Presented By Ze Nunes
Founder of MACH Acoustics
Lecturer At the University Of Bath

"MACH Acoustics takes time to analyze, consider and propose solutions, that promote an architectural approach. The sensitivity and technical performance capability is well respected by the practice." Jo Bacon – Allies & Morrison Partnership

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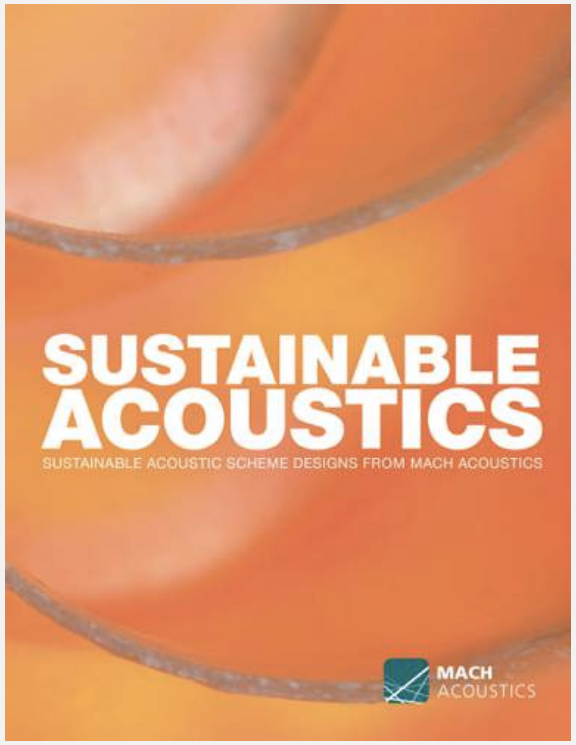

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THE FUNDAMENTALS OF ACOUSTICS

Facade Lecture Notes

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THE FUNDAMENTALS OF ACOUSTICS

ACOUSTICS

Acoustics is not a challenging subject nor is it a black art, it is simply another science governed by physics. However there are two key challenges.

The first is the way our ears work. We have an amazing ability to hear extremely quiet sound, as well as exceptionally loud sounds. To enable us to have such an impressive dynamic range, we are limited by the fact that we can only hear a significant change in level between two sound levels.

In other words, we can hear the difference between 1 unit and 2 units of sound, however we cannot hear the difference between 100 and 101 units of sound. For a change to be heard in this instance, sound levels would need to change to 200 or more units of sound.

From the video shown, it is possible to see that sCound contains many different characteristics.

However for the purpose of communication, complex sounds need to be summarized in the form of a few letters and numbers. This raises the second key challenge in the discipline of acoustics.

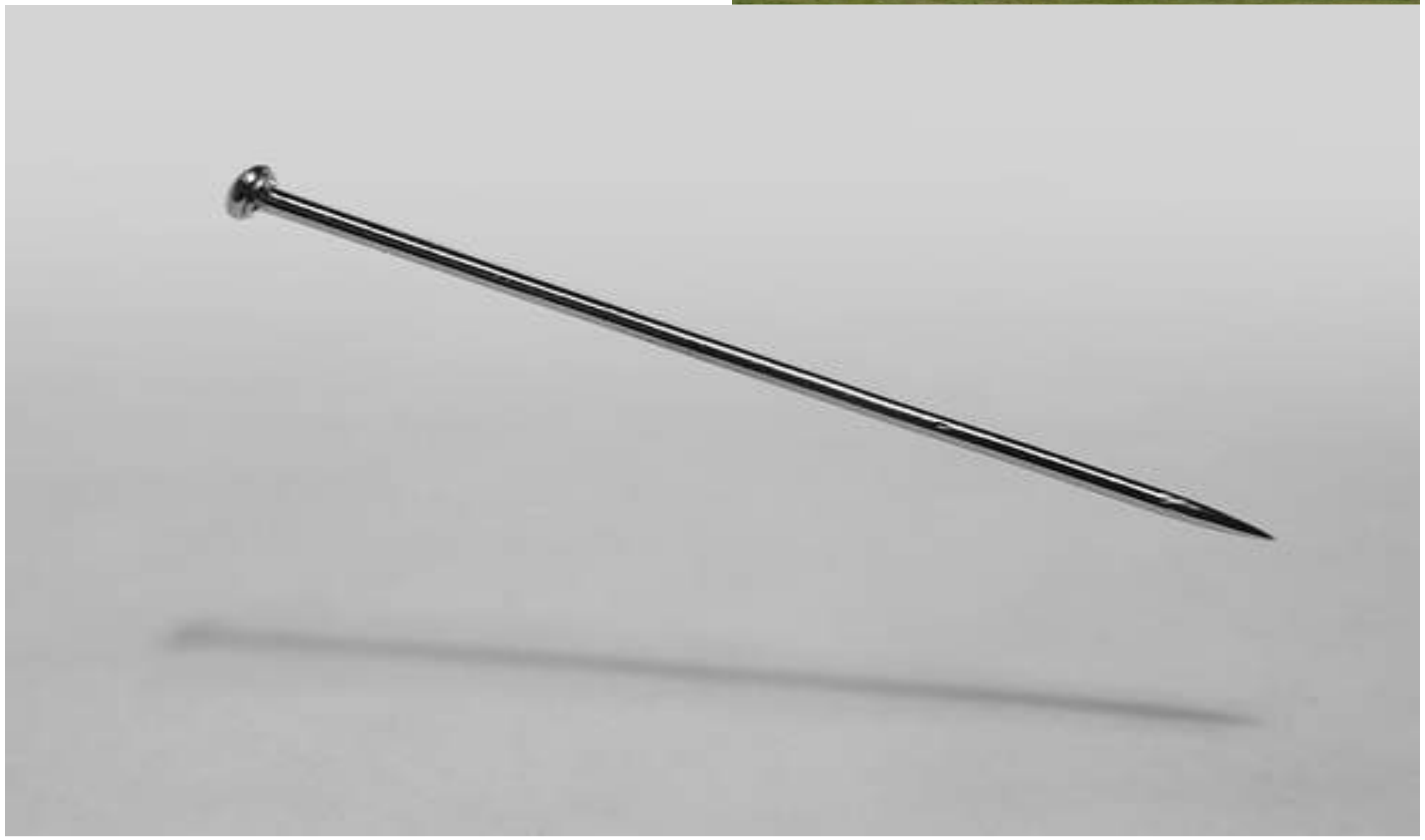
https://youtu.be/DFx4CxrKk_Y

OUR EARS

Our ears allow us to hear a pin drop, as well as jet aircraft taking off at a relatively short distance, without causing damage to our ears. A pin typically weighs 1 gram, whilst a jet air craft can weigh a few thousand tons, meaning our ears have a massive dynamic range, in the order of 10,000,000,000.

Our skin, on the other hand, has a dynamic range between 0° and around 70°. Therefore, our skin can tolerate a change in temperature of only around 70° before being damaged. However our ears are limited by the fact that we can only detect significant changes in levels, thus we can only just detect if a particular sound is doubled in level. For example, if you drop 2 pins rather than 1 pin, we can detect a difference, however, the difference between 100 and 110 pins is undetectable.

This shortfall of not being able to hear a small change is what enables our ears to hear the huge range in levels discussed above.



WAVE CREATION 1

The principles of sound are covered by acoustics, which in turn is a study of wave propagation. The basic principle behind a wave is the propagation of fluctuating pressure, caused by movement of air.

Using a loudspeaker as an example, the air molecules directly in front of a loudspeaker have a given mass. When the cone moves forwards, the air in front of the speaker is forced to move, these air particles, therefore, gain momentum. When the loudspeaker moves back in, the momentum held within the mass of the moving air maintains the particle

movement, hence a wave travels away from the loudspeaker. When the cone moves into the cabinet, a partial vacuum is created in front of the loudspeaker, this creates the negative pressure part of the wave. When the loudspeaker pushes back out, the momentum from this movement forces the low-pressure part of the wave to propagate away from the loudspeaker.

https://youtu.be/_ltdRM5hV5Q

https://youtu.be/4_YRy-pSNIE

WAVE CREATION 2

The video to the right shows a paddle being pushed through water, as the paddle moves, water builds up against the paddle. This water has mass, where the movement of the paddle gives momentum to this mass. As a result of the energy conservation law, this momentum results in the fluid propagating away when the paddle stops, slows down or changes the direction.

Pulling the paddle backward means that water now builds up on the back of the paddle, while water is pulled away from the front of the paddle. This is the generation of the negative pressure part of an acoustics wave.

Again, when a paddle moves forwards, the water builds up on the front of the paddle and the cycle is repeated resulting in a wave propagating away from the paddle.

https://youtu.be/rcFzPlYpvJI

https://youtu.be/xLX-anq6I5U

ENERGY HELD IN AN ACOUSTIC WAVE

In the case of acoustics, it is challenging to see sound waves, it is, however, possible to see the effects of moving air particles as a result of sound.

As discussed, a propagating wave has momentum held in the mass of the air particles, when this energy is exposed to a structure, parts of this energy will be transferred into the structure. The amount of energy being transferred is proportional to the surface area of the structure and the sound pressure level.

The positive and negative fluctuation held in the wave forces the structure to move.

https://youtu.be/L823C8l1vwo

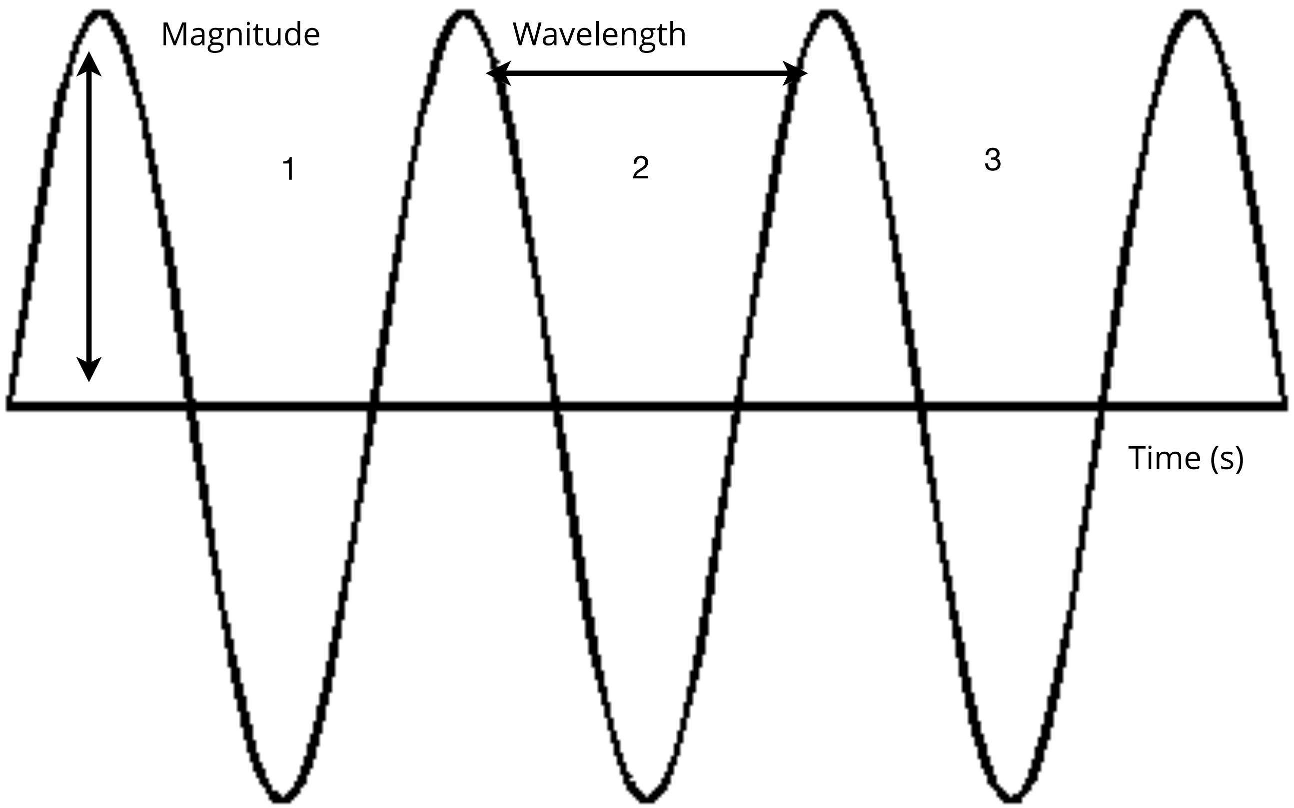
CHARACTERISTICS OF A WAVE

There are three main characteristics of a wave that are important within acoustics: Magnitude, Frequency and Wavelength.

The **Magnitude** is the size of the wave. Also referred to as Amplitude, this is the maximum displacement of the wave from its undisturbed position. In acoustics, the magnitude is expressed in decibels (dB), which will be discussed more in the next chapter.

The **Frequency** of the wave is the number of cycles per second. In the diagram on the right, we can see that the wave completes 1 cycle each second, and therefore has a frequency of 1 Hertz (Hz) where 1 Hertz = 1 cycle per second.

The **Wavelength** is the distance from a point in a wave cycle to the exact same point in the next cycle. This is measured in meters. Wavelength is inversely proportional to the frequency of the wave i.e. Wavelength = 1 / frequency, and is denoted as the greek letter lambda (λ).



FREQUENCY RANGE

The illustrative video shows that playing different piano keys results in different frequencies being produced. It is, therefore, important when looking at interpreting acoustics as a set of numbers that the frequency characteristics of a sound is represented.

Our ears are said to operate between 20Hz (20 cycles/oscillations per second) and 20,000Hz. The issue being that there are 19,980 integer frequencies between these two points. This means that a simplification in terms of numbers used needs to be considered.

In architectural acoustics, frequencies below 125 Hz and beyond 4 kHz are seldom considered, due to a lack of importance our ears apply to these frequencies. However in some instance this is increased to 63Hz and 8 KHz.

Additionally, it is possible to group frequency bands together. As such, when discussing things like the frequency characteristics of a room, the sound insulation of a wall, the noise produced by a fan etc, data is either presented in Octave or 1/3 Octave data.

https://youtu.be/GGUQGK4uYY0

OCTAVE & 1/3 OCTAVE DATA

As seen in the previous section, if we wanted to measure and present data for every frequency we can hear, we would require 19980 different numbers. Calculating and displaying the levels for all of these frequencies is possible, but incredibly time consuming.

For this reason 2 scales of measurement have been
developed in building acoustics - Octave and 1/3 Octave.

These scales group frequencies into bands, and display an average level for each frequency within that band. This reduces the number of levels but more often than not provides an accurate representation of the frequency characteristics within a sound.

A frequency band is an octave in width if the upper frequency point is double the lower frequency limit. Therefore an octave band analysis represents the energy in different octave bands. A one-third-octave band analysis is a finer analysis, where each octave is divided in three parts.

Centre frequencies for octave and 1/3 octave data bands can be seen in the table to the right.

