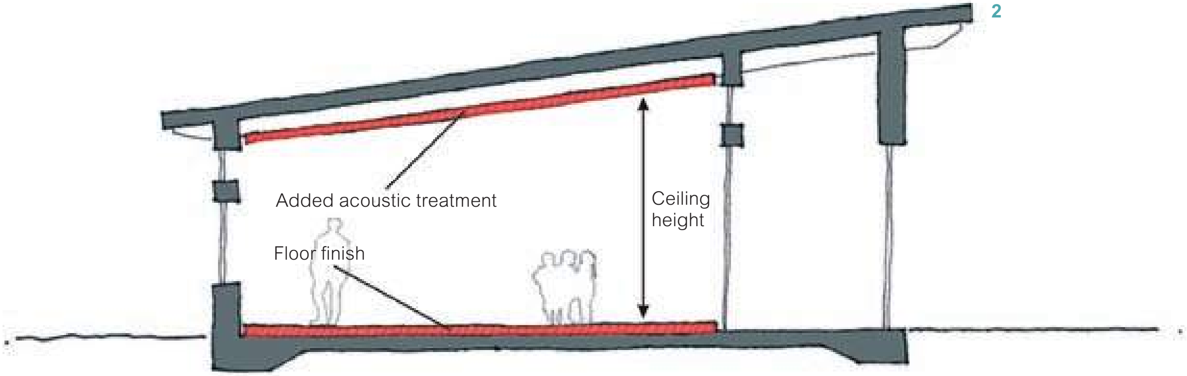
Tmf= 0.80

L 8, W 7.5, H 3.2 — Volume 192 m³

| Reverberation Time: | 125Hz | 250Hz | 500Hz | 1KHz | 2KHz | 4KHz |
|---|---|---|---|---|---|---|
| | 0.71 | 0.65 | 0.67 | 0.82 | 0.91 | 0.94 |

| | | | | | Noise Absorption Coeficient | | | | | | Reverberation Values | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Surface | Materials | W | L/H | surface area | 125Hz | 250Hz | 500Hz | 1KHz | 2KHz | 4KHz | 125Hz | 250Hz | 500Hz | 1KHz | 2KHz | 4KHz |
| ceiling treatment | quattro 41 | | | 25 m² | 0.50 | 0.70 | 0.80 | 0.70 | 0.60 | 0.55 | 12.7 | 17.8 | 20.3 | 17.8 | 15.2 | 14.0 |
| ceiling | Plaster board | 8 | 7.5 | 35 m² | 0.20 | 0.15 | 0.10 | 0.05 | 0.04 | 0.05 | 6.9 | 5.2 | 3.5 | 1.7 | 1.4 | 1.7 |
| vent opening | total abs. | 7 | 0.3 | 2 m² | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 |
| external wall | Plaster board | 8 | 3.2 | 10 m² | 0.20 | 0.15 | 0.10 | 0.05 | 0.04 | 0.05 | 1.9 | 1.4 | 1.0 | 0.5 | 0.4 | 0.5 |
| windows | Glass | 8 | 2 | 16 m² | 0.05 | 0.03 | 0.02 | 0.02 | 0.03 | 0.02 | 0.8 | 0.5 | 0.3 | 0.3 | 0.5 | 0.3 |
| internal walls | Plaster board | 23 | 3.2 | 74 m² | 0.20 | 0.15 | 0.10 | 0.05 | 0.04 | 0.05 | 14.7 | 11.0 | 7.4 | 3.7 | 2.9 | 3.7 |
| floor | Linoleum | 8 | 7.5 | 60 m² | 0.02 | 0.03 | 0.03 | 0.03 | 0.03 | 0.02 | 1.2 | 1.8 | 1.8 | 1.8 | 1.8 | 1.2 |
| doors | Door | 0.9 | 2 | 2 m² | 0.10 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| additional abs | Ecophon Master C alpha direct fix | | | 10 m² | 0.20 | 0.72 | 0.95 | 0.95 | 0.90 | 0.90 | 1.9 | 6.8 | 9.0 | 9.0 | 8.6 | 8.6 |
| | - | | | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | | | | | | | | | | Total Surfaces | 42 | 47 | 45 | 37 | 33 | 32 |
| Air | | | | 192 m³ | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.576 | 0.576 | 0.576 | 0.576 | 0.576 | 0.576 |
| Objects | Quantity | | | | 125Hz | 250Hz | 500Hz | 1KHz | 2KHz | 4KHz | 125Hz | 250Hz | 500Hz | 1KHz | 2KHz | 4KHz |
| - | 0 | | | | - | - | - | - | - | - | - | - | - | - | - | - |
| - | 0 | | | | - | - | - | - | - | - | - | - | - | - | - | - |
| - | 0 | | | | - | - | - | - | - | - | - | - | - | - | - | - |
| - | 0 | | | | - | - | - | - | - | - | - | - | - | - | - | - |
| - | 0 | | | | - | - | - | - | - | - | - | - | - | - | - | - |
| - | 0 | | | | - | - | - | - | - | - | - | - | - | - | - | - |
| - | 0 | | | | - | - | - | - | - | - | - | - | - | - | - | - |
| - | 0 | | | | - | - | - | - | - | - | - | - | - | - | - | - |
| | | | | | | | | | | Total Object | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | | | | | | | | | Total | 43 | 47 | 46 | 38 | 34 | 33 |

2



### Example 1 - Carpeted Office, Ceiling Height of 2.8m and Required RT of 1 Second

From **4** the required levels of surface treatment are found by multiplying the floor area with the required percentage, for example

28% * 60m² = 0.28 * 60 = 16.8m

16.8m² metric Sabines of 100% acoustic absorption is therefore required within this 60m² space. However, real absorption is rarely so efficient.

### Correction for Material Selection

The acoustic absorption of finishes is between 0 and 100% absorption, therefore a scaling factor is also needed for a given finish. As noted, materials are often rated between A and E, the scaled factors for these materials is therefore given below.
A = 1.25 * surface area of finish - see pages 50-51
B = 1.42 * surface area of finish - see pages 52-53
C = 2.00 * surface area of finish - see pages 54-55

### Example 1 - Continued

Perforated plasterboard with a Class C rating is proposed for the soffit finish. As such 33.6m² of perforated plasterboard is required to achieve a reverberation time of 1 second.

### More than One Finish

If more than one finish type is being proposed please see BB93, example Option C.

**Lino Flooring** 3

| Reverberation time | 1.5 | 1.25 | 1 | 0.8 | 0.6 | 0.4 |
|---|---|---|---|---|---|---|
| Floor to ceiling 2.4m | 26% | 31% | 39% | 48% | 64% | 97% |
| Floor to ceiling 2.8m | 30% | 36% | 45% | 56% | 75% | - |
| Floor to ceiling 3.2m | 34% | 41% | 52% | 64% | 86% | - |
| Floor to ceiling 3.6m | 39% | 46% | 58% | 72% | 97% | - |
| 6 m | 64% | 77% | 97% | - | - | - |

**Carpet Tiles or Industrial Carpet with no backing (coef 0.17)** 4

| Reverberation time | 1.5 | 1.25 | 1 | 0.8 | 0.6 | 0.4 |
|---|---|---|---|---|---|---|
| Floor to ceiling 2.4m | 9% | 14% | 22% | 31% | 47% | 80% |
| Floor to ceiling 2.8m | 13% | 19% | 28% | 39% | 58% | 96% |
| Floor to ceiling 3.2m | 17% | 24% | 35% | 47% | 69% | - |
| Floor to ceiling 3.6m | 22% | 29% | 41% | 55% | 80% | - |
| 6 m | 47% | 60% | 80% | - | - | - |

**Basic underlay and carpet (coef 0.3)** 5

| Reverberation time | 1.5 | 1.25 | 1 | 0.8 | 0.6 | 0.4 |
|---|---|---|---|---|---|---|
| Floor to ceiling 2.4m | 0% | 0% | 9% | 18% | 34% | 67% |
| Floor to ceiling 2.8m | 0% | 6% | 15% | 26% | 45% | 83% |
| Floor to ceiling 3.2m | 4% | 11% | 22% | 34% | 56% | 100% |
| Floor to ceiling 3.6m | 9% | 16% | 28% | 42% | 67% | - |
| 6 m | 34% | 47% | 67% | 91% | - | - |

### Example 2 BB93 Primary School Classroom

60m² Classroom with a floor to ceiling height of 3.2m.
BB93's reverberation time target is 0.6s
The floor is carpeted; hence 69% of the floor area is required to be treated.
0.69 * 60 = 41.4m of Treatment is required

**Option A** - Class A ceiling tiles are proposed to be used, therefore 51.75m² of treatment is needed. This figure is less that the floor area; hence a plasterboard border could be used.

**Option B** - Class B suspended rafts are proposed, the required area of the rafts is therefore 58.8m².

**Option C** - Class B suspend rafts, in combination with 10m² of Class A wall panels (10/1.25=8, 41.4-8=33, 33*1.42=46.9), therefore 46.9 m² of suspend rafts are required.

**Option D** – The classroom ceiling height is dropped to 2.4m, Class B suspended rafts are proposed, the required area of the rafts is therefore 40m².

MACH ACOUSTICS

# Class A Absorbent Finishes

1 Suspended ceiling tiles

2 & 3 Acoustic beams, see page 59 for further details

4 Acoustic pads on wall

5 Armstrong hexagonal acoustic ceiling system

6 Perforated or slatted wooden strips, open area >20%

7 Ceiling tiles with plasterboard surround

8 Vicoustic wall panels

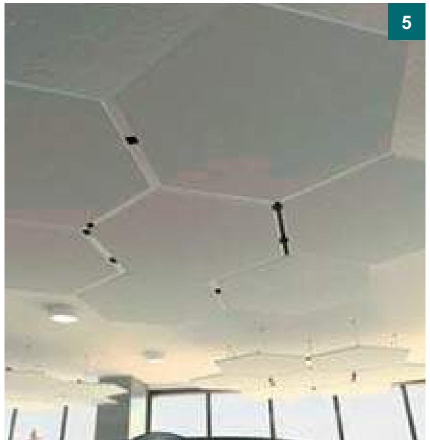
1

2

3

6

4



5

7

8

**9** Mineral wool providing fire protection and acoustic absorption

**10** Large grey acoustic panels fixed to the underside of walkways

**11 & 13** Coloured acoustic wall panels

**12** Classroom using conventional ceiling tiles to control reverberation times

A range of these products can be sourced through MACH Products. Please see our website www.machproducts.com

9

10

11

12

13

# Class B Absorbent Finishes

**1 & 3** Wooden slats covering an absorbent product such as mineral wool, Warmcell or equivalent, open area 15%

**2** Canvas placed over acoustic absorption

**4 & 5** Acoustic artwork printed on canvas combined with acoustic foam infill

**5** Acoustic wall panels

**6** Acoustic absorption placed above suspended light fittings


1


2


3


4


5


6

7 Acoustic wall panels printed on thin plastic sheets covering fire resistant acoustic foam pads

8 & 11 Perforated metal panels providing Class B absorption. This system combines both ventilation and acoustic requirements to a given space if treated correctly. Perforation rate >20%. This is not a Class A product due to the solid elements within this design

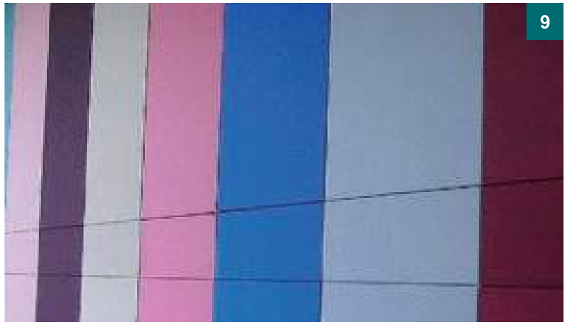
9 Acoustic foam covered with felt providing an interesting wall covering

10 Perforated wooden panels: Perforation rate 15%, hence this is only a Class B absorber. If the perforation rate is increased to >20%, this would be a Class A product

A range of these products can be sourced through MACH Products. Please see our website www.machproducts.com

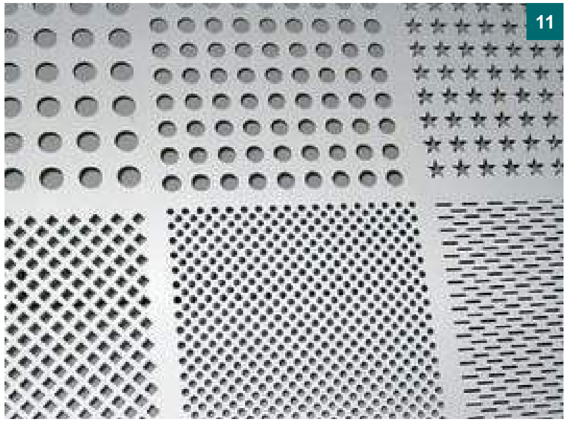
7

8



9

10



11

# Class C Absorbent Finishes

**1, 2 & 3** Acoustic Wallpaper

**4** Perforated wall panels, the fine perforations limit the acoustic performance of this product to Class C

**5** Perforated plasterboard, these products have a limited performance since it is not possible to perforate the entire sheet. This is down to the structural requirements of the plasterboard needing to be maintained

**6** Thin plastic sheets which can be stretched to form interesting and contorted shapes. The acoustic absorption is provided to walls and ceilings, in the form of mineral wool. The absorption is therefore placed behind the thin plastic sheets

1


2

3

4

5

6

**7** Foam covered in rubber. This is a durable product which is sufficiently robust to be used as furniture

**8** Acoustic Art work formed by routering contorted panels into a timber panel

**9 & 12** Wood wool, this product comes in sheets and is easily applied to a space.

**10** Sprayed acoustic absorbent material

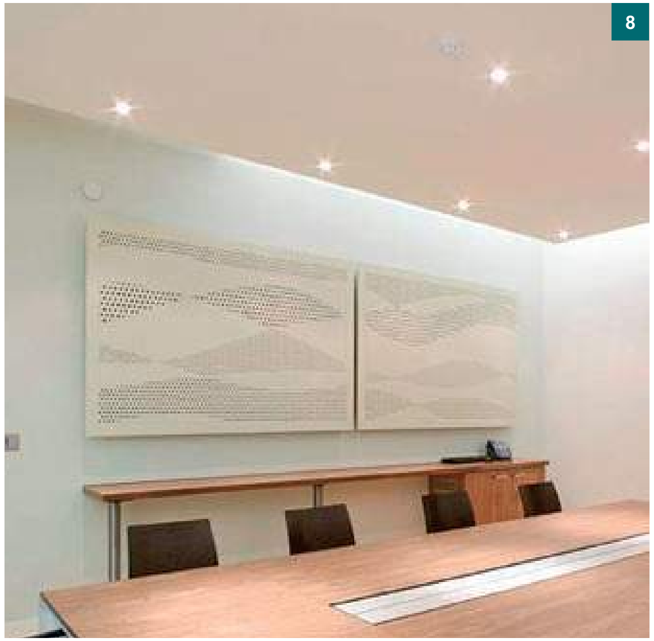
**11 & 15** Suede and leather covered foam

**13** Wooded Slats, if a larger gap between the slats where to be used, a higher acoustic performance would be achieved. Open area 5%

**14** Mesh covering absorbent material

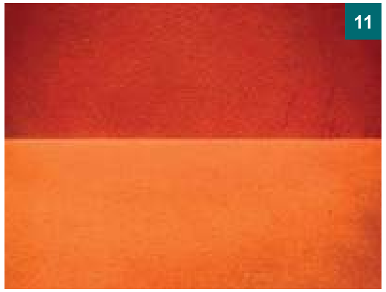
A range of these products can be sourced through MACH Products. Please see our website www.machproducts.com


7


8


9

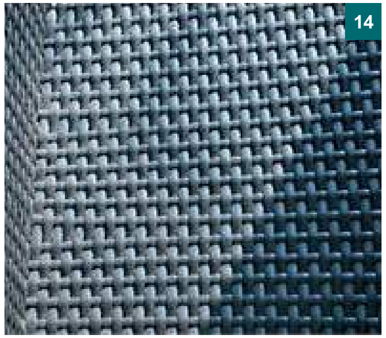

10


11


15


12


13


14

# Sustainable Acoustic Absorption

Acoustic absorption is often based around rock or glass wool, products containing high levels of embodied energy, rock wool having the negative impact of rock extraction. Alternatively absorption can be provided from sheep's wool **1**, recycled plastic bottles **2**, recycled cloth **3**, mashed up newspapers **4**, wood scraps **5**, recycled car dashboards **6**, recycled cloth/foam and so on.

Architecturally, sheep's wool and other green acoustic absorbers need to be finished for aesthetic reasons and to enhance robustness. This architectural finish is simply required to be acoustically transparent; such as perforated wood/metal, tissues, cloth, felts and other finishes.

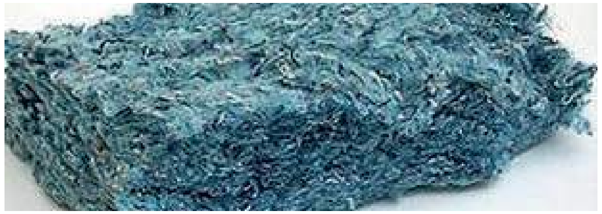
MACH Acoustics has proposed to use a waste product from Tandem Chairs for one of our green projects **8**. These chairs are formed from routed plywood sheets such to make the elements making up the Tandem Chair. The waste product is a plywood sheet containing large holes **9**. These holes could be slightly reshaped and covered with black tissue.

Illustration **7** shows the use of Bamboo for providing an architectural acoustically transparent finish.

1


2


3

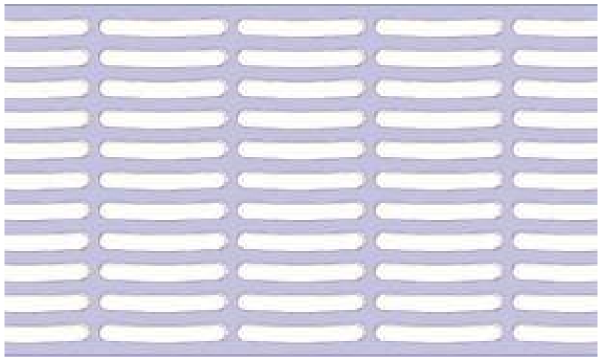

4


5


6


7


8


9

## Thermal Insulation and Acoustic Absorption Combined

10


11

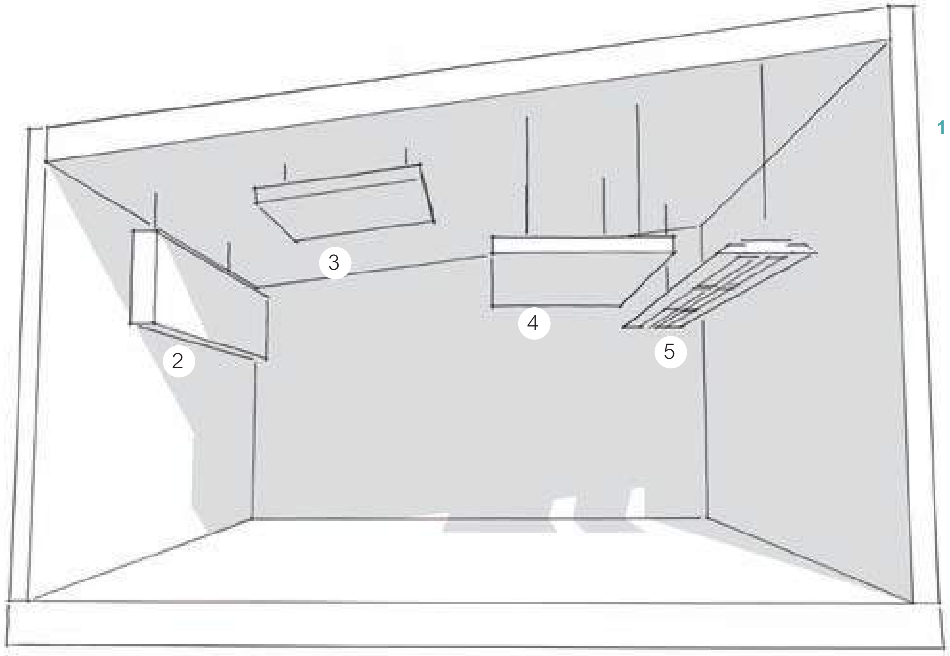
Fibrous materials such as Thermofleece, Warmcell, Pavatex, Rockwool all provide good levels of thermal insulation, as well as high levels of acoustic absorption. These products are therefore used to enhance the U-values of a building envelope. Fibrous materials can also be used to add acoustic absorption to a room. The acoustic absorption is achieved by installing the thermal, fibrous insulation into the building envelope and then lining a roof/facade with an acoustically transparent finish for example a perforated or slatted finish. Note that the use of vapour barriers between the lining and the thermal insulation is seen as acceptable, but this is dependent upon the thickness of the vapour barrier.