Octave	Third
16	16
	20
	25
31.5	31.5
	40
	50
63	63
	80
	100
125	125
	160
	200
250	250
	315
	400

Octave	Third
500	500
	630
	800
1000	1000
	1250
	1600
2000	2000
	2500
	3150
4000	4000
	5000
	6300
8000	8000
	10000
	12500

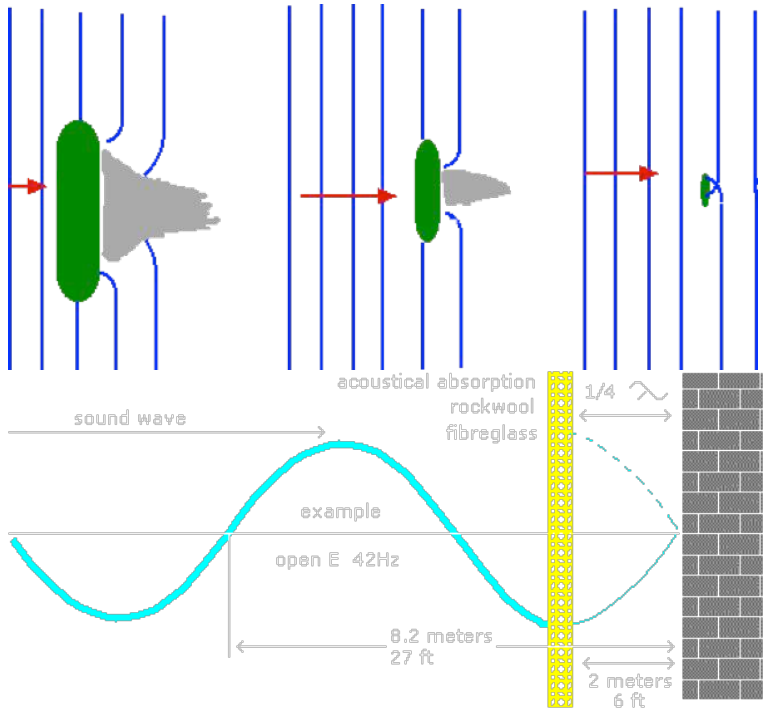
THE IMPORTANCE OF WAVE LENGTH

The wavelength of a sound is important since it affects the way sound and a given structure will interact. For example,

A large structure compared to a sound wavelength, will cover a fair portion of the wave, if not multiple waves, meaning that a shadow will appear on the far side of the structure.

If the size of the structure is reduced to below ½ the wave length, sound will now bend past the structure, considerably reducing the size of the sound shadow on the far side of the structure, If the size of the structure is reduced further, more and more sound will bend around the structure, reducing the size of the shadow further.

The second image shows part of a sound wave passing into an absorbing structure. As can be seen from this image, as the wavelength of sound is reduced, a greater portion of the sound will be held within the absorbent material. For this reason, an absorbent material will also provide a higher degree of absorption at high frequencies.



TIME

Along with Magnitude, Frequency, and Wave Length, Time is a critical component when describing the acoustical characteristics of a sound scape.

- Sound can be considered continuous or impulsive.
- A sound can have a rhythmical characteristic or be random in nature.
- It is also possible to have a combination of all the components above. Including the addition of many other elements

However, the important aspect to consider is that all of the above characteristics are time dependent, meaning that when one studies a given sound or acoustical environment, it is fundamental to consider the time span over which the assessment is carried out.

In addition, it is also important to consider that statistical analysis may be used to identify the above characteristics. Hence when one is looking at a sound scape, the average level, the peak level and/or the minimum level may be used to describe the sound over one of two different time spans.

https://youtu.be/DFx4CxrKk_Y

TIME

Equivalent continuous sound level The most widely used unit is the equivalent continuous A-weighted sound pressure level (LAeq, 7). It is an energy average and is defined as the level of a notional sound which (over a defined period of time, T) would deliver the same A-weighted sound energy as the actual fluctuating sound.

Percentile level

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

LA1, T - This is the A-weighted level exceeded for 1% of the measurement period. It is often used to represent typical maximum levels that occur during the measurement period. LA10, T - This is the A-weighted level exceeded for 10% of the measurement period. It is often used to represent the sound level from road traffic.

LA90,7- This is the A-weighted level exceeded for 90% of the measurement period. It is often used to represent the background level.

Maximum and minimum sound levels LAmax, T.This is the maximum sound pressure level measured during the measurement period T. LAmin, T is the minimum sound pressure level measured during the measurement period T.

Sound level meter time constants To give meaningful results, sound level meters use sound pressure levels averaged over short intervals (within the overall measurement period, T). Time constants for this averaging, defined in international standards, include 'fast' (125 ms) and 'slow' (1 s).The percentile levels described above are affected by the choice of time constant. By definition, all percentile levels must be measured with the fast time constant.

LAeq, T is not affected by the sound level meter time constant. LAmax,7"and LAmin, Tcan be measured with either fast or slow time constants so it is important that the results state which time constant has been used.

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ACOUSTIC & PERCEPTION: HOW WE INTERPRET SOUND

Facade Lecture Notes

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ACOUSTIC & PERCEPTION: HOW WE INTERPRET SOUND

LOUDNESS

Loudness is one of the core acoustic components used to describe sound. Loudness is a subjective quantity, dependent upon both the magnitude (the size) of the sound wave and the way our ears interpret this wave.

As noted, our ears can detect a change in level which is 10 million times louder than the quietest detectable sound. This range allows us to hear a pin drop followed by a plane taking off. Putting this into context, if we placed our hand on ice or in hot water, it would become uncomfortable in a short period of time, and it wouldn't be long before damage occurred. In numerical terms, our skin has a dynamic range of ≈70°, while our ears however have a dynamic range of 10,000,000,000.

Our body therefore reacts evenly (linearly) to changes in temperature. Our ears however, do not work in this way. As a result, they can only detect a change when there is a considerable increase or decrease in level.

Meaning we can hear the difference between 1 & 2, 2 & 4, 4 & 8, 8 & 16, 16 & 32, 32 & 64 and so on. Were a difference between 1 & 1.1, 10 & 11, 100 & 110 etc is undetectable. It is this inability to hear small changes which allows the human ear to hear a pin drop, followed by a jet taking off.

These three videos demonstrate the above effects, i.e. these videos illustrate the way our ears work. In all videos, the Rolling Stones Logo represents a visual and representation of a unit of sound.

Video 1 - The sound level is then increased by a factor of two i.e. 1, 2, 4, 8, 16, 32, 64, 128, 256 and 512 units of sound. However, the audio sounds like it is simply increasing by 1,2,3,4,5,6,7,8,9 and 10. Video 2 -   Plays 100 and 101 units of sound intermittently. In this instance, our ears cannot detect a change in sound level.

https://youtu.be/JxK_3s8zr2E

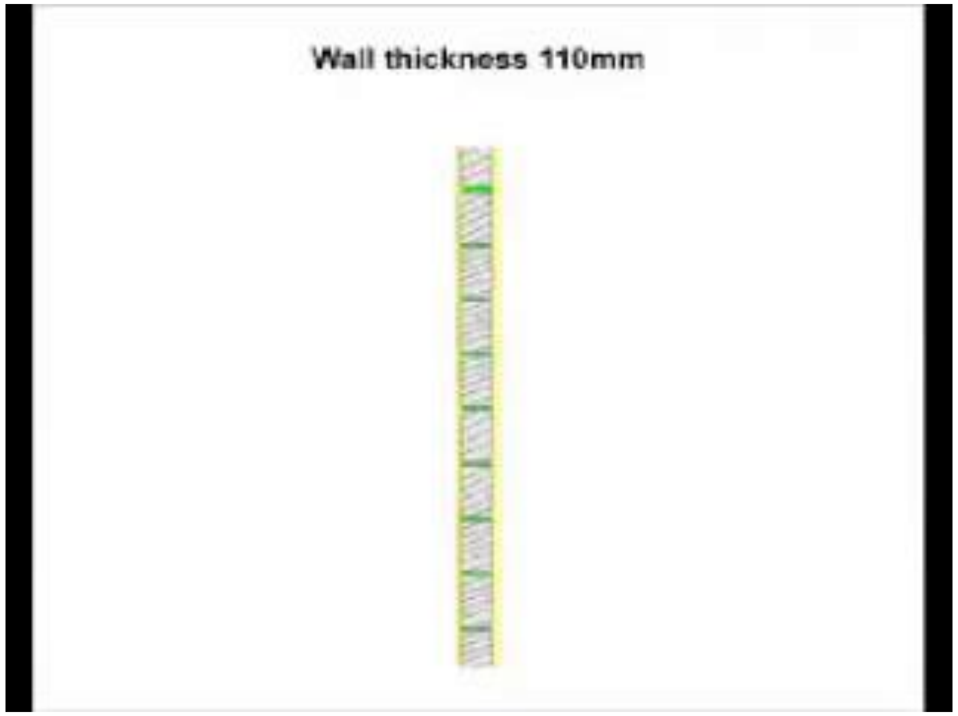
https://youtu.be/nSSh6isSSCw

https://youtu.be/HiJSa4j7osg

WHY ARE THESE FACTORS IMPORTANT?

These examples illustrate how the structures we design are dominated by the way our ears work.

Example 1 – Since our ears work in a logarithmic manner, the thickness/mass of a structure needs to be doubled before we notice a reasonable change in level. This video shows the effect of changing the thickness of a wall and its effect on sound insulation. Example 2 – This second video shows the effect of adding a layer of plasterboard to a block wall. Since there is no real change in the mass of the wall, the effect on the sound insulation provided by the wall is minimal.



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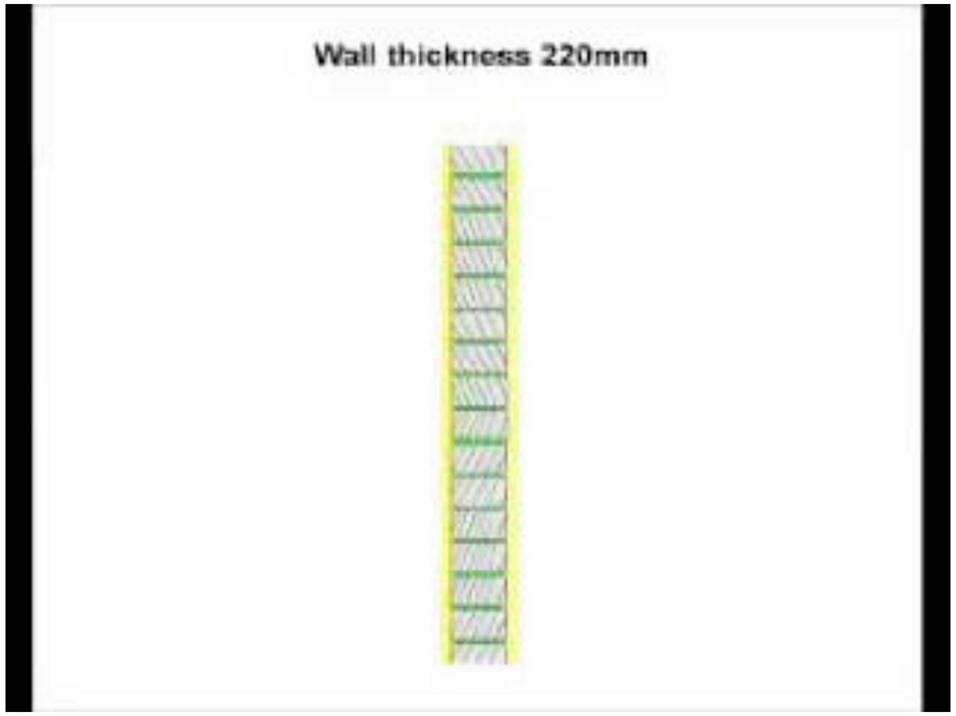


https://youtu.be/xgB-lVtfKyc

DB - DECIBEL

As noted, our ears have an impressive ability to hear a huge range of sound levels, without being damaged. However this ability use to only hear a change in levels.

The smallest sound we can hear has a Sound Power level (See page XX) of about 0.000,000,000,01 watt/m2 (a pin drop) and the threshold of pain is around 1 watt/m2 (a jet taking off), this is a range of 1 to one thousand million.

As seen some very large numbers need to be written down to represent a sound wave. In addition to this, we need a method showing that we can hear the difference between 1 and 2 but not 100 and 101.

Alexander Graham Bell, the Scottish telephone engineer, simplified converting these enormous numbers into logarithms so the threshold of hearing would be 0 and the threshold of pain would be 12. He called them Bels. This has now been adapted to decibels, where 1 dB is equal to a tenth of a Bel, increasing Bell's range from 0 - 12B to 0 - 120dB

An important aspect of the Decibel (dB), is that it is not a unit in the sense that a meter or a kilogram are well-defined units of distance and weight. A decibel is the ratio between two sound levels - the measured sound pressure level and the minimum sound level a person with good hearing can detect.

$$L_P = 10 * log_{10}\left(\frac{P}{P_o}\right) = 10 * log_{10}\left(\frac{P}{20\mu Pa}\right)$$

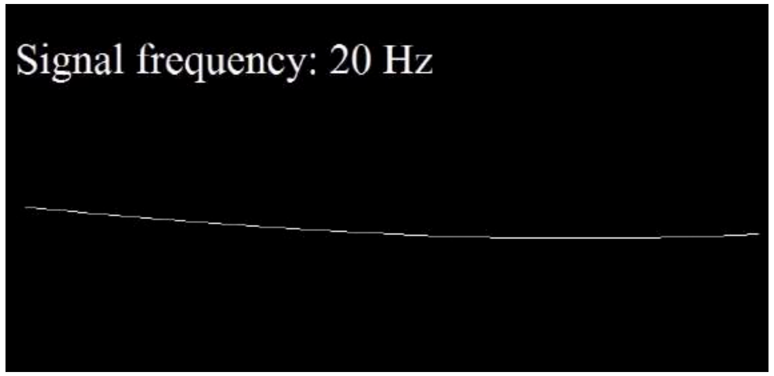
EQUAL LOUDNESS CURVES COPY

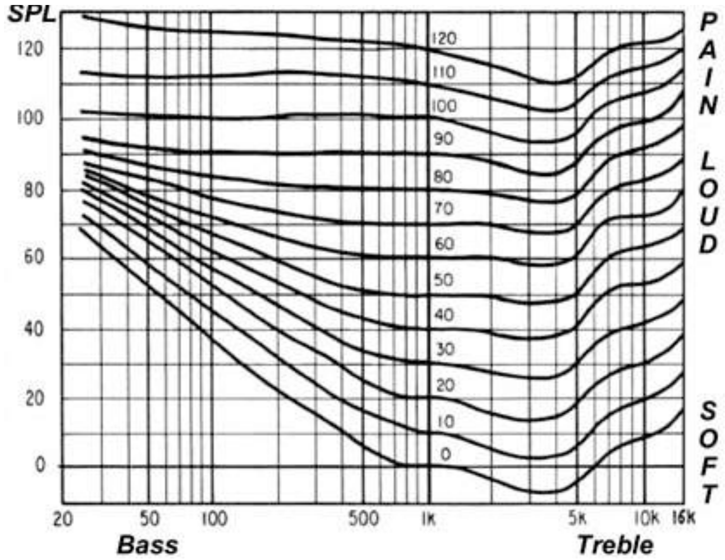
In a similar way to sound level, our ears do not offer the same levels of importance to all frequencies and therefore different frequencies with equal magnitude are heard at different levels.

This is an important factor when designing buildings, as we need to pay more attention to the frequencies which our ears are most sensitive to.