Put simply, providing the sound within a room can reach the fibrous, thermal insulation within the roof make-up, the thermal insulation will also provide good levels of acoustic absorption.

### Case Study – Eden's Education Buildings

The roof to Eden's Educational Building is formed from a timber structure, see illustrations **10** and **11**. Thermal insulation made from recycled newspaper was used to provide the thermal insulation. To achieve the acoustic requirements of the exhibition space the plywood sheet used for lateral bracing was perforated to 20% open area. This principle has been used across a range of schools, higher education buildings and other MACH projects.

# Thermal Mass and Acoustic Absorption




Thermal mass cooling is an important consideration in green building design. Conventional acoustic absorbent materials are added to the soffit of a building, this design therefore clashes with thermal mass cooling. There are two solutions to this problem. The first is to apply the acoustic treatment to the walls, this works but can take up a lot of wall area and can be expensive. It is also important to maintain the acoustic treatment well above finger height, in order to increase the durability and control the cost of maintaining the acoustic finishes.

The second method is to suspend the acoustic treatment. Illustration **1** provides a range of design options which provides both acoustical absorption and thermal cooling.

**2** - Acoustic beams can be extremely effective since all sides of the beams will provide acoustic absorption.

**3** - Raft ceilings - it is often the case that 30-50% of the ceiling can be covered whilst still providing the thermal cooling. Rafts of acoustic treatment can therefore be used below concrete soffits.

**4** - Suspended acoustic panels - A similar design to that of **2**, but in this case, the acoustic panels are suspended on wires.

**5**- Acoustic light fittings - Perforated metal wings are added to the side of a light. Again, this is an effective method of adding acoustic absorption to a space, since both the top and bottom of the panels provide absorption.


2


3


4


5

## Acoustic Beams

Suspended acoustic treatments can be an effective way of reducing the reverberation time within a given space. Beams absorb sound on more than one surface, resulting in significantly less square meters of acoustic treatment being required compared to ceiling tiles or wall panels.

Acoustic beams can also be used to enhance the architecture of a space. MACH Products supplied the acoustic beams for Dartington School **6**. Primary school classrooms at Dartington where treated with three rows formed from a pair of beams suspended on thin metal cables, with lights below. In addition to these beams, a band of acoustic absorption was added around the perimeter of each classroom, providing 16m² of additional treatment to comply with BB93's target of 0.6s.

The required size and number of acoustic beams is typically a function of the room volume and floor finishes. Table 7 provides a method of estimating the required levels of acoustic beams for a conventional 56m² classroom with a floor to ceiling height of 2.8m. Table **7** highlights the estimated additional levels of Class A treatment to comply with BB93's specification for Primary Schools, Rt = 0.6s and for Secondary School classrooms Rt = 0.8s. The levels of treatment are provided for 3/4 rows of 8m long beams, with a height of 300mm to 400mm. Treatment levels are also given for different floor finishes: Lino, Needle felt carpet and Needle felt carpet on a felt backing.

Note, Table 7 should be used as guidance only. Increased ceiling heights will require additional levels of treatment to those given.

6

7

| No- Rows of Acoustic Beams, 8m in length | Floor Finish | Additional levels of treatment to comply with BB93 | | | |
|---|---|---|---|---|---|
| | | Rt = 0.6s 300mm beam | Rt = 0.8s 300mm beam | Rt = 0.6s 400mm beam | Rt = 0.8s 400mm beam |
| 3 | Lino floor | 31m² | 19m² | 27m² | 14m² |
| 4 | Lino floor | 27m² | 14m² | 21m² | 8m² |
| 3 | Needle felt carpet | 20m² | 8m² | 16m² | 4m² |
| 4 | Needle felt carpet | 16m² | 4m² | 10m² | 0m² |
| 3 | Felt backing carpet | 12m² | 0m² | 7m² | 0m² |
| 4 | Felt backing carpet | 7 | 0 | 0 | 0 |

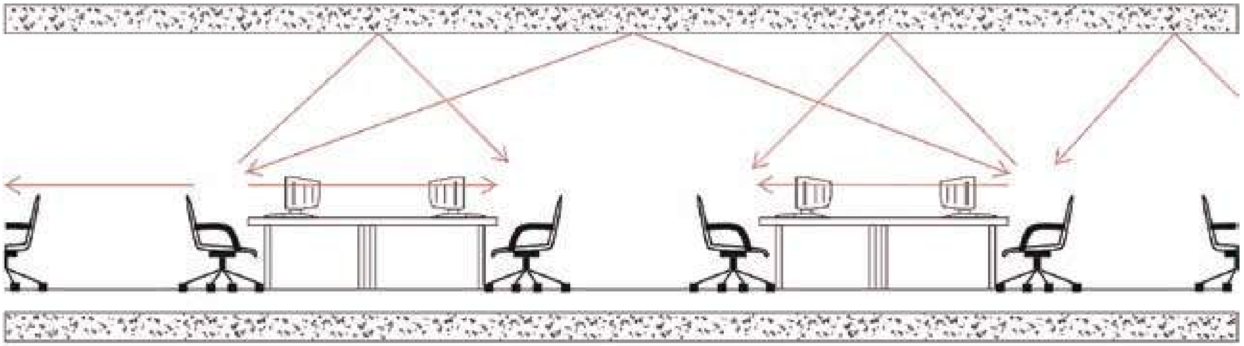
# Acoustics of Open Plan Offices

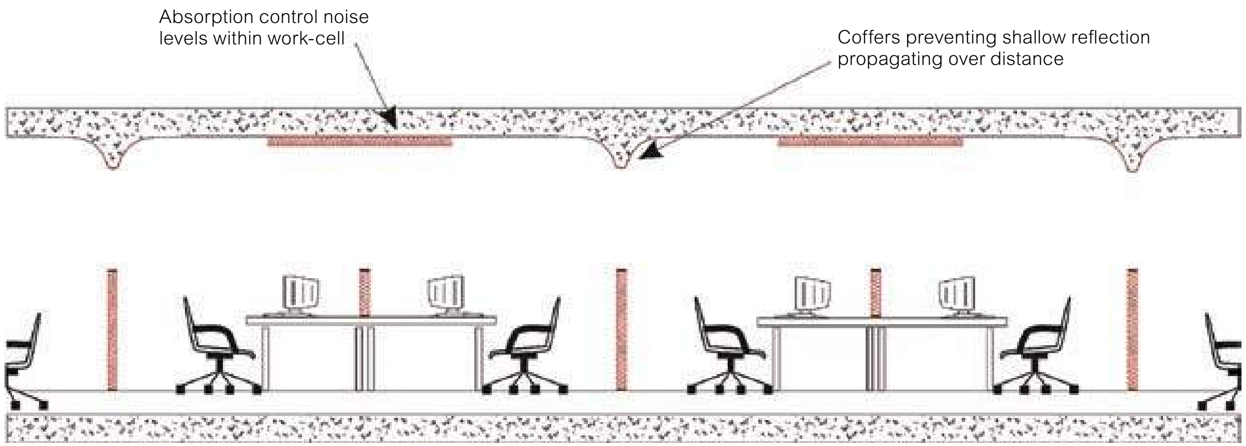
Privacy can be used to describe the level of acoustic separation between desks in an open plan office. If privacy levels are too low, speech, phone calls and other noise sources can cause a disturbance to multiple office users. Privacy between work stations is the main acoustic consideration in the design of open plan offices.

Privacy is both a function of background noise and the propagation of sound between work stations. As such it is important to consider the design of environmental noise break in or services noise; both these parameters should not be designed too low. Background noise levels within a naturally ventilated building are hard to keep constant due to variations in road traffic levels, the potentially quiet location of the building and other factors. The use of acoustic screen and other factors within the office space therefore become more critical in these buildings.

Recommended background noise requirements are a function of office size; large open plan offices have a higher noise requirement. Upper and low levels of background noise are provided by BREEAM, BS8233 and BCO, such to guarantee a degree of noise masking in large offices.

In MACH Acoustics experience offices can be designed with little or no acoustic absorption whilst still providing a suitable acoustic environment. The key is to ensure that line of sight between desks is obstructed by screens, the layout of the building or other elements. It is also important to prevent reflections off of hard surface/soffits. This can be done by placing panels of acoustics absorption over desks in combination with a coffered ceiling or down-stand beams.


1

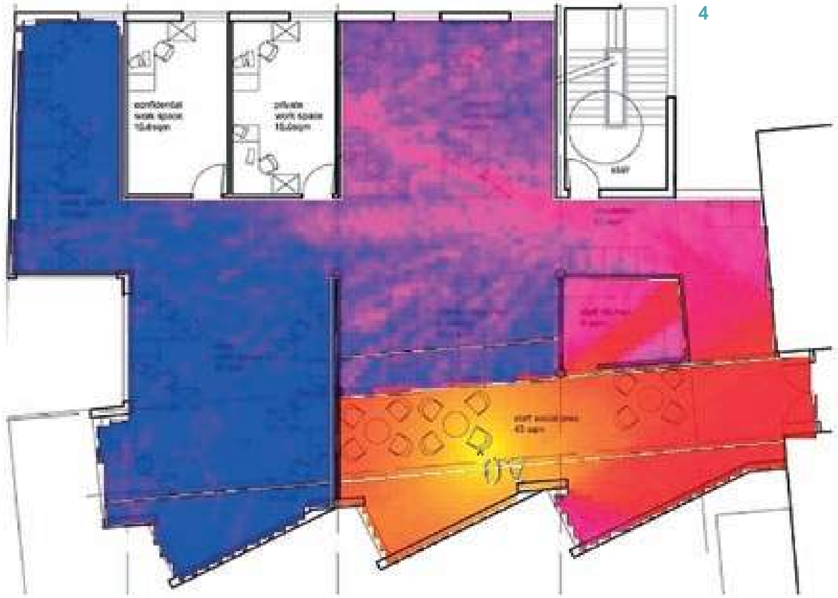


2

1 Office space with poor privacy level
2 Office space with good privacy level

# Case Study - Atrium and Open Plan Office - Bristol University

3



4

## Brief

Bristol University were concerned about the spread of noise across the various floors through a large atrium. Concerns were also raised with respect to a cafe at the base of the Atrium. The question was raised "what can be heard and what can we do to suppress the spread of noise?" The building was proposed to be naturally ventilated with an exposed concrete soffit; further concerns were raised with respect to the spread of noise across the open plan office floors.

## Design Scheme

As in the case of most room acoustic assessments, MACH Acoustics used a detailed computer model of the building. This modelling technique enabled the spread of noise from a source or multiple sources to be mapped across an office floor or through a building section. Determining the spread of noise and the effects of soft treatments along with acoustic screening is therefore possible and highly accurate method of modeling.

A set of results from MACH Acoustics work is shown above. The model on the left **3** shows the spread of noise from the cafe to the ground floor office accommodation. Here it can be seen that high levels of noise spread from the atrium to the office accommodation. Based upon the results of audio simulations and auralisation the university required improved levels of separation between these spaces. The right hand image **4** shows the result of adding acoustic panels to the soffit of the office spaces, in close proximity to the atrium. To reduce the spread of noise an acoustic screen was also used. This did not compromise the proposed natural ventilation scheme. Further audio simulations were presented.

# Case Study - Foreign and Commonwealth Office FCO

## Brief

The FCO proposed to cover one of their four courtyards with a glazed structure. To further enhance this space a new 9 by 9m, 5 storey office block was proposed to be erected in centre of the courtyard.

Having previously covered one of the smaller court yards, acoustics was seen to be a significant issue.

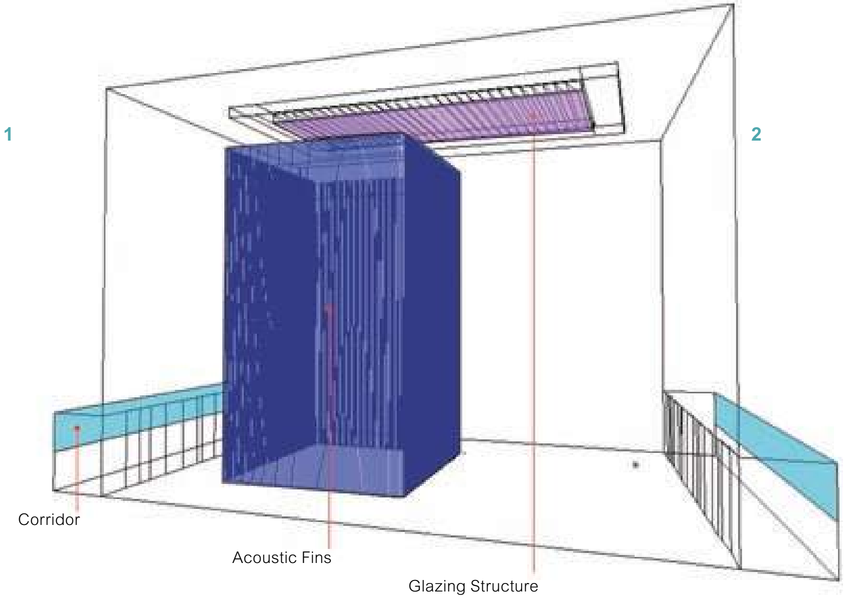
## Design Scheme

One the most important aspects when designing room acoustic finishes is to consider that all one is doing is adding the required level of fibrous or open celled material to a given space. It is therefore possible to be exceptionally creative when undertaking this process.

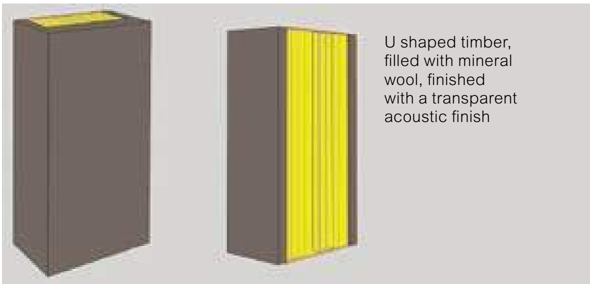
Allies and Morrison's proposal was therefore to clad the tower with acoustically absorbent fins **1**. Such to assess the feasibility of this proposal, a 3D acoustic model of the spaces was formed **2**. This model was used to assess the acoustic design of the fins **3** to **5** as well as the required levels of room acoustics treatments.

The results of the assessment indicated that providing the fins were 250mm deep, 25mm wide and at 750mm centres, the required reverberation time of 1.5 second would be complied with. Aesthetically, the design team considered the fin depth to be too deep. The metal structures supporting the roof were then proposed to also be acoustically clad thus adding more absorption area **6**. This reduced the fin depth down to 140mm.

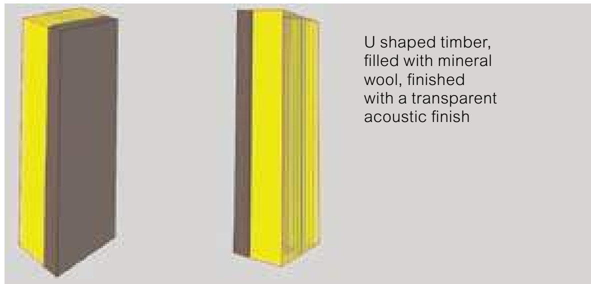
1



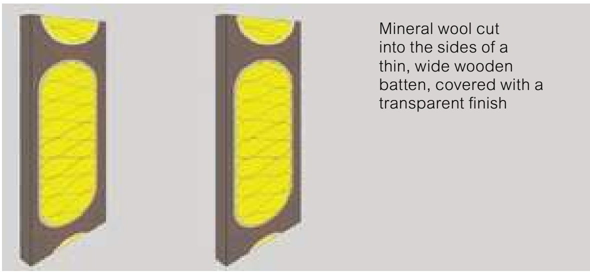

2




3




4




5

6

# Case Study - Scarlet Hotel and SPA - Auralisation

This was a challenging project where Spa treatment rooms were proposed to be formed form tents located within the Scarlet Spa Hotel, Cornwall **7**. These tents **10** did not contain doors and were to be seen as lightweight structures. Acoustic separation between the tents was therefore addressed in depth. Results were presented in terms of a real time audio simulation **8 & 9**.

## Design Scheme

The key to this project was to determine the required performance requirements. This was done through MACH Acoustics in-house auralisation tools. This process enabled the end user to hear the building before it was built. The effects of noise masking, sound transfer and background music, were all represented.

Such to provide the client design goals, a detailed computer model was used to assess the spread of sound between tents. This tool was used to assess the effects of room acoustic treatments, curtains, the layout of the Spa and other architectural features **11** & **12**.

The result is a fantastic Spa with a very different look and open feel. The tents provide a warm and comfortable environment **13**. The level of acoustic separation between tents achieved the required privacy levels.

7

8

9

10

11

12

13

# Case Study - Allies and Morrison Offices

## Brief

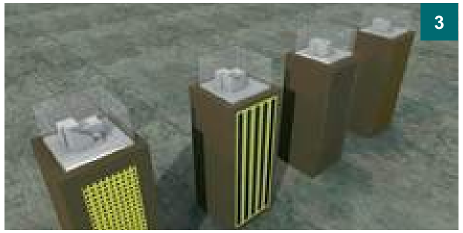
The brief was to provide room acoustic treatments to acoustically soften the reception spaces at Allies and Morrison's Offices **1**

## Design Scheme

The challenge here was to provide design options which fit in with the dramatic, hard, minimalistic reception space. Two design approaches were proposed. The first was to added small amounts of treatment in many locations. These were as follows: to the rear of four large cupboards **2**, to the display cabinets **3**, to the underside of shelves 4, suspended panels fixed into the lighting track **5**.

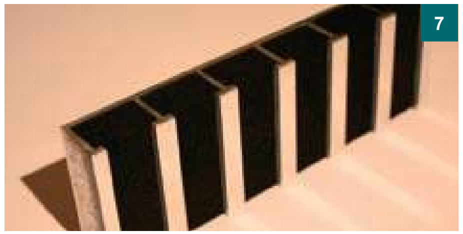
The alternative proposal was to add larger quantities in fewer locations. This included the end wall **6**, here a metal panel with a solid foam infill was proposed, picture **7** shows a sample of this product. The second proposal was to add acoustic beams **9** in front of the window, behind the reception **8**.



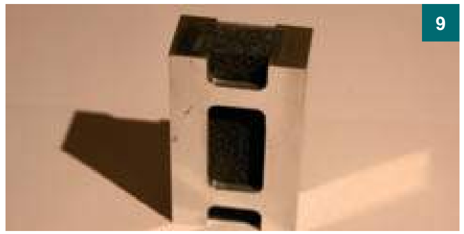












# Case Study - Kent University 500 Seat Round Auditorium

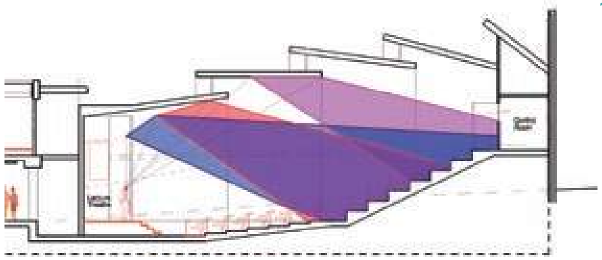
## Brief

As part of a large conference/educational building, Kent University proposed to build a 500 seat Auditorium. The requirement was to provide clear speech, minimising the need for a public address system. One of the main design challenges was fitting this space into a round building.

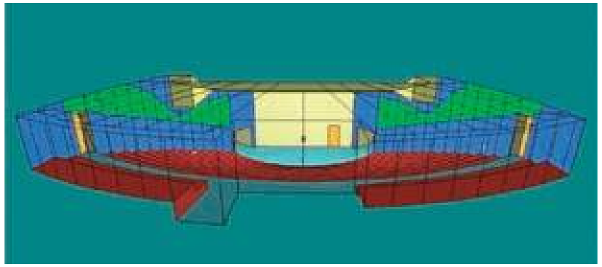
## Design Scheme

The roundness of this building had to be considered carefully. Side wall reflectors placed at the correct angle were used to minimise sound focusing and enhance speech levels at the audience. Additionally, acoustic absorption was placed on the rear walls **12**. The design of the ceiling was undertaken using mirror imaging methods, such that the ceiling angles reflected the spoken voice to the rear of the audience 10 minimising the need for a sound reinforcement system.