The graph to the right illustrates how the ear is more
sensitive to certain frequencies. The curves in this graph are known as equal loudness contours. Weighting networks
reduce the sound pressure level at low frequencies to compensate for the low sensitivity of the human ear at these frequencies. Three such weighting networks are usually provided in a sound level meter, referred to as A, B and C.

Ignoring minor details, weighting network A is an inversion of the 40 phon contour, and weighting network B, is that of the 70 phon contour. Weighting network C is virtually flat above 63HZ and below 8kHz. A graph showing these curves can be shown to the right.





A WEIGHTING

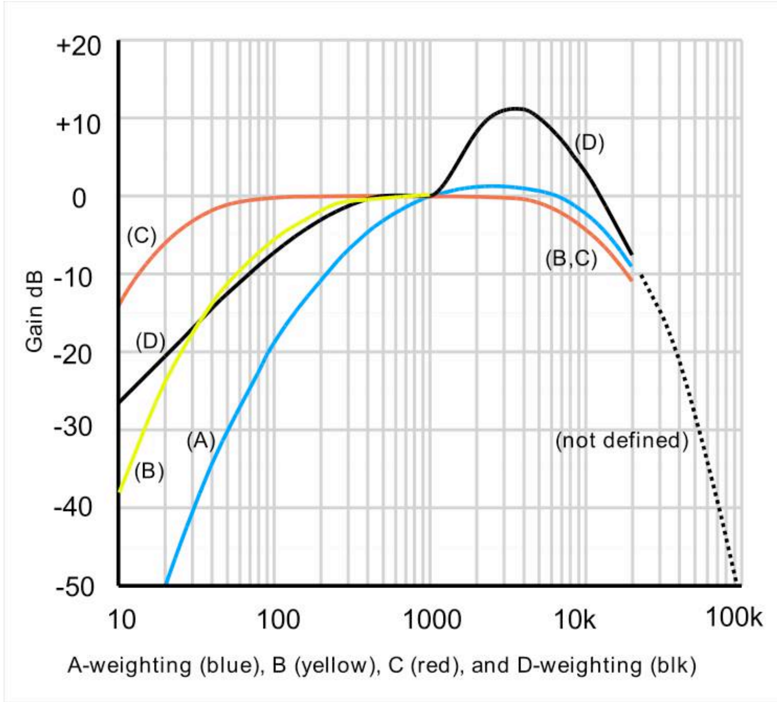
An important factor to consider is that our ears do not have the same sensitivity to all frequencies. A Sound level meter, however, has a flat response to all frequencies. A weighting is, therefore, a method of approximating this flat response, to represent the human ear sensitive to different frequencies.

More importantly, A weighting is applied to the 1/3 oct or oct data, and the results are summed together allowing sound levels to be expressed as an overall single figure value, in dBA.

For clarity and convenience, the A' is often included in the acoustic descriptor, eg L**A**eq, For example, A-weighted levels can be quoted as 55 dB L**A**eq.

The figure on the right shows the internationally agreed weighting curves used to account for the way our ear works, these are called A, B and C.

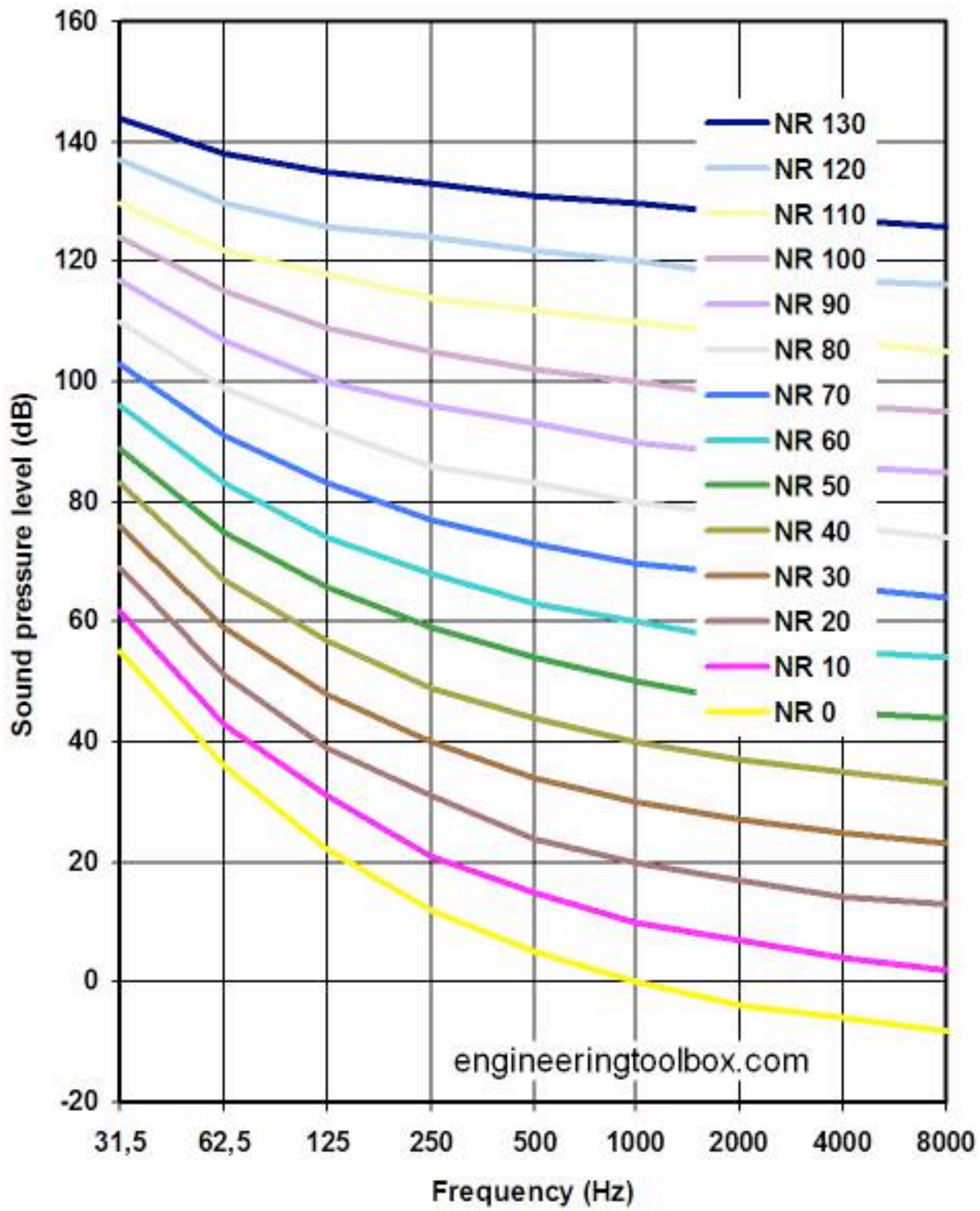
The A-weighting curve is the only one normally used with the field of construction.



W - WIGHT LEVEL

Another common system for producing a single number rating is to specify a number of octave band levels which should not be exceeded. The Noise Rating (NR) system is an example of this. The following graph shows curves labeled NR20, NR25 etc. with the numbers corresponding to the value at 1000 Hz.

For a noise source to be classed as, for example, NR25, no octave band noise level may exceed the values shown above for the NR25 rating. This approach is most often used in specifying building services noise levels. eg the ventilation noise in a theater should normally not exceed NR30.

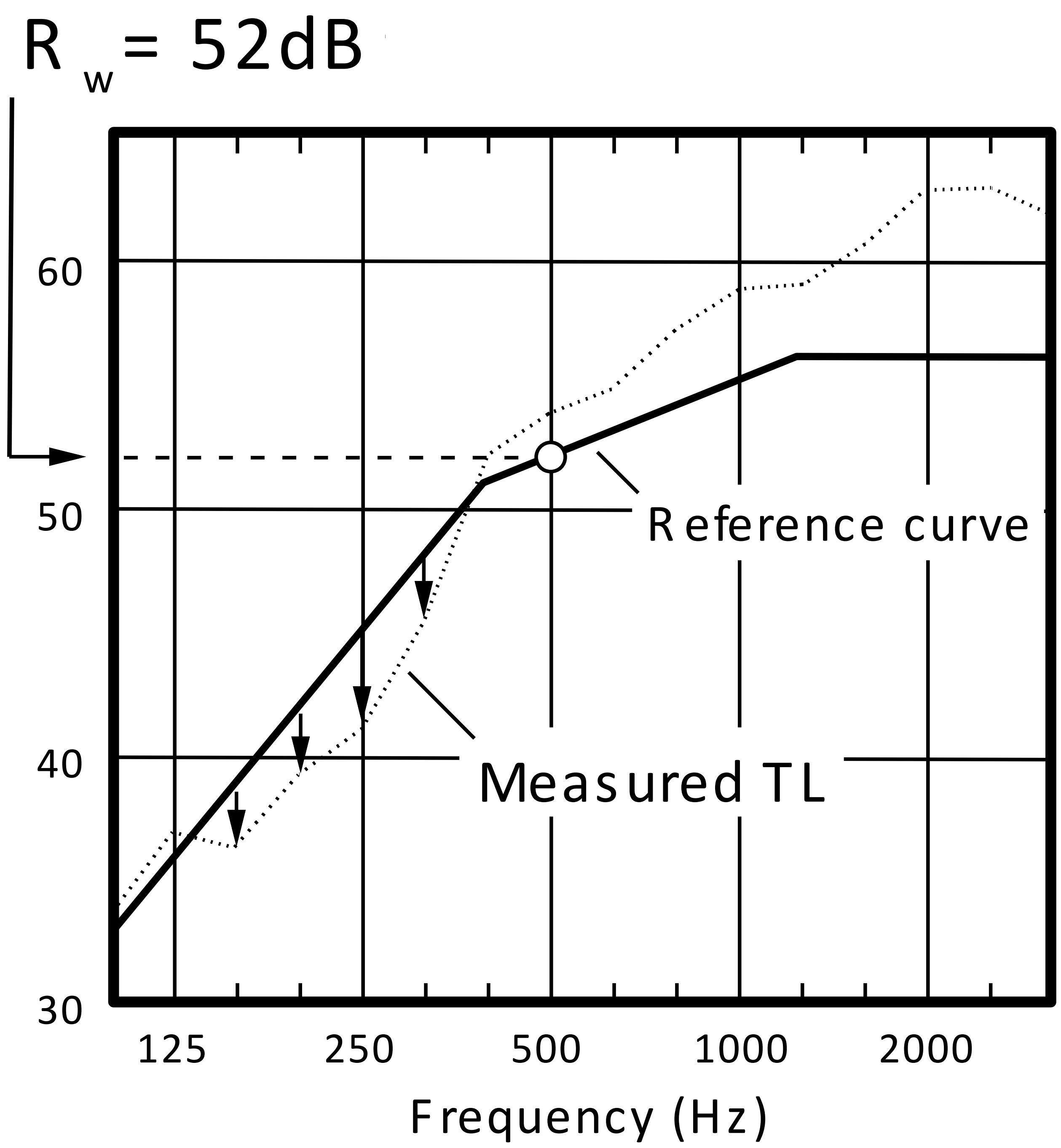


NR - NOISE RATING

Most constructions provide higher airborne insulation against mid and high frequency as speech) than low frequency sounds (such as the bass in music).

This typical characteristic is defined in BS EN ISO 717-1:1997 as a rating curve that can be applied to one third octave band values from 100 Hz to 3.15 kHz.

The rating curve is used to calculate the following single-: quantities: weighted sound reduction index ,Rw, weighted apparent sound reduction index, R'w, weighted level difference, Dw; weighted standardized level difference, DnT,w: weighted BB93 standardized level difference Dn(Tmf.max),w



NR - NOISE RATING

Weighted Difference level (Dw) -The most basic index is the Weighted Difference level Dw. This index is defined by measuring in decibels (dB), the noise level produced on each side of a building element under test (e.g. a wall) when noise is produced in a room on one side (or outdoors) and measured both in the room where the noise is produced and in the room on the other side of the element under test. This measurement may be carried out by measuring the levels in octave bands, or in 1/3 octave bands. (the latter is normally used for most applications).

The minimum requirements of the standards require for the frequency range from 100Hz to 3.15 kHz to be measured (16 1/3 octave bands). In some situations, measurements may be carried out in the bands down to 50 Hz and/or up to 10 kHz.

The measured levels in each 1/3 octave band (or octave band) from the source room (or area) (S) are then compared to the measured levels in the receiving room (R), and the difference is taken (S-R). this produces a measured difference level 'D' for each frequency band in the measured spectrum.

To produce a **single integer** number the measured spectrum is plotted on a graph, and compared against a reference curve (defined in ISO 717-1 for airborne sound insulation, and 717-2 for impact sound insulation). The reference curve is moved in 1 dB steps until the total of the unfavorable deviations (measured points on the graph below the reference graph) is as close to 32 as possible but not greater than 32.

Sound Reduction Index (Rw) -This is a laboratory-only measurement, which uses knowledge of the relative sizes of the rooms in the test suite, and the reverberation time in the receiving room, and the known level of noise which can pass between the rooms in the suite by other routes (flanking) plus the size of the test sample to produce a very accurate and repeatable measurement of the performance of the sampled material or construction.

RW, DW, DNTW ETC.

Apparent Sound Reduction Index - This is a field measurement which attempts to measure the sound reduction index of a material on a real completed construction (e.g. a wall between two offices, houses or cinema auditoriums). It is unable to isolate or allow for the result of alternate sound transmission routes and therefore will generally produce a lower result than the laboratory measured value. The calculation method used to produce the Sound Reduction Index takes into account the relative size of the tested rooms, and the size of the tested panel, and is therefore (theoretically) independent of these features, therefore a 1x1 panel of plasterboard (drywall) should have the same Rw as a 10x10 panel.

Normalized Level Difference (Dn) - This is an index which is measured in field conditions, between "real" rooms. It is a measurement which deliberately includes effects due to flanking routes and differences in the relative size of the rooms. It attempts however to normalize the measured difference level to the level which would be present when the rooms are furnished by measuring the quantity of acoustic absorption in the receiving room and correcting the difference level to the level which would be expected if there was 10m2 Sabine absorption in the receiving room. Detailed, accurate knowledge of the dimensions of the receiving room are required.

Standardized Level Difference (DnT) - Similar to the normalized level difference, this index corrects the measured difference to a standardized reverberation time. For dwellings the standard reverberation time used is 0.5 seconds, for other larger spaces longer reverberation times will be used. 0.5 seconds is often cited as the approximate average for a medium-sized, carpeted and furnished living room. Due to not requiring detailed and accurate knowledge of the dimensions of the test rooms, this index is easier to obtain and arguably of slightly more relevance.

SOUND MASKING

An important aspect in acoustics is the fact that we can only measure and hear the loudest sound taking place at a given time. This is because the louder sound masks the quieter sound.

Sound masking has many negative effects, for example; When you are unable to hear a speaker in an auditorium, this is likely to be as a result of the difference between background noise and the spoken voice being too small. If the speaker were to raise their voice the effects of masking would be reduced, and the voice would become intelligible.

In the case of an auditorium, the spoken voice needs to be projected over a large area which makes it difficult to increase the level. As such, background noise levels within auditoriums are designed to very low levels, such to increase the difference between background noise levels and speech levels, making the speaker easier to understand.