The overall acoustic performance and the effects of design changes were all assessed by means of a detailed computer model of the space **11**. This is a useful and sophisticated method of enabling design changes to be assessed and ensured that the maximum level of acoustic performance for the auditorium could be met



10



11

12

# Case Study - Sound Absorbent Sculpture

A different way of adding acoustic absorption to a space is in the form of an acoustic sculpture. The key requirement here is to ensure that the sculpture has a sufficient surface area to accommodate the required levels of treatment, such to affect the room acoustics of a given space.

## 6 : Open Plan Teaching

# Introduction

More and more schools and colleges are focussing on the immense benefits offered by open plan teaching. The promise of a flexible learning environment, with all the stimulation and innovation possible in a less codified design arrangement is very attractive to both teachers and students alike. Shared teaching resources and flexible breakout spaces for students are seen as the ideal in modern educational facilities. However, open plan design has often failed to fulfil the promise of an exciting and efficient learning environment.

For open plan arrangements to work effectively, the specific educational needs and the day to day operation of the space must be considered. Future needs must also be factored into design goals. Finally, architecture, services, acoustics and design must be integrated to meet the design goals. By working and liaising with teachers, it is clear that this type of teaching environment can work very well providing the specific educational requirements are fully understood and the correct design goals are set.

In MACH Acoustics' experience, effective education environments need a diverse range of learning zones: designated teaching areas, group tables for supervised and unsupervised studies, individual learning spaces, creative spaces, media zones and so on. All of these zones must be sympathetically integrated into one space for open plan teaching to fulfil its exciting potential.


1


2


3


4

**1 to 4** Example of open plan learning environment

### Acoustic Design

One of the main criticisms levelled at open plan educational environments centres on poor acoustics. However, there are some key tools and design techniques which can be used to enhance the acoustic performance of these spaces, and avoid potential problems. These tools are introduced below and then covered in more depth throughout this chapter.

Distance – Sound levels reduce over distance and this has two consequences which have to be considered when designing open plan spaces.

Firstly, a teacher's voice will decay over distance. As such it is vital that when addressing pupils, the distance between teacher and pupils is kept at a minimum to keep speech levels high. The second beneficial consequence is that a degree of separation can be achieved between two spaces by increasing the distance between the teaching zones. When designing open plan spaces it is therefore vital to look at the effects of sound decay over distance.

Layouts – The layout of the space dictates the distance over which communication takes place and hence noise levels within the learning zone. Teachers addressing pupils over long distances are required to raise their voices to be heard at the back, which often results in raised voices and therefore noise transfer between learning areas. Clustering group tables promote random, unnecessary communication from one table to another, which is not only disruptive to the educational process but significantly increases noise levels. Table layout must therefore be carefully considered.

Soft Treatments – Soft treatments provide a marked reduction in occupancy noise levels as a result of the sound being absorbed by panels on walls and ceilings or even soft furnishings. This is of great benefit to an open plan design, providing a quieter, more flexible space. A reverberation time of 0.4 seconds is one of MACH Acoustics' design goals and therefore substantial amounts of soft treatments are required to meet this design target.

Screens – Breaking the line of sight between learning zones is often an effective way of providing acoustic separation between two spaces.

It is important to recognise that screens do not have to be standard, uninspiring, felt covered wooden boards between desks. They can take many forms; seating, glazed elements, recessed spaces, corners, shelving, moveable panels, projector screens etc. Innovative use of screening can enhance the design quality as well as the acoustic efficiency of an open plan space.

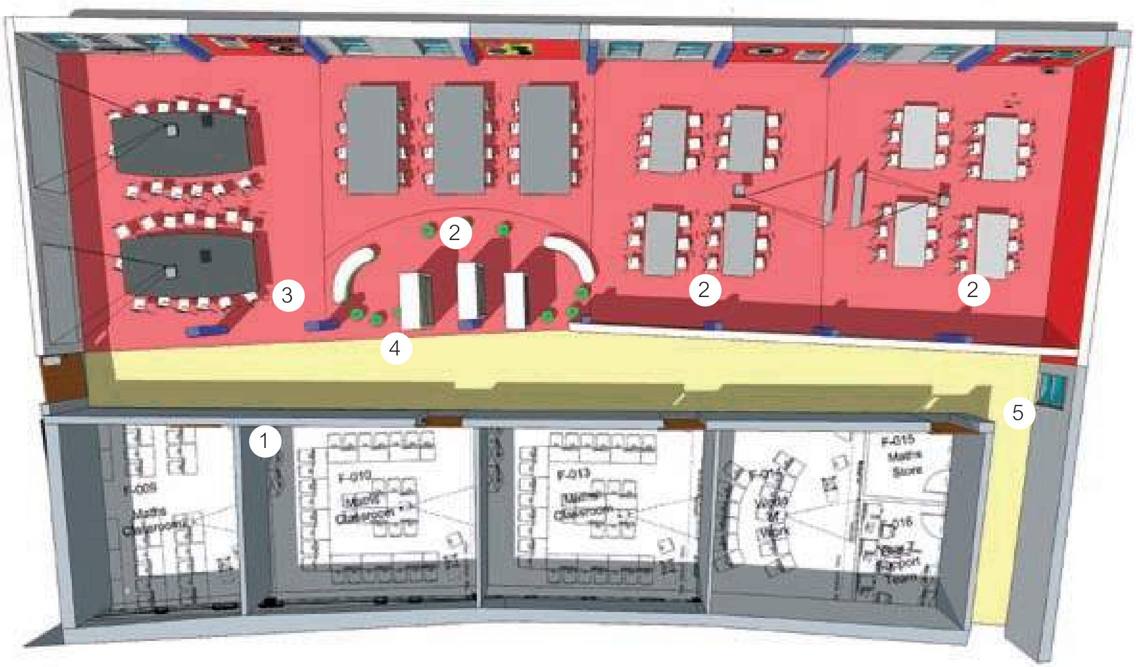
Partitions – Where an open plan area is being used to provide a full array of educational facilities, a degree of enclosed, cellular space will be required. Partitioned areas will be required when playing DVDs, to accommodate multimedia equipment, for drama activities, dance, undertaking noisy play and so on. Cellular spaces may also be needed for quiet teaching. It is therefore advised that all large open plan spaces include at least one or two cellular spaces.

### Benefits of Open Plan

One of the main benefits of open plan teaching is improved levels of communication, both auditory and visual. An open plan arrangement makes it easier for teachers to employ innovative teaching styles and to observe the techniques of other teachers. Improvements in the assessment of student performance, levels of support and student behaviour is also possible since each student's activity is either visible to all teachers or can easily be communicated as the student moves from one learning zone to another. Open plan arrangements reduce student segregation, with less able students occupying the same space as higher performing students, thereby promoting cross learning.

Open plan spaces offer great potential for pooling resources. Equipment and learning support staff can be allocated more efficiently, in a larger and more organic space. A broader range of teaching zones and educational facilities/activities can be offered in a more dynamic and colourful design space, enhancing student enthusiasm and their respect for learning. With such obvious benefits, it's clear that open plan design can provide an excellent learning environment. However, it is fundamental that design ideas compliment the educational requirements and provide improved communication and enhanced diversity.

# Case Study - Poorly Laid Out Teaching Plaza




The arrangement illustrated above is essentially four standard classrooms with the walls removed. This layout falls short in providing either the beneficial diversity of open plan teaching, or many of the educational benefits of open plan learning. This layout also has many acoustic limitations, as detailed below.

**1** – Part of the corridor wall has been removed so students in the open plan space may be disturbed by movement in the corridor. Removing the corridor wall has no educational or design benefit and is therefore not recommended. A full height glazed partition would provide a visual connectivity, whilst providing adequate acoustic separation.

**2** –The matrix of desks encourages non educational, disruptive communication to take place between tables, see page 74 for further details. With this table layout, teachers will need to project their voices to be heard by students at the back of the learning zone. Both of these factors will noticeably increase noise levels in this space, which will limit the performance, flexibility and overall user satisfaction of the space.

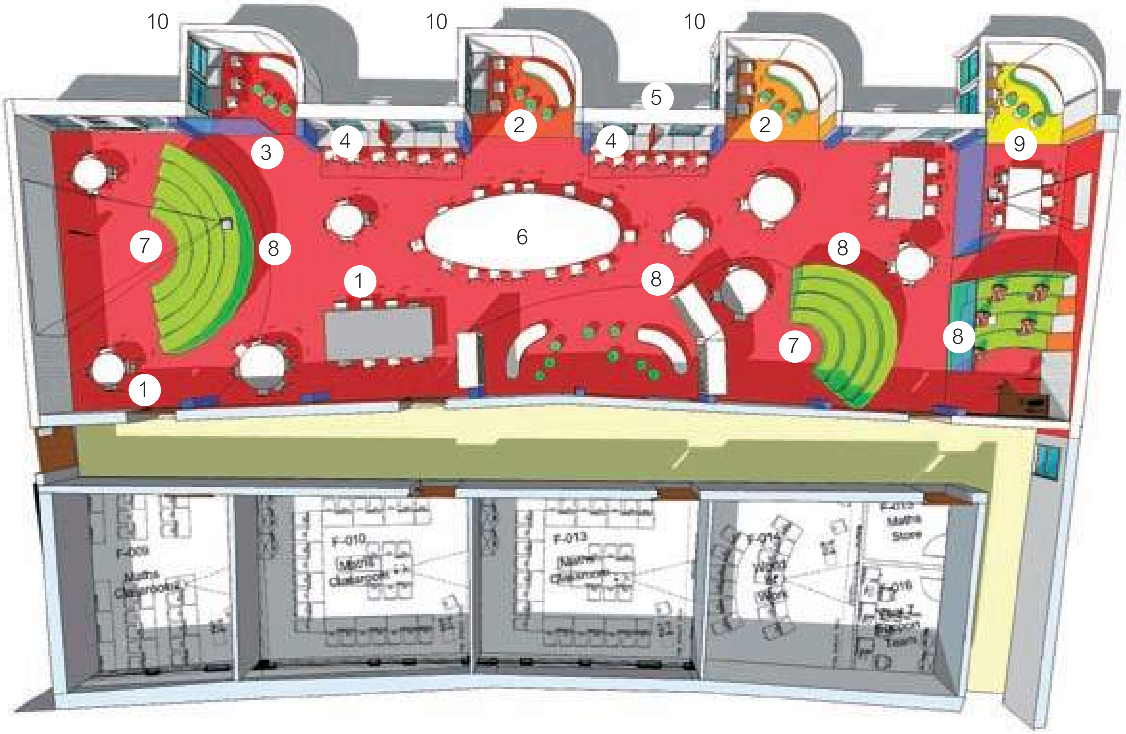
**3** – Placing two didactic teaching spaces adjacent to each other will result in considerable levels of cross talk between teaching zones. Pupils will tend to be distracted by adjacent teaching activities. It is not recommended that didactic teaching spaces be placed adjacent to each other.

**4** – This plaza does not contain screens of any form, which results in an acoustically open space. Bookshelves, glazed screens, room corners and other elements could have been used to provide acoustic breaks. Failing to add screens will result in the propagation of the spoken voice and excessive noise spill from one zone to another. Both of these factors result in acoustic problems.

**5** - This space does not contain cellular areas for specifically noisy or quiet activities. This limits the potential educational diversity of this plaza. Open plan spaces are not normally suitable for either exclusively quiet learning or noisy activities, such as drama and multimedia. It is therefore advised that a degree of cellular spaces are provided.

The above plaza does not take specific measures to accommodate the acoustics of open plan teaching; hence the acoustic performance of this space is likely to be problematic. This conventional layout seems to be driven by the ease of converting back to an old, uninspiring four classroom layout. In summary, it is felt that a more inspiring functional space could be provided.

## Case Study - Well Laid Out Teaching Plaza




The teaching plaza illustrated above moves away from the conventional classroom layout. The result is a colourful, personal space, providing a wide range of education zones and resources for teachers and pupils. This space has many advantages over a standard classroom, resulting in an improved educational experience.

The design goal for this plaza was to accommodate 60-90 pupils, providing all aspects of teaching, focussing on both individual and group learning. The completed plaza provides a wide range of teaching spaces.

**1** - Small group work tables have been dotted throughout the plaza. The carefully considered distance between desks helps reduce disruptive, unnecessary communication between group tables, resulting in reduced noise levels within this space.

**2** – More private, cluster spaces have been added by stepping out the facade. These spaces are acoustically and visually screened from the main teaching area, thereby creating a more private learning area. **3** - One of these spaces contains a glass screen to further increase privacy, making it ideal for one-on-one work or noiser group activities.

**4** - Desks have been placed adjacent to the facade. The desks provide individual learning stations with the benefit of restricted visibility to the remainder of the plaza. Students using these desks should enjoy improved concentration due to a reduced amount of distraction. **5** - A divider/screen added along the length of these tables helps to further reduce noise levels, by restricting the line of sight along the length of the work stations. **6** - A large central group table has been added with students all facing inwards. This minimises shouting and improves visual communication between students.

7 - To enhance speech intelligibility for dictatorial teaching, banana-like tiered seating has been used. Here, students and teacher sit extremely close to each other, improving speech intelligibility and reducing the need for the teacher to raise his/her voice. Three didactic spaces have been provided, one at each end of the plaza and one in the corner behind an acoustically screened space. These spaces have the advantage of being somewhat acoustically separated due to their location.

**8** - Acoustic screens have been added in many inventive forms to these spaces such as the banana seating itself, glazed screens, bookshelves and other arrangements.

**9** - Enclosed spaces have been provided for activities involving higher noise levels.

**10** - The increased wall space created by the stepping out the facade, acoustic screens and other factors all assist in optimising the acoustic treatments to this space.

MACH ACOUSTICS

# Distance - Didactic Teaching

Speech intelligibility and a good visual connection are essential requirements for didactic teaching. Most learning environments will require a space where instruction and information can be transmitted to a large number of students at one time. It is therefore essential to have at least one or two areas dedicated to this type of teaching.

In order to maximise speech intelligibility during this type of teaching, the distance over which the spoken voice is required to travel should be minimised. Based upon acoustic on-site tests, it is advised that the distance between the teacher and pupils be kept less than 4.5m; however this distance does depend on background noise levels and other acoustic effects within the open plan environment.

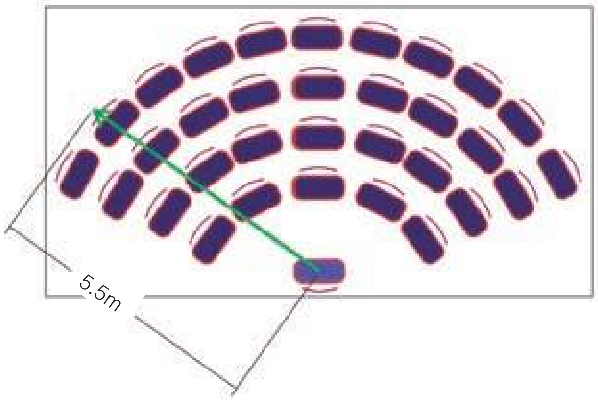
To meet this requirement, seating layouts and furniture should to be considered. Images **1** & **2** show two example layouts incorporating a semi-circular and rectangular seating layout. It is clear that the more effective layout is the semi circular design.

A considerable reduction in communication distance can be made by removing tables and chairs. Raked seating is also an effective method, not only reducing the distance between the teacher and pupils, but also improving the line of sight which in turn helps with speech intelligibility.

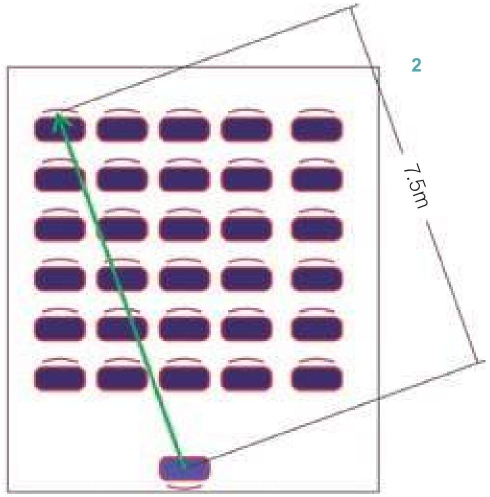
This seating layout can be achieved by raising the pupils by means of small steps, cutting steps into the ground or raising the seating in the form of a Greek amphitheatre.

1

32 Seats - Equal Room Size

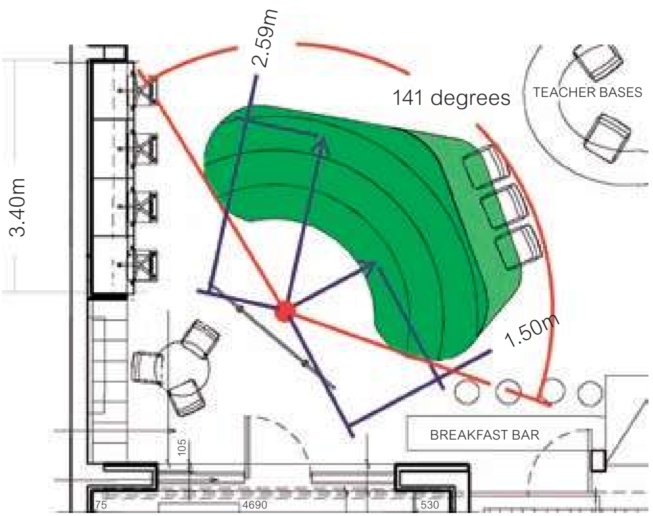



2




30 Seats - Equal Room Size

3




**1 & 2** Example of how two different desk layouts effects the distance, and subsequently speech intelligibility, between a teacher and the back row of desks

**1** A semi circle can be used to address 32 pupils over a maximum distance of 5.7m

**2** Seats arrange in conventional rectangle, results in the maximum distance being increased to 8m

**3** Removing the desk and raking the seating, results in the banana, addressing 30 pupils over 2.6m

## The Banana

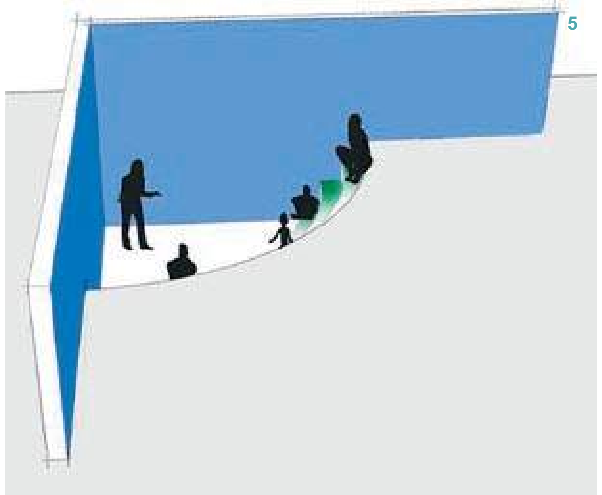
The banana seating **3** has been successfully implemented in two open plan spaces; however the design principles behind the banana have been used by teachers for many years in a wide range of locations.

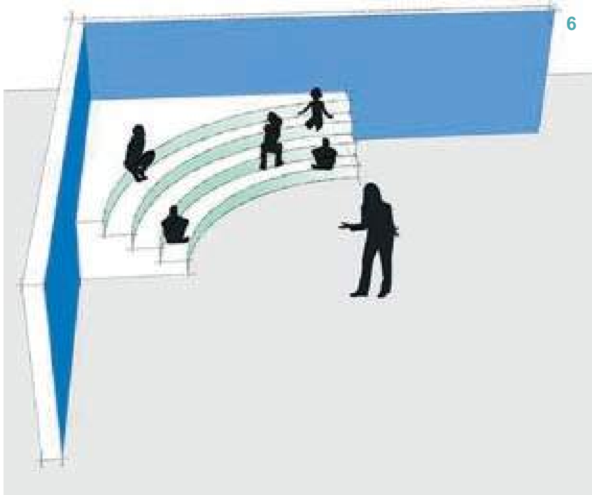
One concern which has arisen with respect to the banana is student health and safety issues. The feedback we have received is that this is not an issue; however it is important to recognise that there are alternative designs, see options **4** & **5**, which seem to be safer options.