Sound masking also has positive effects however, and moderate background noise levels can be beneficial in covering unwanted noise. For example; In large open plan offices noise transfer between workstations can be a significant
issue.

The more intelligible speech transfer, phone rings and so on, the greater the level of disturbance between each workstation. In this case it is important to ensure that background noise levels are high enough to mask these sounds and consequently reduce the intelligibility of noise from adjacent work stations.

SOUND MASKING- SECOND PAGE

Another good example of positive masking is with the design of mechanical plant. When designing suitable environmental plant noise from machines such as an air handling unit, it is important to consider the existing environmental noise levels.

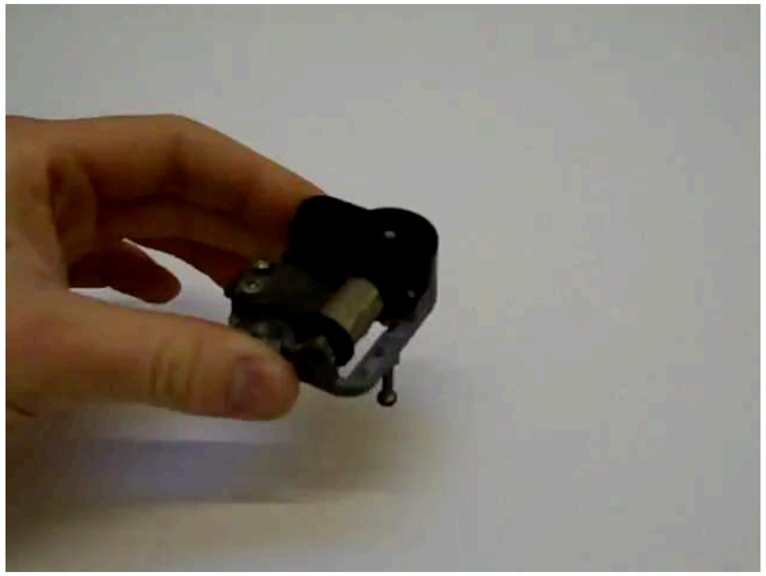
If the AHU is to be installed at the end a runway or adjacent to a motorway, it would be acceptable for the noise level from this unit to be considerably higher than that of a unit installed in a quiet part of the countryside.
This is because the sound from the runway and motorway will mask any sound coming from the AHU. The low levels of background noise in the country side means that there will be almost no masking, resulting in the noise from the AHU being heard at a much higher level.

STRUCTURE BORNE AND AIRBORNE SOUND

Within acoustics there are two main paths in which sound can travel to our ears. The first and most common is from the source, through air, to ones ears; someone speaking results in air pressure fluctuation propagating through the air to the ear. This is known as airborne sound.

The second form of sound is Structure borne, and does not come directly from the sound source, but comes as a result of vibration propagating through a structure and then
radiating off the structure as sound.

The shown video demonstrates key differences between structure borne sound and air borne sound. The sound coming from the music box is considered to be air borne sound. When the unit is placed on the table top, sound levels increase as a result of the vibration. The sound coming from the tabletop is known as structure borne sound. To prove that the sound is coming from the table surface, an acoustic cover is placed over the music box. The sound can still clearly be heard, however the air borne sound component from the music box has been removed. Including a rubber mat under the music box, results in elimination the sound coming from the music box. This occurs because both the air borne sound and structure borne sounds have been controlled. Including a rubber mat under the music box, results in elimination the sound coming from the music box. This occurs because both the air borne sound and structure borne sounds have been controlled.



https://youtu.be/9yPseCcTnsY

STRUCTURE BORNE AS A RESULT OF AIRBORNE SOUND

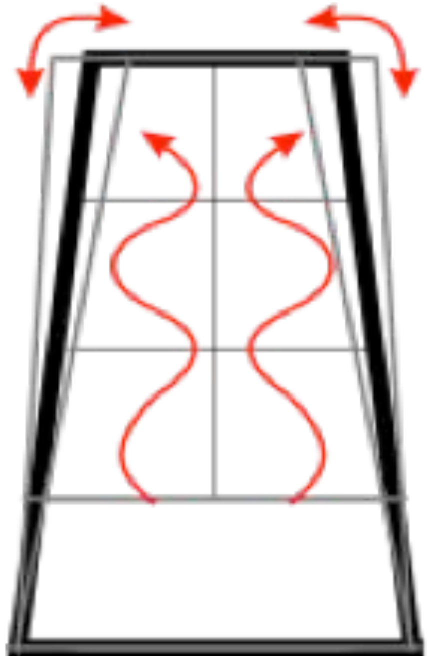
The previous example illustrates how a rotating machine can excite on the surface of a table, and in turn generates structure borne noise. It was also seen how the same machine generates airborne sound.

It must however be noted that structure borne sound is not always generated by a vibrating object. In the case of a night club or music studio, where high levels of sound are produced, the airborne sound produced by the speaker and instruments hit the buildings frame.

As per the previous example the sound causes the building to move/vibrate, as a result of the acoustic energy traveling through the building frame. Since the frame of the building is solid and stiff, if one part of the building moves, the whole building moves, resulting in sound being heard throughout the building. The propagation of sound through the building frame is known as structure borne sound. The stiffer the frame the greater the level of sound propagation.

The video to the right shows how sound causes the window in the car to move backwards and forwards. As a result of a building frame being stiff, the whole building will be moving, as per the glass in the video, meaning that sound will be transmitted through the building.

https://youtu.be/L823C8l1vwo



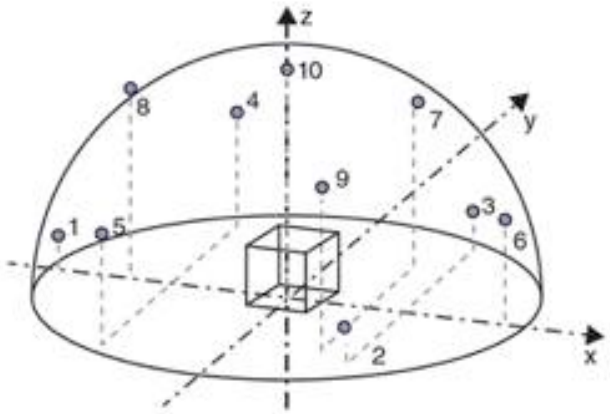
SOUND POWER

There are two ways of describing a sound source, by its sound power level or by its sound pressure level.

The Sound Power is defined as the total amount of sound energy produced by a given source and is measured in Watts. This figure is a constant and is not dependent upon the installation or position of a sound source. Sound power, in light terms, is therefore similar to the wattage of a light bulb. Sound power is measured by assessing the energy emitting through a defined area.

This is illustrated below where a hemisphere of microphones is measuring the sound emitting from a test specimen.

The sound you hear is very different to the sound power produced by the source, since the effects of distance losses, directivity, reflection and so on all contribute to the sound level that we hear. The sound level at the ear or at a microphone is defined as Sound Pressure level, or SPL.



SOUND PRESSURE LEVEL

Using light to represent sound, it can be seen from the images below that for a fixed light power level, the lux level varies considerably depending upon location, while the power of the lights does not change.

Sound works in a very similar way, where lux is replaced by Sound Pressure Level, measured in dB.

Sound Pressure is defined as the difference between the pressure produced by a sound wave and the ambient pressure at the same point in space, and is measured in Pascals (Pa).

Sound Pressure Level is the logarithmic measure of this Sound Pressure, relative to a reference value - the threshold of human hearing. This is measured in decibels.

For a sound source with a fixed Sound Power level, the measured Sound Pressure level will vary in different receiver positions.

This means that Sound Pressure Levels (SPL) must therefore always be defined at a point i.e. 1m from a given source, 5m from road and so on.

SOUND POWER - AREA

Importantly *- Sound Power on an object can be determined by multiplying the surface area of an element by the sound pressure on that element.*

TYPICAL POWER AND PRESSURE LEVELS

Sound pressure (N/m2)	SPL (dB)	Typical Environment
200	*140*	*30m from military aircraft at take off*
63	*130*	*Pneumatic hammer (operator's position)*
20	*120*	*Ships engine room*
0.63	*90*	*Heavy lorries at 6m*
0.2	*80*	*Busy street (kerbside)*
0.02	*60*	*Restaurant*
0.0063	*50*	*Conversational speech at 1m or office environment*
0.002	*40*	*Average suburban area or whispered conversation at 2m*
0.00063	*30*	*Countryside at night*
0.0002	*20*	*Background in recording studio*
0.00002	*0*	*Threshold of hearing*

Power (watts)	SPL (dB)	Example
40 million	194	Saturn rocket
100,000	170	Jet engine
10	130	75 piece orchestra peak measured over 1/8th of a second
1	120	Piano peak measured over seconds
0.01	100	Car at motorway speed
0.001	90	Voice shouting
0.00001	70	Conversational voice
0.000000001	30	Whisper

*Table * SWL of common items. We can clearly see how the use of decibels compresses some very large and small numbers onto a much more manageable scale.*

text

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INTRODUCTION TO ARCHITECTURAL ACOUSTICS

Facade Lecture Notes

CONTENTS

INTRODUCTION TO ARCHITECTURAL ACOUSTICS

- Background Noise
- Sound Insulation
- Room Acoustics

BACKGROUND NOISE

Background noise is one of the key factors affecting the acoustics performance of a building. Background noise is defined as the sound level within the building, when the building is empty but fully operational, in other words fully ventilated.

Background noise has the effect of masking sound, meaning that in educational spaces, it is important to ensure that background noise levels are sufficiently low to ensure that the spoken voice can be heard.

Within auditoriums, the above principle is also true, however the spoken voice needs to travel over greater distances, meaning that background noise levels need to be reduced further. Importantly, background noise in an auditorium affects the production taking place, when the music comes to a abrupt end, low background noise levels are required to ensure that the drama of these and other similar events is achieved.

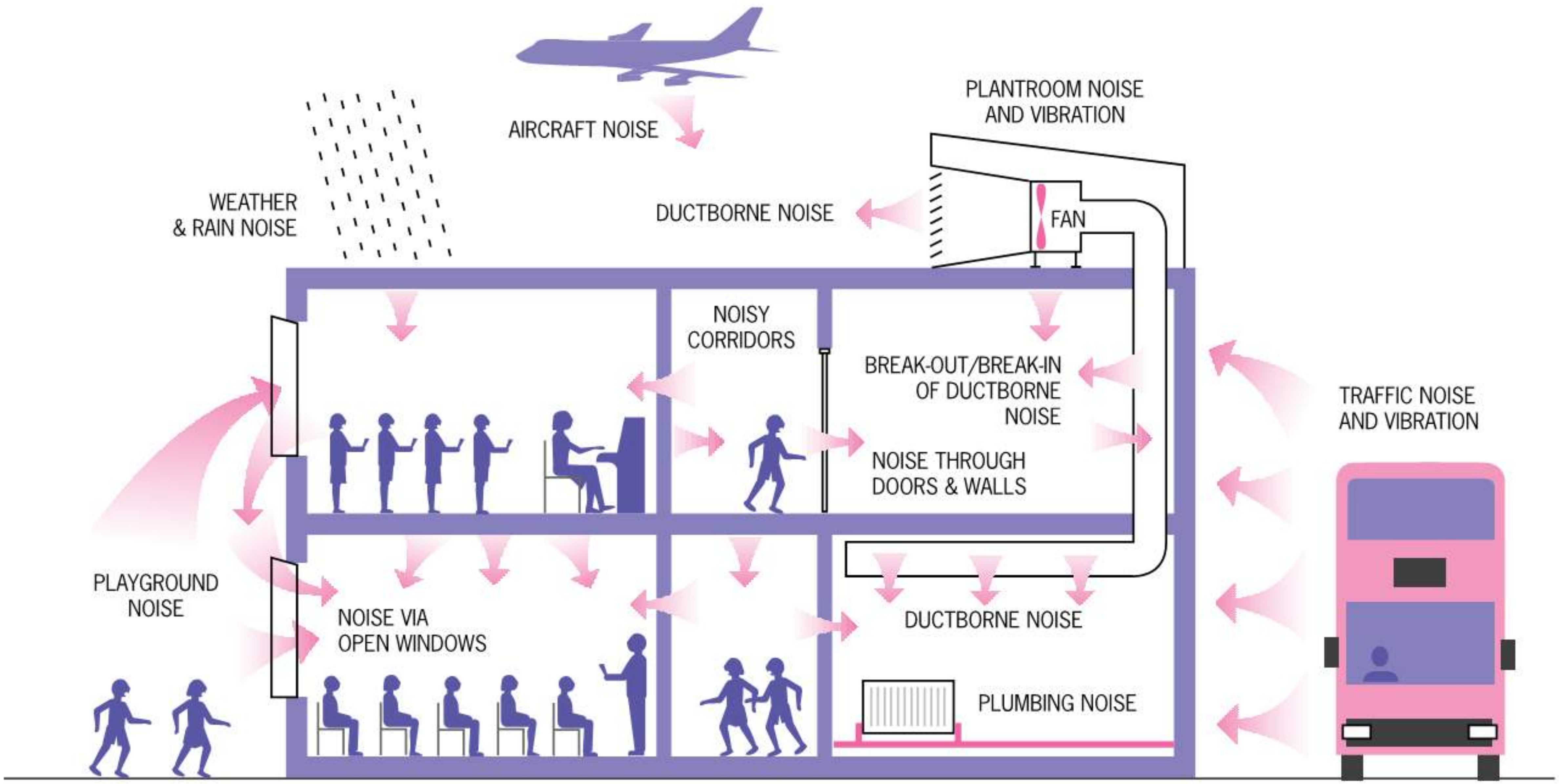
Within large open plan offices, it is important to ensure that noise levels are not too quiet. If a degree of noise is not maintained then privacy and other issues can results in problems.

In the case of Residential and Education/Health Care projects, their acoustic design is about ensuring that

disturbances are controlled.

Noise from Entertainment is different in that it is more about containing noise than it is about keeping it out.

BACKGROUND NOISE



SOUND INSULATION

Sound Insulation is the transfer of sound across a structure element or through a ventilation path. Sound insulation is a ratio of the sound passing across a structure and therefore does not guarantee a level in an adjacent room.

Airborne sound insulation

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

Measurement of airborne sound insulation

The site measurement procedures for airborne sound insulation are given in BS EN ISO 140-4:1998. Normally, pink noise or white noise is played through an amplifier and loudspeaker in the source room, to provide a high sound level across the frequency range of interest. The sound level in the source room must be high enough to ensure that the levels in the receiving room are above the background noise level. The resulting sound levels in the source and receiving rooms are measured in one-third octave bands. As the sound levels vary with location, they are averaged either across a number of fixed microphone positions or by using a continuously moving microphone. The resulting time and space averaged sound levels are denoted L1 in the source room and 12 in the receiving room.

Level difference, D D is the difference in sound levels in dB between the source room and the receiving room:D = L1 -L2dBThis level difference depends on:

• direct sound transmission through the separating element (ie separating wall or floor) flanking sound transmission through flanking elements (eg flanking walls, suspended ceilings, access floors etc)

wall and floor dimensions

reverberation time of the receiving room.