During the design stages of the banana, it has been found that it is important to provide pupils with sufficient leg room. The design of the second banana has deeper seating and angled backs, to accommodate these requirements.

It has also been found that over time, the bananas get moved and joined together within the teaching space in order to address different sized groups. A method of interlocking the bananas and moving this seating would therefore be a useful design feature.

4


5


6


7

# Layouts - Unsupervised Group Work

Unsupervised group work, while an important element in learning, can also be one of the greatest sources of noise within a teaching space. As a result, this activity can be significantly detrimental to the acoustic performance of open plan design. The ideal solution is to provide individual areas for groups to work together. These spaces need to be laid out to promote group learning, but also to prevent casual and non-work related communication between group tables.

One of the worst table arrangements for group work **1**. This layout encourages non-educational interaction between tables, which not only loses the focus of the group (from an educational point of view) but also significantly increases noise levels, as communication tends to take place over larger distances.

Placing group work tables throughout the learning space focuses groups and results in reduced noise levels **2**. However, a possible drawback is that teachers are required to move around tables more and may find it difficult to focus or address a larger group.

Separating group tables is demonstrably one of the most important design requirements of open plan spaces.

1 Island table layout, encourages noise

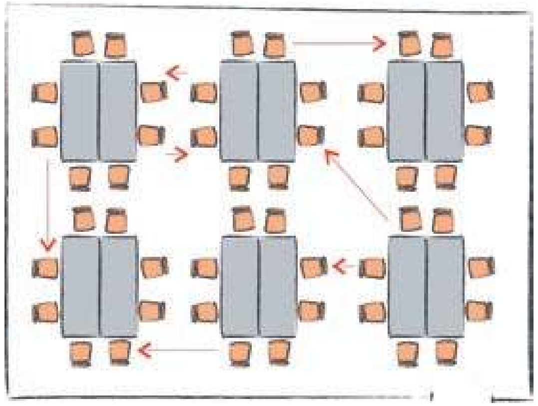
2 Ideal open plan layout

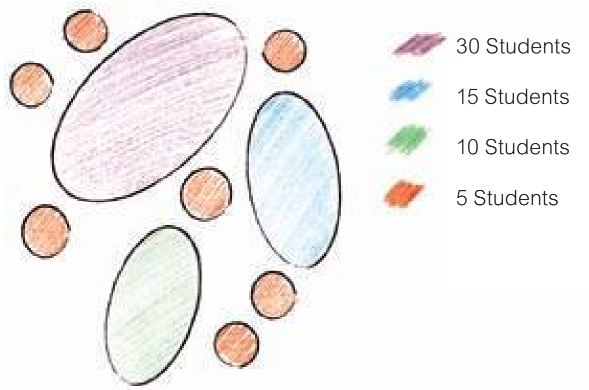
3 Group table isolated for the remainder of the plaza

4 An individual soft seating area for 3 pupils, in a corner away for other teaching spaces

5 Two group table at each end of an banana

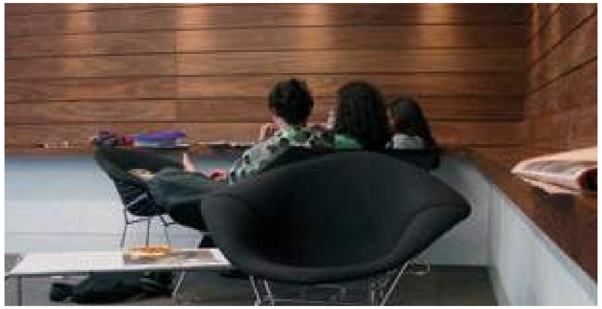
6 High back seating, providing acoustics screen and reducing levels of speech between group work tables


1



2


3


4


5


6

## Layouts - Individual Learning

Open plan designs must allow for individual learning spaces. The key objective is to provide work stations which encourage individual learning, whilst limiting unnecessary conversation and distractions between work stations. This can be achieved by reducing the visual connectivity between work stations, by means of screens and the orientation of desks. Screens can be added between work stations or on the tables themselves. Locating seating along the length of facades, walls or in corners or rows, are good methods of promoting individual learning. Improvements can also be made by limiting the movement of seats and as such swivel seats and seats on casters are not recommended.

7 Individual learning areas, all facing the same way, with a central screen braking the line of site to adjacent spaces. This arrangement encourage individual learning

8 Screen between work station, help provide a more individual spaces

9 These seats face aways for the main educational spaces. The dividing screens and different colour tables ensure pupils out communicate over short distances


7


8


9

# Noise Levels and Room Acoustic Treatments

## Background Noise Levels

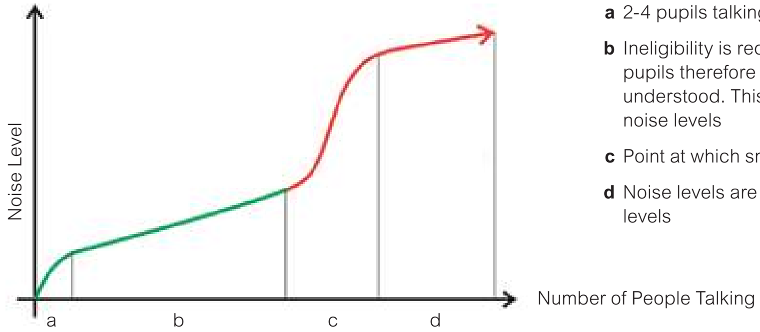
The key to successful open plan design is reducing background noise levels, and conversely, increasing speech levels. Reducing noise levels is important as high background noise levels are disturbing, compromise concentration and make speech unintelligible over distance. Therefore to make an open plan space work correctly, with multiple activities taking place simultaneously, it is necessary to control noise levels

## Reverberation times

Reverberation times and room acoustics are extremely important elements in the acoustic design of open plan teaching spaces. Soft treatments are needed to ensure good speech intelligibility, to absorb sound and to control the build up of noise.

One of the principle factors affecting noise levels is reverberation time. The 'snowball effect' of reverberation time is illustrated in Image **1**. This illustration shows noise levels in a room increasing relatively constantly, as the number of people talking increases. At the snow ball point, noise levels dramatically increase as people sub-consciously begin to raise their voices to be heard over the background noise. These noise levels are obviously detrimental to the performance of the open plan space.

In order to mitigate this effect, it is important to add sufficient soft and absorbent treatments to achieve a reverberation time of 0.4 seconds. This reverberation time can only be achieved by adding sufficient levels of soft treatment; see Reverberation and Room Acoustics Chapter which provides an indication as to the required levels of treatment.



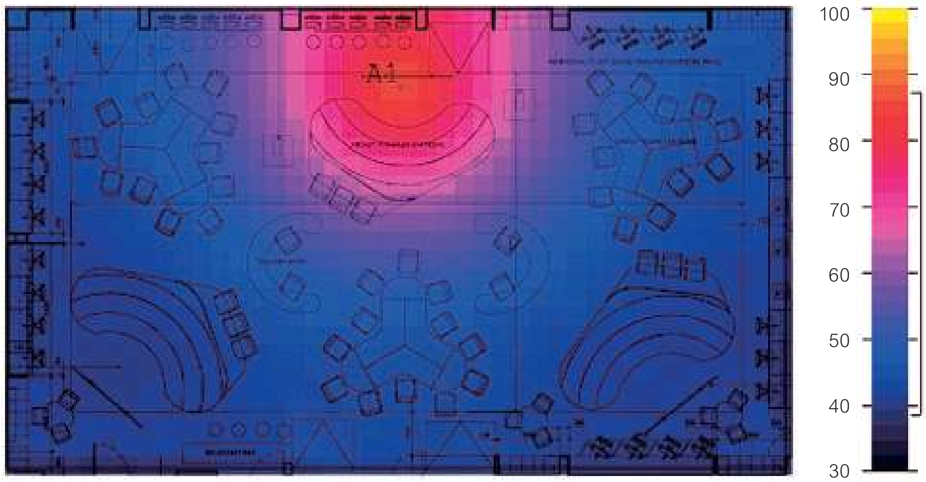

**a** 2-4 pupils talking

**b** Ineligibility is reduced due to high background noise, pupils therefore talk louder to make themselves understood. This has the effect of escalating background noise levels

**c** Point at which snowballing effect takes place

**d** Noise levels are limited by maximum comfortable speech levels

1




2

## Soft Treatments

Where soft treatments are located in the open plan space will have an effect on their efficiency. Acoustic absorption placed close to a particularly noisy area will be more effective than material placed much further away. In addition to soft treatments, it is also important to consider the positioning of hard reflective surfaces. These should ideally be placed behind the teacher and above an audience. The effects of finishes should ideally be assessed using ray tracing modelling software **2**.

## Open Plan in Atriums and Circulation spaces

Open plan spaces are often situated in atriums and circulation spaces. These spaces can provide functional, open plan areas but often suffer from two drawbacks. The first is disturbance from pupils moving through the circulation space. This can be improved through careful consideration of layout and the use of visual screens in and around the open plan area.

The second difficulty is in achieving the required level of soft treatment within these spaces. As per the Reverberation and Room Acoustics Chapter, it is important to understand that these treatments can take many forms. The four illustrations provide a range of design options.

**3** - The ceiling within the circulation zone has been acoustically treated. Perforated plasterboard is often used in these instances. This finish is unfortunately not particularly effective. Perforated wood/metal, wooden slats, ceiling tiles and other high performance finishes are preferable. It is also recommended that more surfaces, in addition to the ceiling be treated.

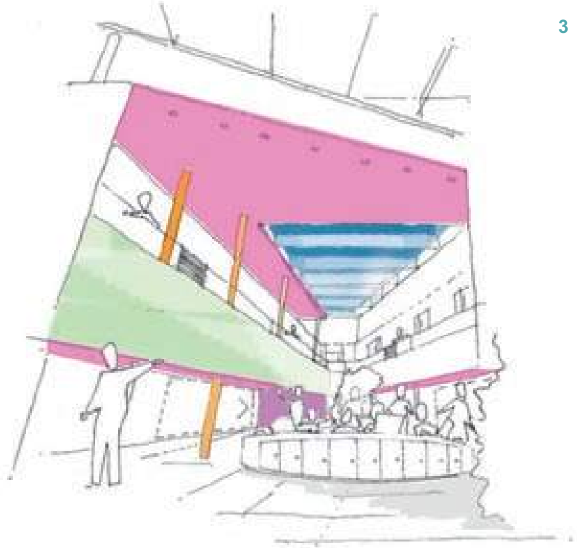
**4** - Acoustic banners, wooden fins, cladding around beams, the backs of cupboards exposed to atriums and other elements, are all effective methods of adding acoustic treatment to spaces in atriums.