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

DnT=D + 10log(T/To) dB

BB93 standardized level difference, Dn(Tmf,max)

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

Sound reduction index, R

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

SOUND INSULATION

Apparent sound reduction index, R' -

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

The apparent sound reduction index, R', of wall or floor constructions in schools (and all other buildings), is usually lower than the laboratory measured value ofR. The difference between the results is usually due to flanking transmission and a lower standard of workmanship on site.

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

Measurement of impact sound insulation

The site measurement procedures for impact sound insulation are given in BS EN ISO 140-7:1998. Impact sound insulation is measured using an ISO standard tapping machine, which consists of a series of hammers driven by an electric motor so as to produce a continuous series of impacts on the floor under consideration.

The resulting sound level in the receiving room is measured typically in one-third octave bands. The receiving room is usually the space directly below the floor excited by the tapping machine, although the impact sound insulation can also be measured in other neighbouring rooms.

As the sound levels will vary with location in the receiving room, they are averaged either across a number of fixed microphone positions or by using a continuously moving microphone.

Impact sound pressure level, Li

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

Standardized impact sound pressure level L'nT

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

L'nT=Li-10lg(T/To) dB

BB93 standardized impact sound pressure level L'n(Tmf,max)

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

Weighted standardized impact sound pressure levels DnTw and LnTw

To reduce the impact sound pressure level data from values in frequency bands to a single-number quantity, BS EN ISO 717- 1 & 2 :1997 contains rating curves that can be applied to one-third octave band data for DnTw and LnTw levels. This curve along with a best fit method can be used to convert the one-third octave band data into a single number

ROOM ACOUSTICS

Sound in rooms

Sound within an enclosed space will reflect off the surfaces, resulting is different rooms sounding differently.

I like the analogy of comparing a dead room and a live room as to that of a pond and a swimming pool respectively. A pond contains shallow banked edges, meaning that waves from say a rock being thrown into the pond, pushes up the bank and slowly rolls back into the pound. The energy in the wave is therefore absorbed and is not reflected back into the pond, meaning that only the original wave in the pond will be seen propagating through the pond. Within a swimming pool, the hard vertical edges of the pool reflect all the sound back into the pool. Resulting in the presence of multiple waves, which in turn cover the original wave from the rock.

Room finishes therefore have a considerable impact upon the way a given room sounds. If a room is finished with hard surfaces, the listener's impression is comparable to the visual impression gained in a room full of mirrors: too bright (= not understandable), too glaring (= too loud), and there is a lack of orientation. The reason for this is the sound bouncing off hard surfaces, just like light is reflected by very bright surfaces.

But in contrast to light, the time component - i.e. when the reflections reach the ear - plays a crucial role with sound. This is easiest to understand if we emit a brief impulse, i.e. a bang, and track the propagation in a model by way of sound waves.

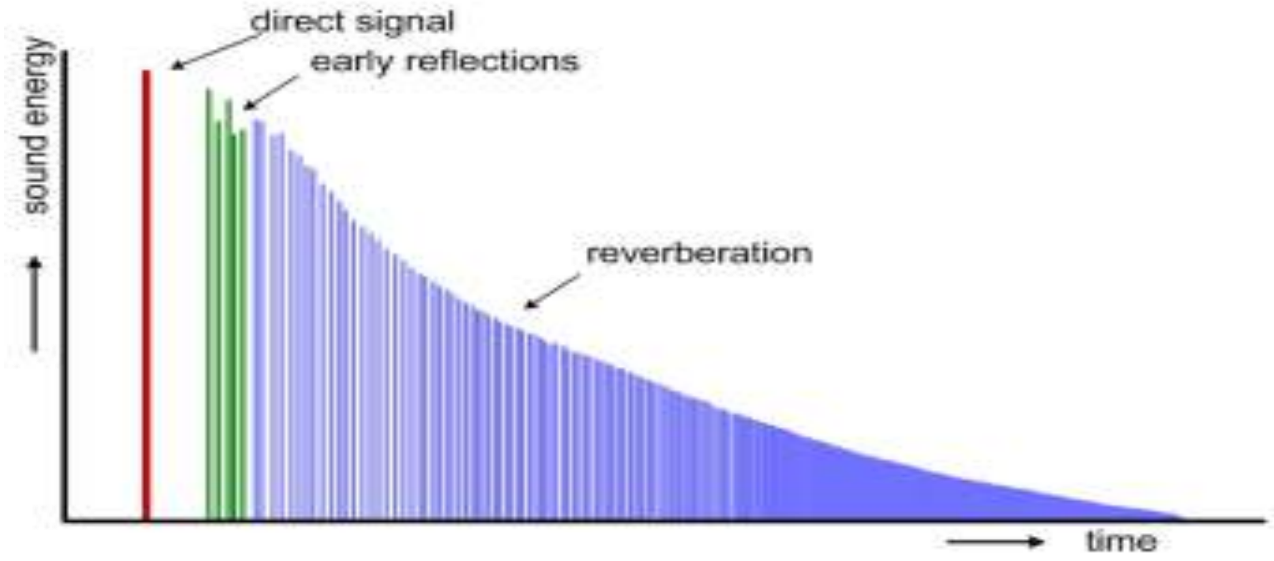
The so-called direct sound reaches the listener first because it has to cover the shortest distance. It is followed by reflections from the ceiling and walls. Just like light, sound is reflected from flat surfaces such that the angle of incidence is equal to the angle of reflection. The inter-aural time differences are determined by the paths the sound waves have to travel in the room.

The number of reflections increases with time, but the energy of the individual reflections decreases owing to the spherical sound propagation and the losses due to absorption during the reflection process.

The figure above shows such a schematic echogram - also known as an echograph or room impulse response. When we speak or play music in a room, the signals are superimposed on each other in the same way and reach the ears of the listener thousands of times with corresponding time delays and weakening.

Direct sound -

We use the direct sound to localize the sound source, i.e. it enables us to position a source in space even with our eyes closed - and we are able to do this even though the energy of all reflections together is considerably greater than that of the direct sound alone. If there are obstructions between the listener and the sound source, the direct sound can be weakened to such an extent that our localization is impaired. Guaranteeing an unobstructed direct sound propagation is therefore always important when acoustic intelligibility and clarity are important.



Early reflections

Reflections that reach the listener within 50 ms of the direct sound increase the intelligibility of speech owing to the ability of the ear to integrate those sounds. An inter-aural time difference of 50ms corresponds to an approx. 17m difference in the lengths of the paths travelled by the direct sound and the reflection. The intelligibility of music is further enhanced by reflections with an inter-aural time difference of up to about 80 ms (= 27 m difference in the paths travelled). Intelligibility means the distinguishability of successive reflections in a musical performance in a closed room despite superimposed diffuse sound.

Based on these fundamental relationships, it is possible to derive direct consequences for the room geometry and, in particular, for the line of the ceiling in larger venues. Such rooms should be designed so that early reflections are directed towards the listeners. In addition, if the early reflections reach the ears of the listeners from the sides, this enhances the three-dimensional acoustic impression. This feeling of being "surrounded" by the music is these days an important quality criterion for concert halls in which symphony orchestras perform.

Reverberation

The early reflections are followed by the reverberant sound in which the density of the reflections increases and in many rooms the energy decreases at an approximately exponential rate. The reverberation of a room is the most important acoustic quality feature, especially since the reverberation, in contrast to the early reflections, is usually not, at best only marginally, dependent on position.

Which reverberation time is desirable for which room depends entirely on the function of that room. In cathedrals and churches, for example, a long reverberation time reinforces the sacred character and provides organ and choral works with the proper acoustic environment. In contrast to this, the reverberation time in lecture theatres should not be too long in order to avoid successive syllables being lost in the reverberations (although it is possible to adjust for this by speaking slowly).

Disturbing reflections

If high-energy reflections occur in the reverberant sound, these may be perceived as echoes, i.e. we hear the sound signal twice. Flutter echoes are periodically recurring reflection sequences which, for example, can build up between parallel wall surfaces. Such echo effects can disrupt music and speech quite considerably and should therefore be avoided.

Reflection and absorption of sound

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

Absorption coefficient

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

Absorption classes

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

Scattering coefficient, s

When sound is reflected from a surface it is partly reflected in a specular direction (ie the angle of incidence equals the angle of reflection) and partly scattered into other directions.

The amount of reflected sound energy that will be scattered is given by the surface's scattering coefficient, s where a perfectly smooth surface giving pure specular reflection has a scattering coefficient of 0 and a very irregular surface scattering all sound away from the specular direction has a scattering coefficient of 1. Scattering coefficients are a relatively new measure in room acoustics so there is little data currently available but they are important in room acoustics computer modeling.

Reverberation time, T

After being emitted from a source, sound waves are repeatedly reflected from room surfaces and, as a result of absorption, gradually reduce in strength.

The reverberation time, T, of a space is a measure of the rate at which the sound decays. It is defined as the time taken for the reverberant sound energy to decay to one millionth of its original intensity (corresponding to a 60 dB reduction in the sound level).

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

T=0.161 V/(S1+S2+Si...) (total absorption in the room)

where Si and (<i) are respectively the surface area and absorption coefficient of each surface / in the room. An example of the application of this equation is given in Appendix 6**.**

Mid-frequency reverberation time, Tmf

The sound absorption of surfaces usually varies with frequency and therefore the reverberation time in a space also varies with frequency. In BB93 the reverberation time criteria are set in terms of the average value of the three octave bands, 500 Hz, 1 kHz, and 2 kHz, denoted as 7mf

Speech Intelligibility

Us a method of describing how ineligible sound is within a spaces. Speech intelligibility is a function of the source sound level (higher the better), background noise (lower the better), and rooms acoustics.

Other acoustic measures

Sound heard in a room generally comprises an extremely complicated combination of many reflected and scattered sound waves. This situation is made manageable by considering only the overall statistics of the sound field such as the reverberation time. Unfortunately, this does not convey all the intricate

Speech Transmission Index, STI

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

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

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FIELD AND SOURCE CONDITIONS

Facade Lecture Notes

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FIELD AND SOURCE CONDITIONS

FREE FIELD AND DIFFUSED FIELD

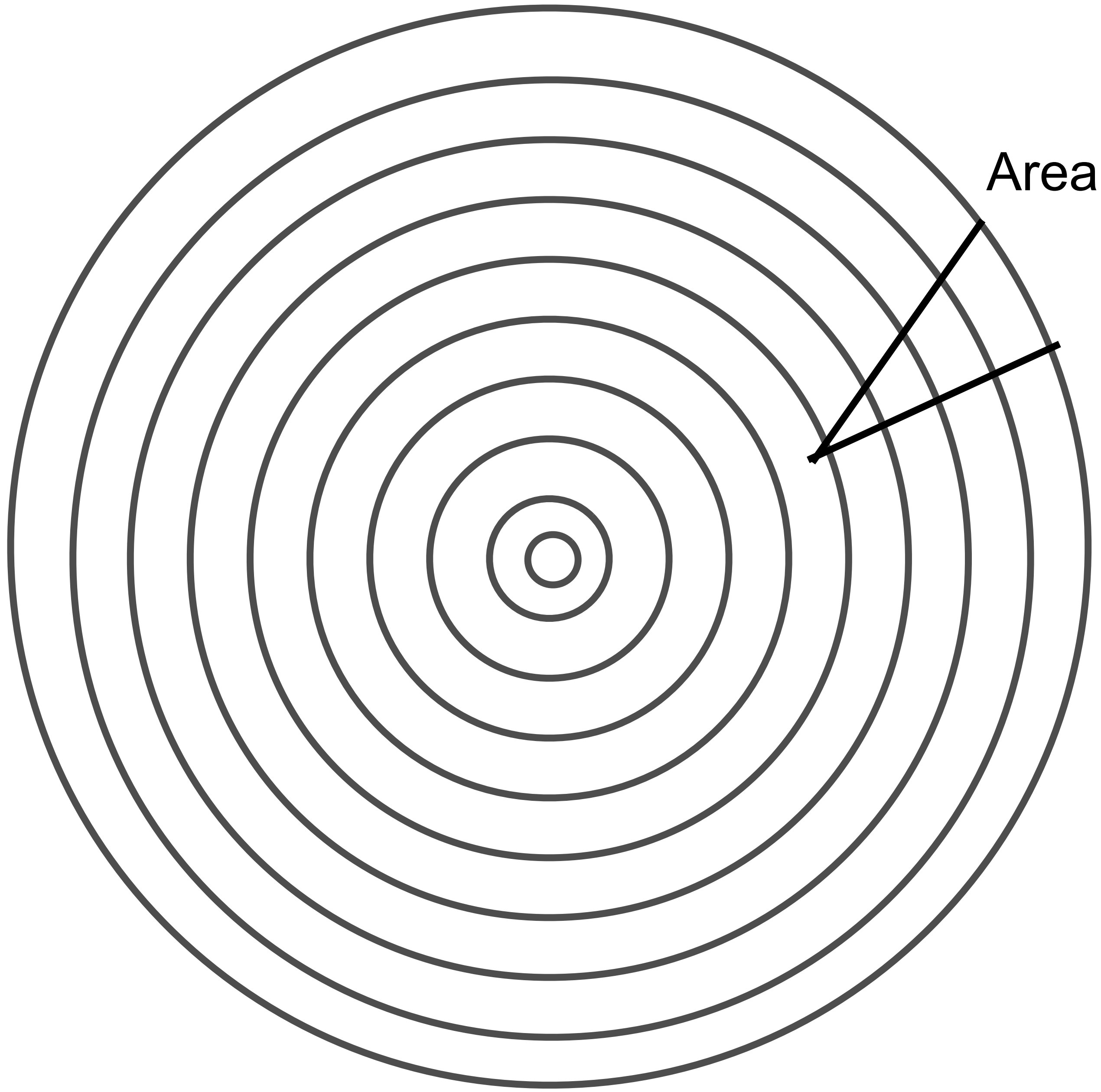
text

SOURCE TYPE - POINT SOURCE

Area = r^2

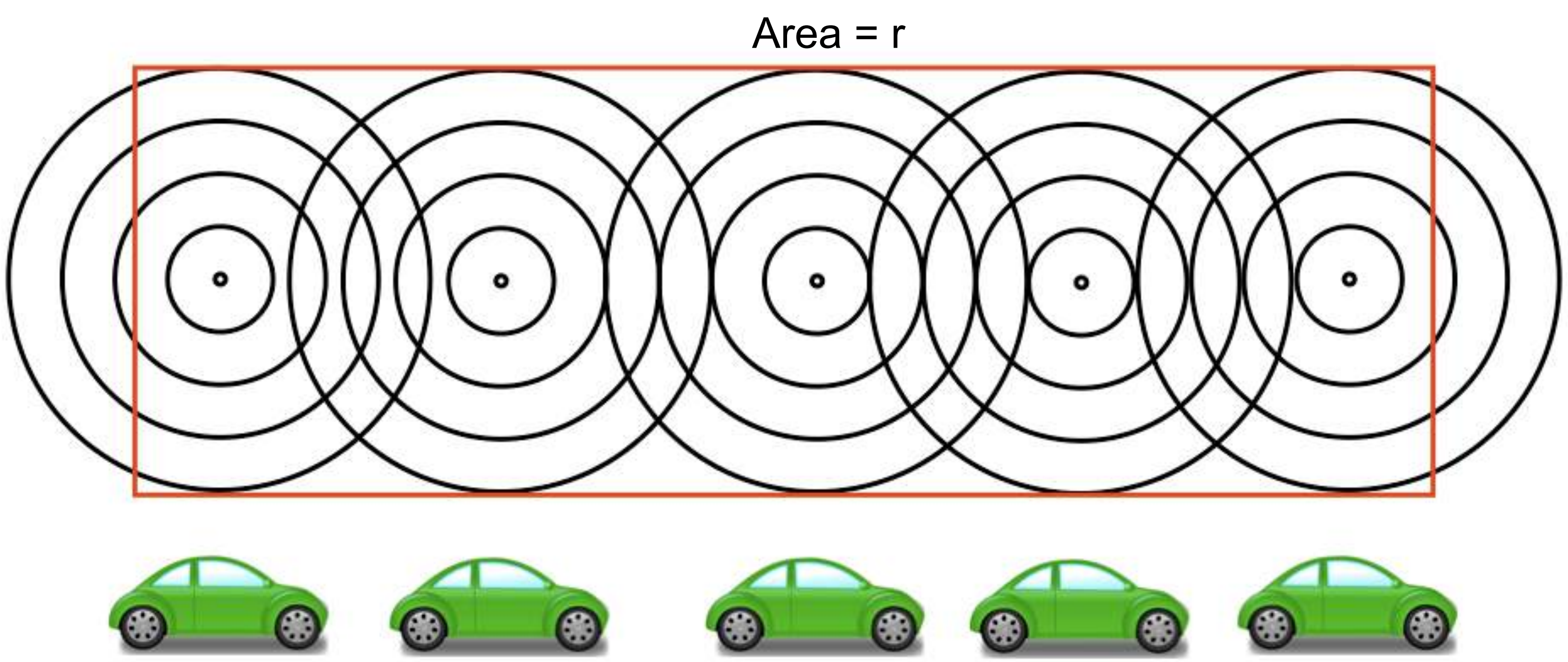
Loss over distance=Area=10*log (r^2)

Loss over distance = between 10*log(r^2) & 20 *log(r)



SOURCE TYPE - LINE SOURCE

Area = r Loss over distance = Area = 10*log(r)

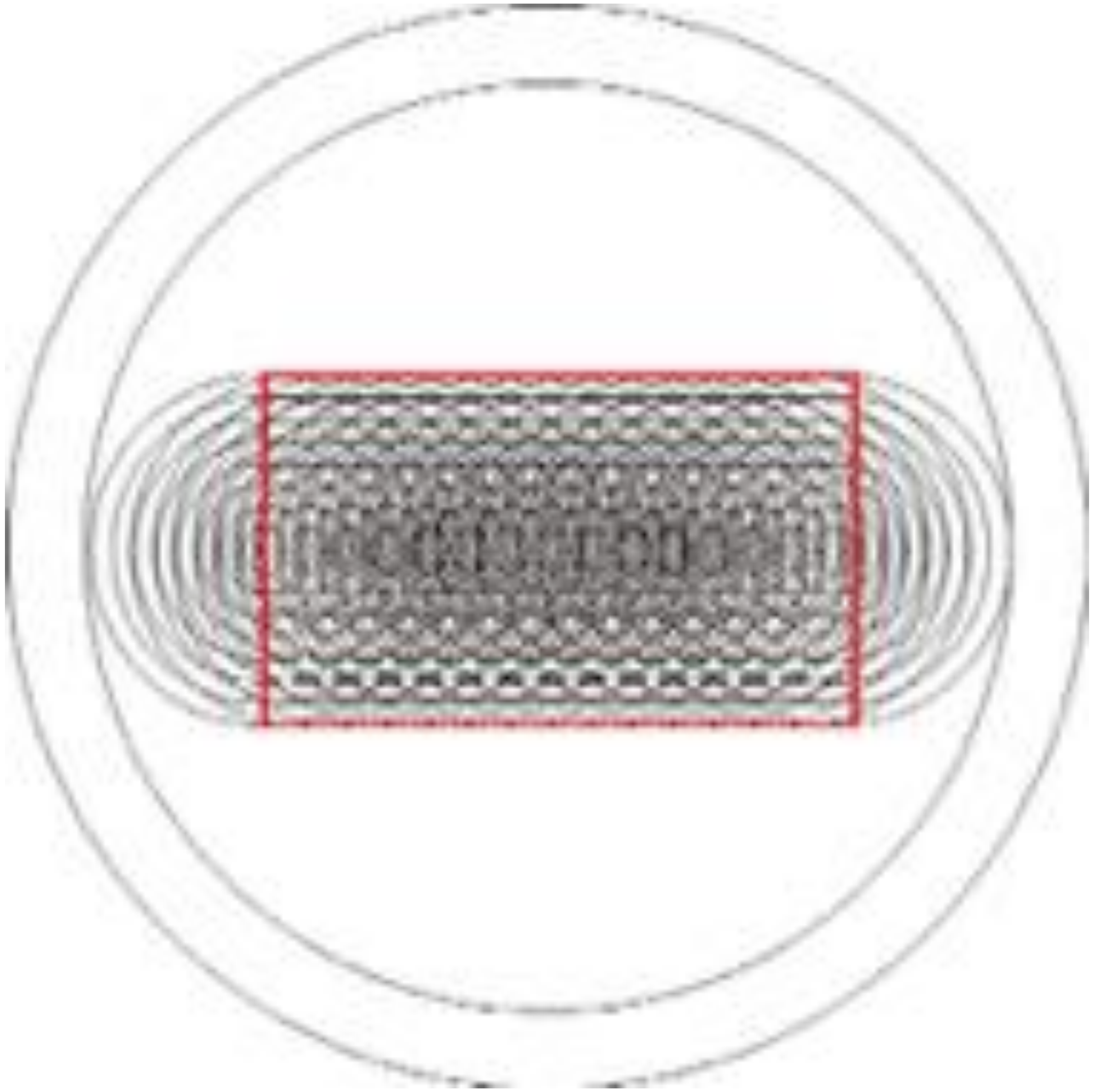


DECAY OF SOUND - LINE SOURCE

DECAY OF SOUND - POINT SOURCE

DECAY OF SOUND - POINT SOURCE / LINE SOURCE

text



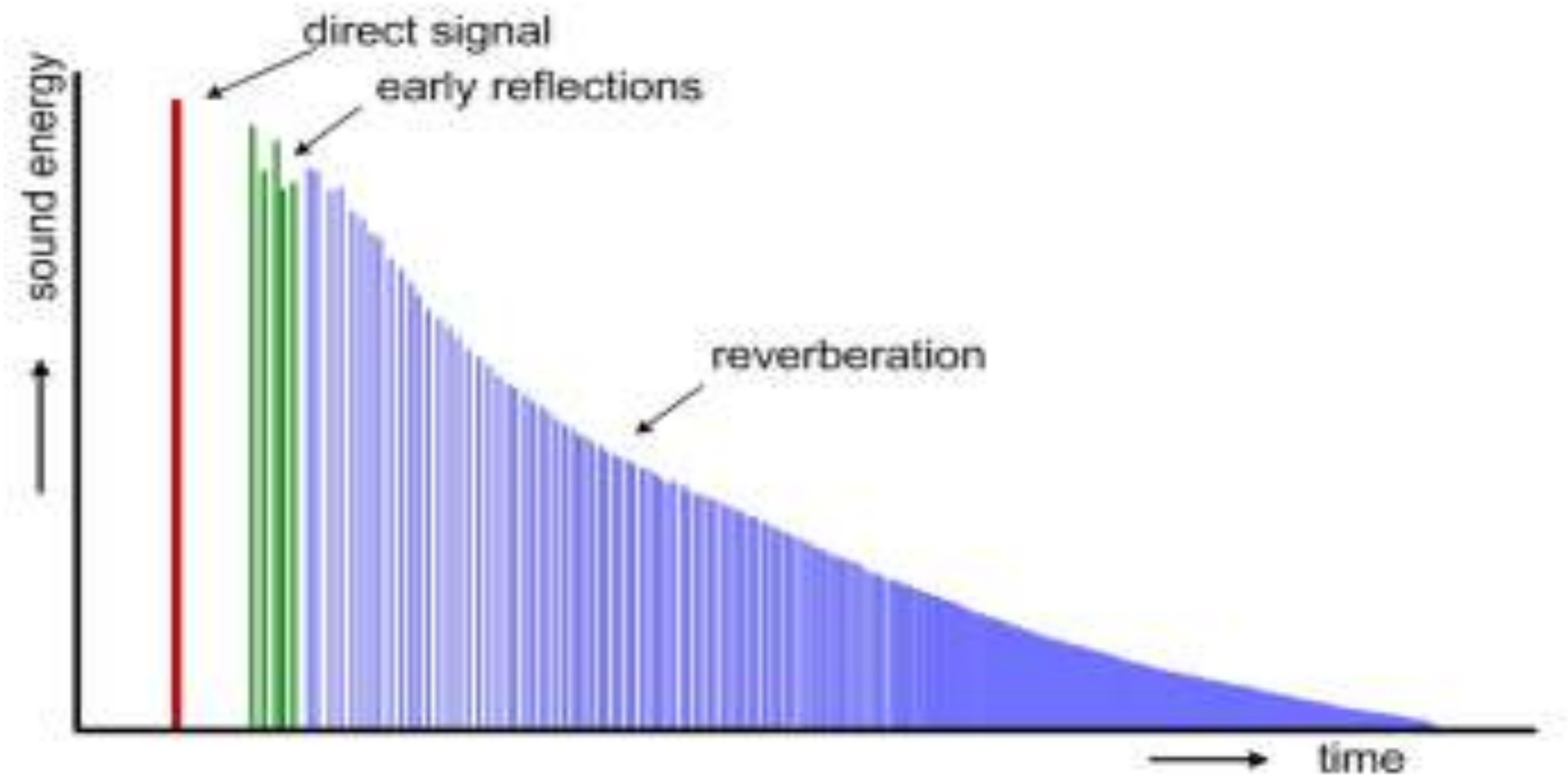
DECAY OF SOUND - POINT SOURCE / LINE SOURCE

SOUND WITHIN ROOMS

Sound within a room acts differently to sound outdoors. When sound is generated in a room, the sound that reaches the listeners ears is made up of the direct sound and
reflected sound from the surfaces in the room.

The direct sound is the sound taking the shortest path between the sound source and the listener. The reflected sound is that coming off the surfaces of the wall within the space.

These reflections are typically split into two, early reflections: those arriving within 50ms of the direct sound, and the late reflections; where late reflections are the reverberant tail of the impulse response of the room.



DECAY OF SOUND IN ROOMS

As noted above, sound from a point source decays at -6 dB for each doubling of distance. The sound between two points in a room does not follow this simple rule.

The sound in a room will be dependent upon the levels of the direct sound and the levels of the reverberant sound field, where the reverberant sound field is proportional to the levels of soft treatment in a room, which is a function of its reverberation time.

In simple terms as one approaches the source, the sound will be dominated by the direct sound, meaning that the decay will be close to the inverse square law i.e. -6 dB for doubling of distance. However, when the reflected sound is the dominate source, the sound level in the spaces will be maintained to be fairly constant over distance as shown in the graph to the right.

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ENVIRONMENTAL ACOUSTICS

Facade Lecture Notes

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ENVIRONMENTAL ACOUSTICS

POINT SOURCE

Although the best way to find out how loud something is direct measurement, this is often not possible. The noise source might not yet be on site, or we might not have access to the location, for example a soon to be built stadium or a resident's garden.

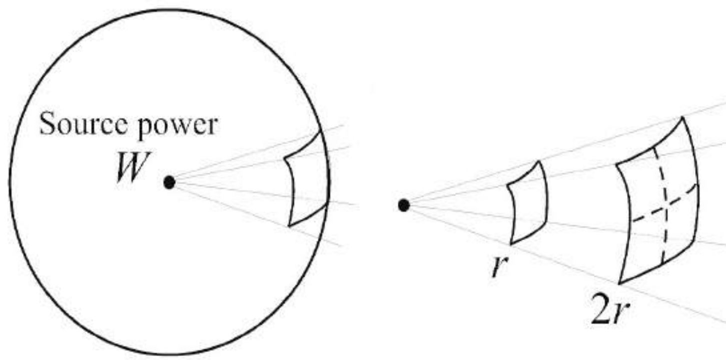
In such cases it is necessary to model the sound source. The equations we use to make many assumptions, the main two are: the nature of the source (e.g. point source or line source) and the modes of propagation (e.g. spherical or cylindrical).

Manufacturers often give the sound power of their equipment. To find the sound pressure level at a distance r from the source we can use:

$$SPL = SWL - 20log_{10}(r) - C.$$

Where SPL is the sound power level and SWL is the sound power level. For spherical spreading C=11, for hemispherical spreading C=8.

This equation expresses, as shown in Figure *, sound from a point source falls off with r^2 (note, 20log(r) = 10log(r^2)). This leads to the conclusion that sound from a point source falls by 6dB for every doubling of distance, r.



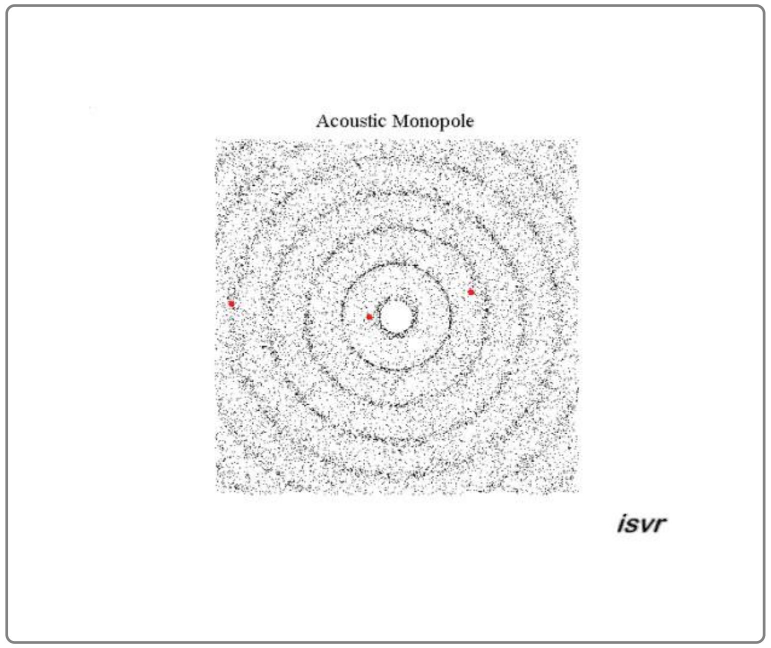
POINT SOURCE

Sound will drop off with r^2 from a point source because as the distance doubles the area of the sphere the sound is smeared across doubles. [8] *replace with mcmullen 8.4

If the ground between the source and the receiver of the sound is acoustically reflecting, these reflections act as a source too, doubling the amount of sound in the environment. The doubling of the number of identical sources increases the SPL by 3 dB (this will be discussed later). Therefore if the intervening ground is reflecting, it will count as another source and equation * will be replaced by (note how the minus 11 has changed to minus 8, i.e. an addition of 3dB):

SPL = SWL – 20log(r) – 8 eq*

If you don't know whether ground is absorbing or not, just assume it isn't as this will give a more cautious estimate of any likely disturbance. If you don't know whether ground is absorbing or not, just assume it isn't as this will give a more cautious estimate of any likely disturbance.