**5** - Acoustic artwork can be added to balustrades and walls within an atrium.

**6** - An effective alternative to these forms of treatment is to suspend acoustic absorption within atriums.

**Please see www.machproducts.co.uk for further details**

3



4

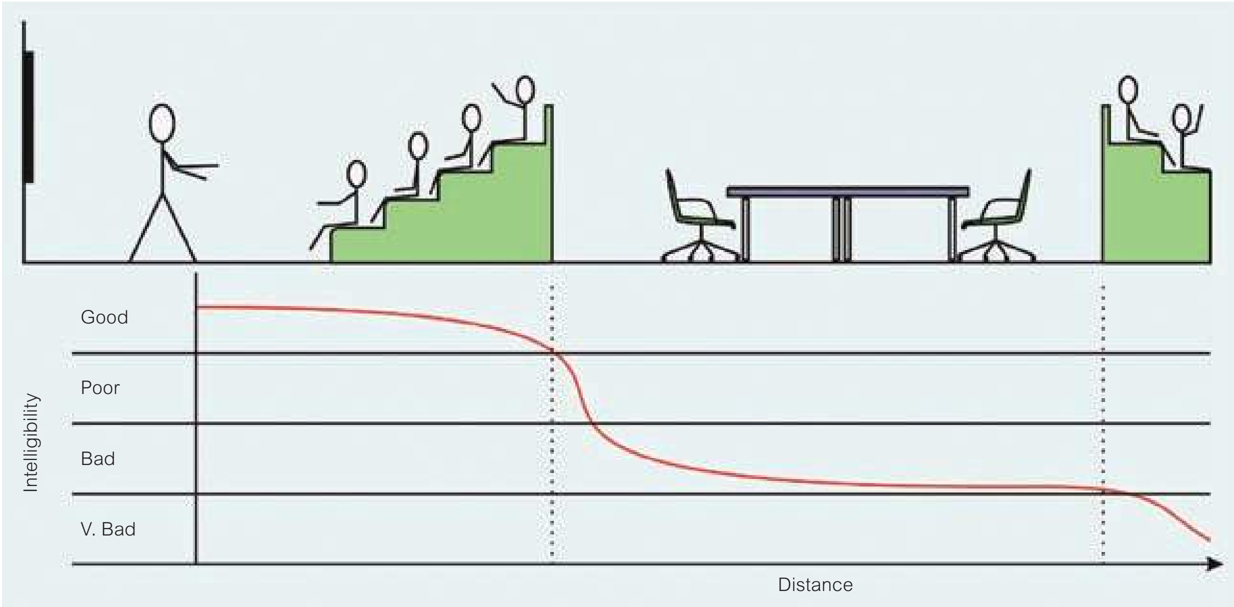
5

6

# Acoustics Screens

Screens can play an important role in the acoustic performance of open plan teaching spaces. The key benefit of well designed and effectively placed screens is acoustic separation between teaching zones. Example 1 illustrates the measured speech intelligibility from a teacher addressing pupils across two bananas and a group space. It can be seen that intelligibility drops off slightly as the receiver moves away from the teacher. This is due to the decay of sound over distance. If the depth of the seating was increased any further, the intelligibility levels at the rear seating would fall into the poor intelligibility band.

Due to the raked seating of the banana, the group space has no line of sight to the teacher. When the line of sight to the spoken voice is broken, intelligibility levels drop off dramatically **1**. This reduction in intelligibility will result in an effective level of acoustic separation between these two teaching zones.




1

2

3

4

5

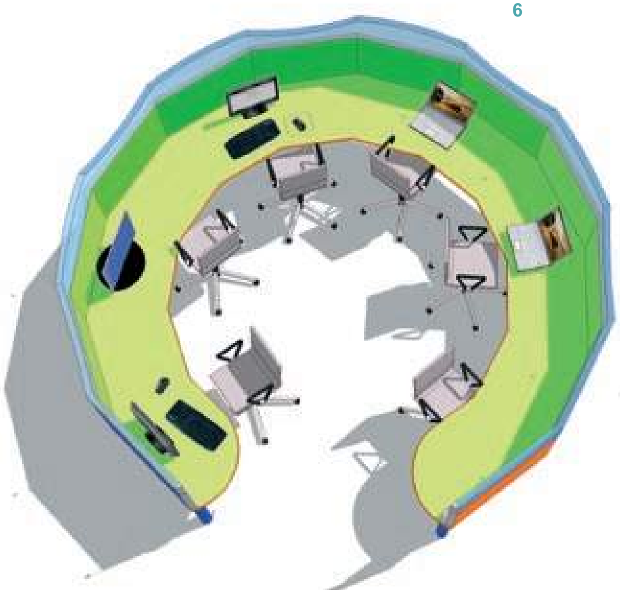
## Design Option for Screens

The design of screens can take many innovative forms. **2** & **3** show sliding screens which can be moved between desks to provide a more individual learning environment. **4** & **5** show how it is possible to wrap acoustic screens around a small group of spaces. These screens can be used to reduce noise levels within a given area or to contain noise from multimedia equipment. 8 shows a range of free standing, architectural, horseshoe screens, adding diversity and design interest to a space.

### Whispering Circle

Incorporating screens into furniture is an interesting way of adding screens to an open plan space. The whispering circles **6** & **7** show one possible option. The advantage of using a circle is that the sound is focused and kept within the circle; the containment of sound is shown in the modelled sound map **9**. The intense colour highlights how the teacher's voice is maintained within the central whispering circle

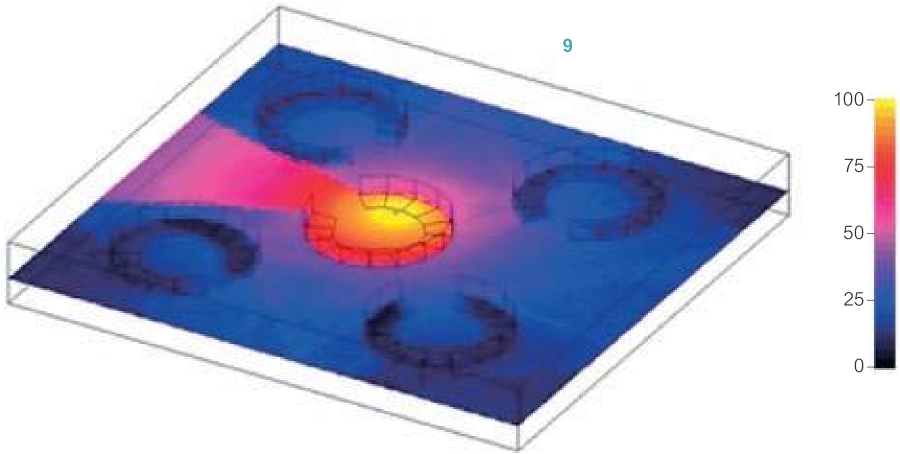
6



7

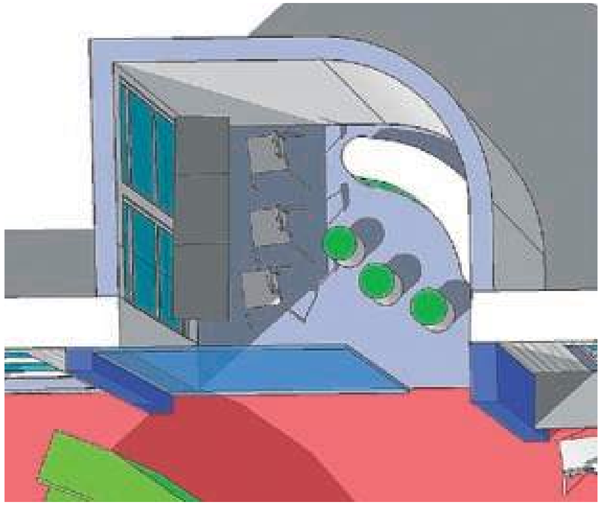
8

9

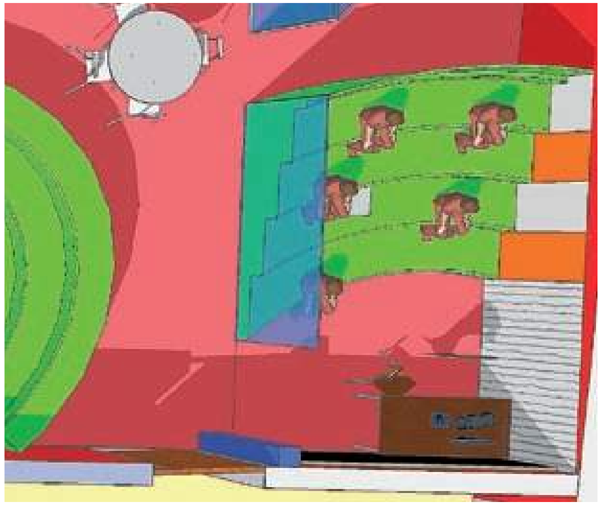


## Glazed Screens

Large glazed screens are a useful way of providing acoustic separation between two learning zones **1**, **2** & **4**. The benefit of glazed screens is that they provide good levels of acoustic separation, whilst maintaining one of the key benefits of open plan spaces; a visual connectivity between learning zones. To maximise the acoustic potential of screens, they should run from the floor finish to the underside of the ceiling and have a mass exceeding 10kg/m2, i.e. 15mm plasterboard, 18mm plywood, 8mm laminated glass and so on.



1



2

## Cellular Space

Teaching incorporates a broad range of activities with a wide range of acoustic requirements. The use of audio equipment and DVD's, theatre, dance and other noisy activities **3** must all be allowed for in meeting curriculum requirements or as incidental elements in lessons. If the open plan space must accommodate these noisier activities, it is recommended that a degree of cellular spaces are provided within the open plan area. A small number of cellular spaces are also recommended for quiet learning.

3

4

**MACH**
ACOUSTICS

**Tel** 0117 944 1388
**Email** info@machacoustics.com

www.machacoustics.com
www.machproducts.com
www.machtesting.com

81-83 Stokes Croft, Bristol BS1 3RD