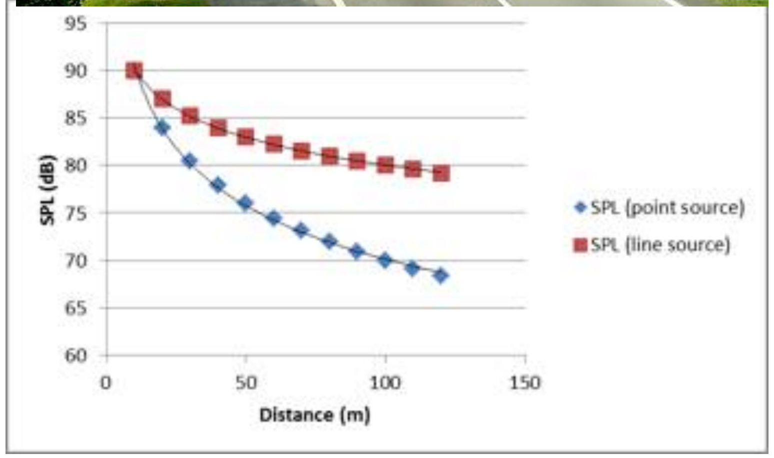
LINE SOURCE

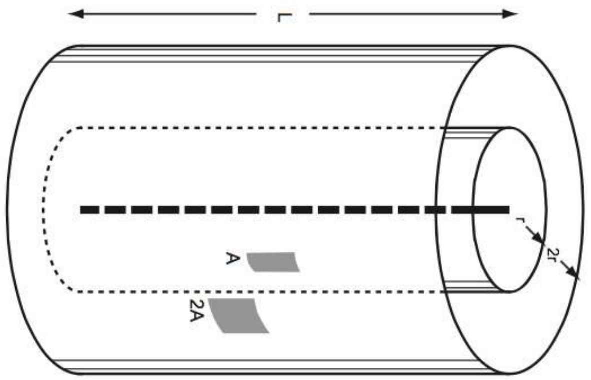
If the source is a line, for example a very busy road, the sound will radiate in the shape of a cylinder, (see Figure bellow).

For a cylinder equation 10 becomes:

$$SPL = SWL - 10log_{10}(r) - C \qquad \textbf{Equ 11}$$

Where C=8 for a cylindrical source and C=5 for a half cylindrical source. So for a line source the sound pressure will drop off with increasing distance r, not r^2. [8] This leads to the conclusion that sound from a point source falls by 3dB for every doubling of distance. Comparing the drop off for a line and a point source graphically, we see that sound from a road would drop off much more slowly (this can have serious implications for noise disturbance from roads):





DOUBLING OF DISTANCE

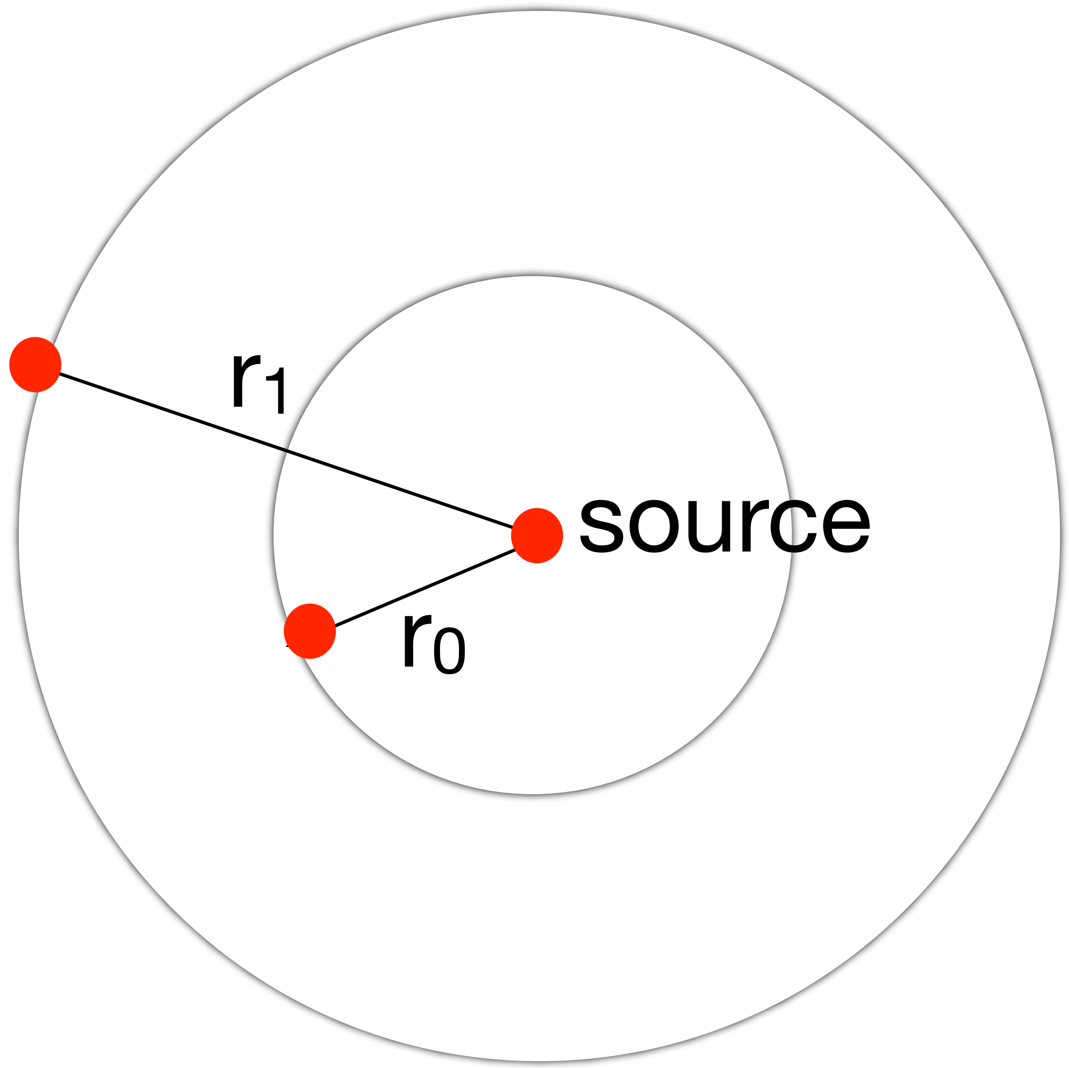
In many cases, a measurement will be taken a certain distance, r_0, from the source. For example, r_0 could be a near the road, possibly at the kerb, and r_1 the distance to a neighboring property. Both To find the change in sound pressure at a distance, r_1, further from the source, we can use the following equations to find the change in sound pressure level between the two locations:

$$\delta SPL = SPL_0 - 10log\left(\frac{r_1}{r_0}\right). \quad \textbf{Equ(12)}$$

$$\delta SPL = SPL_0 - 20log\left(\frac{r_1}{r_0}\right). \quad \textbf{Equ(13)}$$

Where equation 12 is for a line source and equation 13 is for a point source.

Now, if $r_1=2r_0$ then as discussed previously the sound pressure level will have decreased by 6dB for a point source and 3dB for a line source.



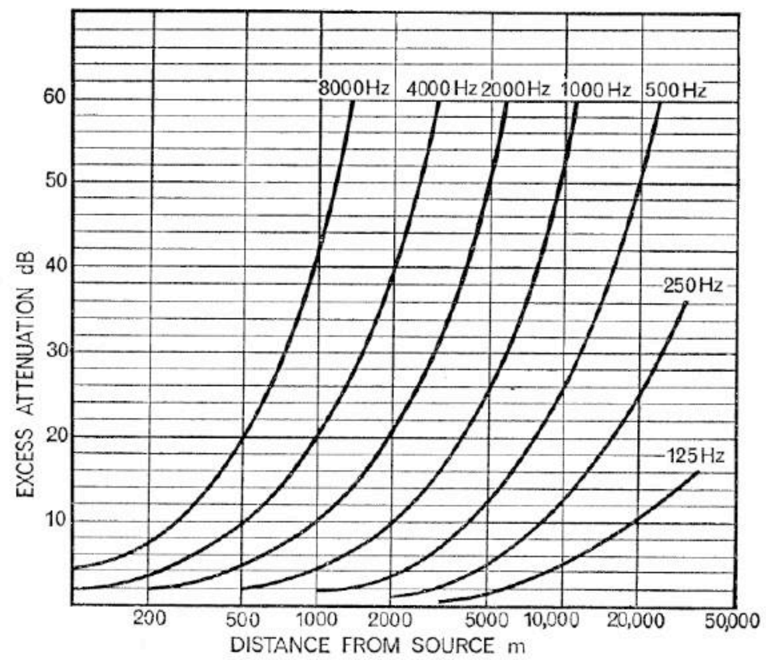
AIR ABSORPTION

As sound propagates through air viscous forces will convert sound energy into heat. This mainly affects the higher frequencies (try stirring treacle rapidly: rapidly = high frequency,).

The graph on the opposite page can be used to calculate the additional reduction in sound pressure level with distance due to air absorption (this depends also on the temperature and humidity of the air).

In many cases, the air absorption can be neglected. However, over large distances it can become a prominent factor, especially for higher frequencies. For instance, from the graph, we can see that an 8 kHz tone 100 m from the source the air absorption will be around 5dB.

Because the amount of additional absorption is highly frequency dependent there are implications for designing spaces for outdoor concerts or other events, as higher frequencies will be attenuated more quickly than low frequencies. This can, therefore, distort music and require the introduction of electronic speakers around the space, or the use of reflections from surfaces that reflect more high frequency sound than low.

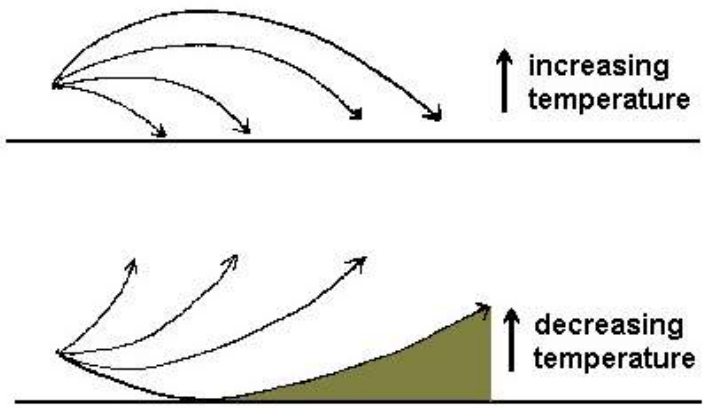


Additional absorption due to air absorption. [1]

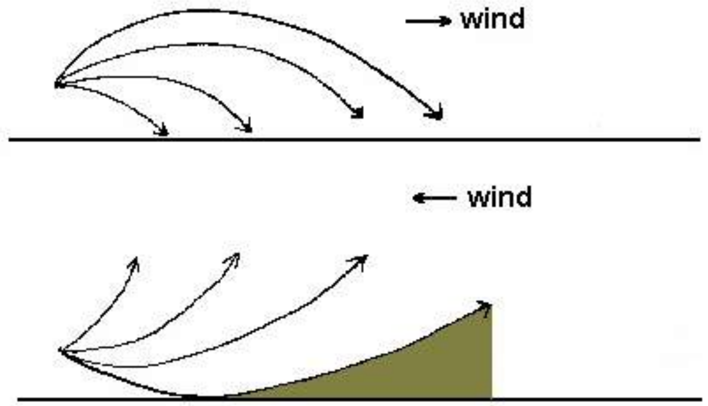
TEMPERATURE AND WIND GRADIENT

Sound travels faster in denser mediums. The density of air is proportional it's temperature. Therefore the sound will travel faster in hotter air.

Within the atmosphere, there is usually a temperature gradient. Generally it is hotter near the ground and it gets cooler the further from the ground you are.   This has the effect of "bending" the sound waves upwards, away from the ground (see (b) in figure *). At night the opposite can occur, it is cooler next to the ground than further from the ground.



In such cases the sound waves bend downwards, towards the ground (see (a) in figure*). The wind can also have an effect on the speed of sound. If the wind is moving in the same direction as the sound is propagating the speed of sound will increase. If the wind is moving in the opposite direction to the propagating sound the speed of sound will be decreased. The wind speed increases with height from the ground.



Therefore if the wind and sound are moving in the same direction the sound will bend towards the ground, if the wind and sound are moving in opposite direction sound will bend away from the ground.

ACOUSTIC SCREENS

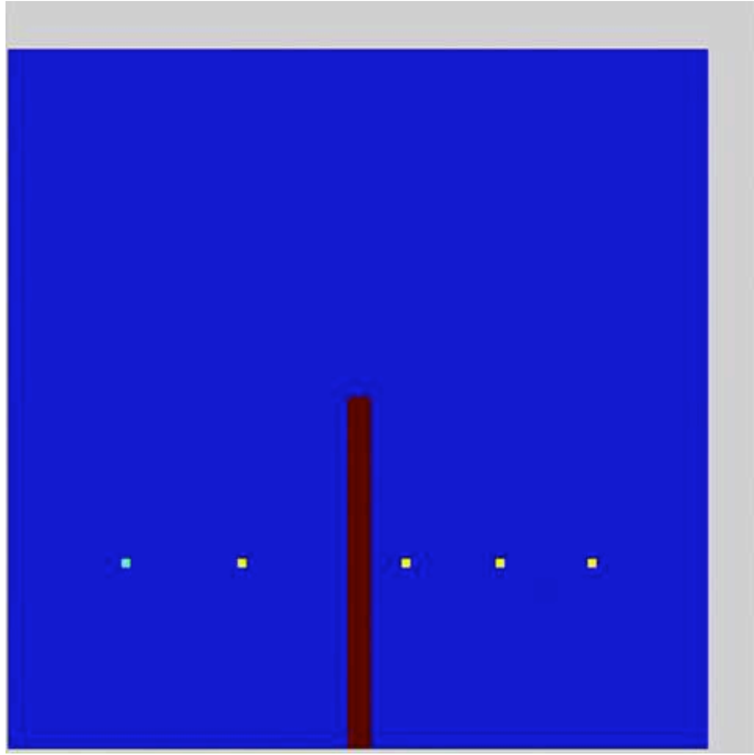
Acoustic screens and are an effective way of reducing the spread of noise across a site. The principle behind the is to block the line of site between a sound source and a receiver location.

However, diffraction limits to the effectiveness of the of an acoustics screen. Diffraction occurs at top of the screen in effect creating a small point source at the top of the screen. This sound source has the effect of bending the sound around the screen.

This effect can be seen in both the image of the model harbor and in the FDTD video shown to the left.

The limitation that this bring is to reduce the effectiveness of the screen as you move away from the screen. The simple triangle image shows the effects of screens. This could be based upon the result of a FTDT model.

Need to look at equating the result of an FTDT model again the levels in in few book.



https://youtu.be/0hw_zn1Nwu4

ACOUSTIC SCREENS

Acoustic screens are an effective way of reducing the spread of noise across a site. The principle behind this is to block the line of site between a sound source and a receiver location.

The screen is only effective if the barrier is large in comparison compared to the wavelength, λ, of the noise (usually this would determine the height of the screen). It is also dependent upon the distance of the screen from the source.

The first step is to work out the path difference of noise over the wall compared to the direct path to the listener.

$$\delta = a + b - c$$

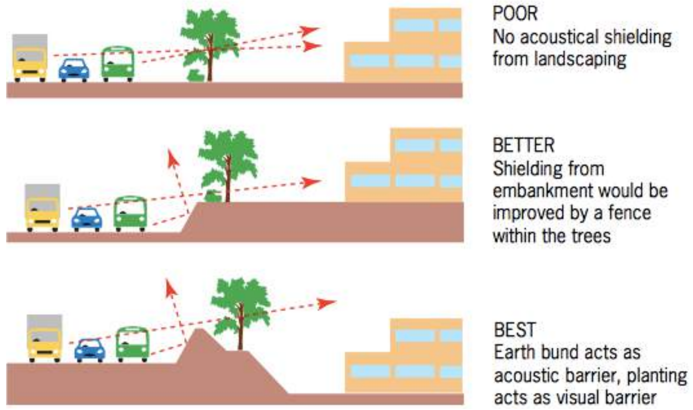
From the path difference, δ, it is possible to find the approximate attenuation via the following equation:

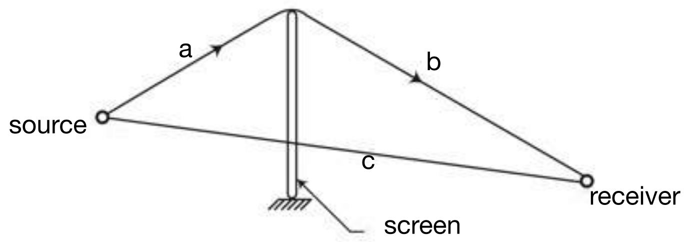
$$E_b = 10log_{10}\left(3 + \frac{40\delta}{\lambda}\right) \qquad \text{equ 15}$$

The conclusions from equation 14 are that the screen should be higher for lower frequencies and placed as close to the source as possible.

There is little point in making the screen out of very heavy material in the hope it will attenuate the sound further, generally 50kg/ m^2 is more than enough.

The acoustic attenuation can be minimal from trees and shrubs. They can be used in tandem with an acoustic screen





ACOUSTIC SCREENS

The screen is only effective if the barrier is large in comparison compared to the wavelength, λ, of the noise (usually this would determine the height of the screen, H). It is also dependent upon the distance of the screen from the source, D_S.

$$x = \frac{H^2}{\lambda D_s}$$

In this equation x relates to a reduction in dB shown in figure*

The conclusions from equation 14 are that the screen should be higher for lower frequencies and placed as close to the source as possible.

There is little point in making the screen out of very heavy material in the hope it will attenuate the sound further, generally 50kg/m2 is more than enough.

The acoustic attenuation can be minimal from trees and shrubs. They can be used in tandem with an acoustic screen for aesthetic value, however should not be relied upon to screen noise.

NEED figures 5.3 & 5.4 from Acoustics and noise control (or similar)

EXAMPLES

An electrical sub station is going to be placed 25 m from a house. A long, 2 m high barrier will be erected 5 m from the sub station to reduce the noise. See the figure above. Calculate the noise reduction produced by the barrier at a height of 1 m at the house.

First, calculate the path difference, δ, using equation 14,

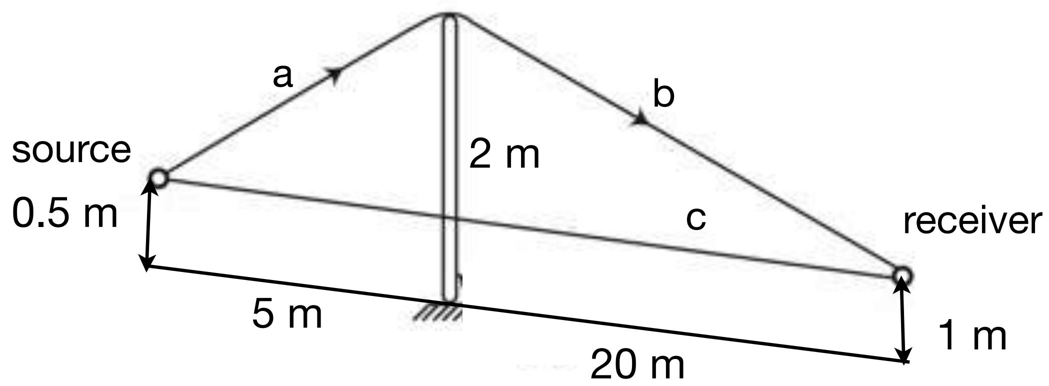
$$a = \sqrt{5^2 + (2 - 0.5)^2} = 5.2$$

$$b = \sqrt{20^2 + (2 - 1)^2} = 20.0$$

$$c = \sqrt{25^2 + 0.5^2} = 25$$

$$\delta = 5.2 + 20 - 25 = 0.2$$

Assuming a sound speed of 330 m/s, at 125 Hz



$$\lambda = \frac{330}{125} = 2.6m \text{ m}$$

Now, using equation 15,

$$E_b = 10log_{10}\left(3 + \frac{40 \times 0.2}{0.71}\right) \approx 8dB$$

we can then work this out for each octave band in a similar way:

Octave Band (Hz)	125	250	500	1000	2000	4000
Attenuation by Barrier (dB)	8	10	12	14	17	20

EXAMPLES

The manufacturer of an air conditioning unit has specified that the sound power level of its unit is 85dB. The unit is mounted on flat, reflective land. At a distance of 50 m from the source what will be the sound pressure level?

Assuming hemispherical spreading and using equation 10,

$$SPL = 85 - 20log_{10}(50) - 8$$

$$SPL \approx 43dB$$

A measurement of a busy motorway was taken 10 m from the road. The sound pressure level was recorded as 70dB What would be the sound pressure level 80 m from the road.

Assuming cylindrical spreading and using equation 13,

$$\delta SPL = 10log_{10}\left(\frac{80}{10}\right)$$

$$\delta SPL \approx 9dB$$

$$SPL_1 = 70 - 9$$

$$SPL_1 = 61dB$$

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ENVIRONMENTAL NOISE

Facade Lecture Notes

CONTENTS

ENVIRONMENTAL NOISE

- LAeq, LAMax, LA90
- Sound Levels Meter
- LAeq
- L1, L5, L10, etc.
- LPeak
-

LAEQ, LAMAX, LA90

Noise, **L_{Aeq}, L_{AMax}, L_{A90}**

L_{Aeq} is defined as the average level

L_{A90} is defined as the background noise level

L_{AMax} is the peak in the noise levels

Time is important since all these parameters change depending upon the time period

Approaching Train

https://youtu.be/efxTw4EQ29Q

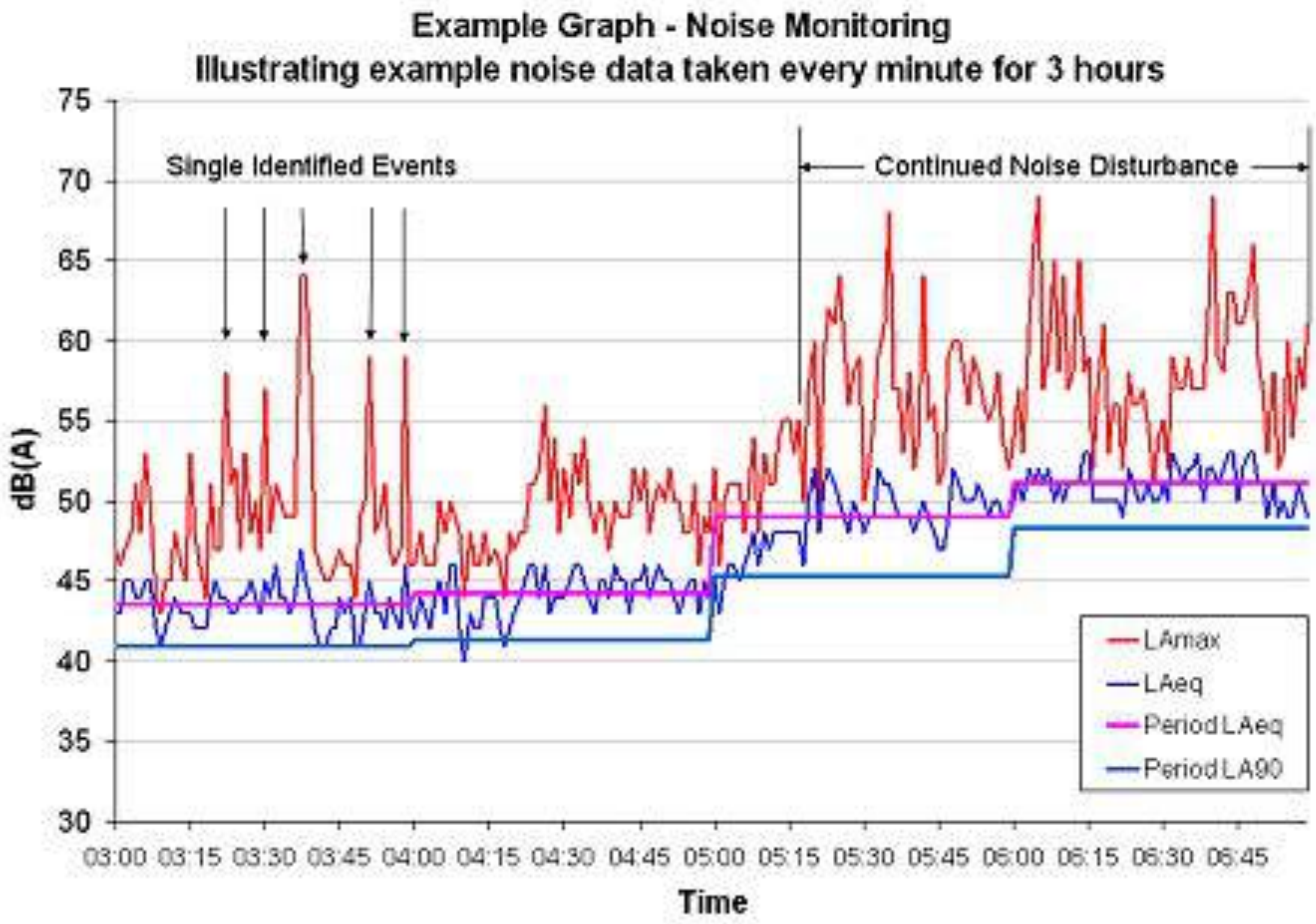
Motorway

https://youtu.be/d4hWcOHGWv8

Road Noises

https://youtu.be/byfdlAfCgVY

LAEQ, LAMAX, LA90



SOUND LEVELS METER

Sound pressure level is measured, unsurprisingly, with a sound level meter. Accurate, calibrated sound level meters used by acoustic consultants are very expensive. However, cheap ones, or even apps on a smart phone, can be used to get an idea of the acoustic environment around you. As is often the case in building physics, you need to have a good idea of what any numbers mean, and a cheap sound level meter can help. You need to get some idea of how loud different environments are, how much sound is attenuated by different constructions, and the amount of reverberation (see later) that each space produces. Without this knowledge you will not be able to design to produce the environment requested by the client, or advise anyone of what might be desirable. For example, one client might request a lively sounding restaurant, another a quiet one. You need to be able to convert their “lively” and “quiet” into dB(A). This will only be possible if you have some experience of the acoustic environment around you. So we recommend you start measuring as soon as you can. The level of noise in any space is changing constantly.

Think of music or speech, there will be quiet moments, then loud peaks. So when you ask the question, why loud is it in this room? One of the things you need to clarify is the time period of the measurement. The other is whether you are interested in the overall level over all frequencies, as might be given in dB(A), or the level within a particular octave band, for example, dB(500Hz).

LAEQ

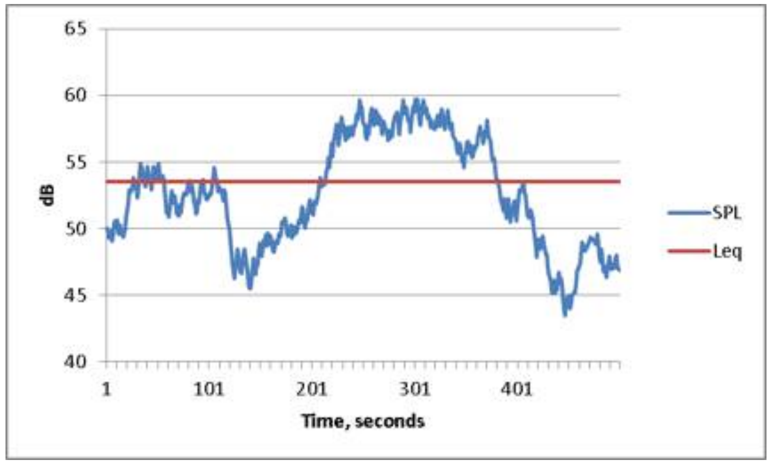
SPL

This is a near-instant value, and depending on the meter setting corresponds to a period of about 0.1 to 1 second. If you have a room full of people all taking away the SPL will be approximately constant. As it will be for many forms of music, for orchestral music it won't be.

Leq

The Leq is the equivalent constant level which has the same energy and consequently the same long term hearing damage potential as the actual varying, measured sound level. i.e. it adds up the energy in the time varying sound and compares it to a source that isn't time varying. It hence accounts for hearing damage being a product of both amplitude and length of exposure. It also gives a way of comparing two very different noise sources that vary differently in time. It is normally measured over a long period, say 30 minutes. If the value has been A-weighted, then it is indicated as LAeq. The time period that the measurement was made over will also be given in the suffix, for example if the period was one hour: LAeq,1hr.

We know from the discussions on adding decibels that a 3dB increase in SPL indicates a doubling of sound energy. Hence, for example, a continuous noise of 90dB(A) for 8 hours gives an LAeq,8hr; as does 93dB(A) for 4 hours, followed by 4 hours of a much lower level; or 99 for 1 hour followed by a much lower level for 7 hours. Figure * shows a time trace of SPL and the Leq.



L1, L5, L10, ETC.

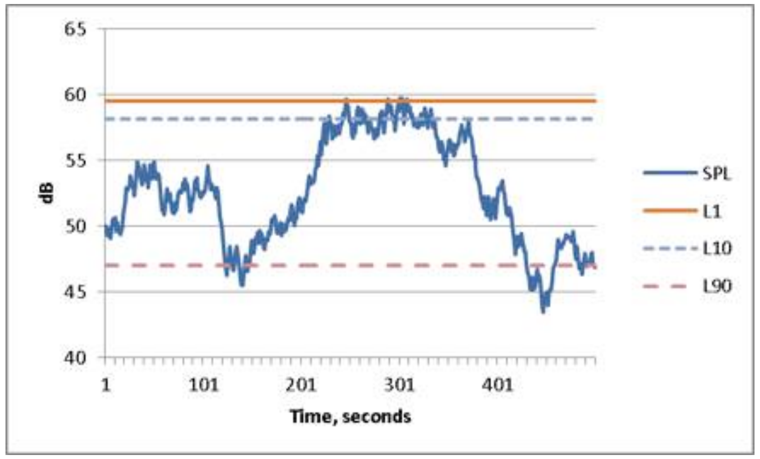
LAeq is known to correlate well the level of annoyance a sound makes. The World Health Organization considers that an LAeq of over 55dB to indicate a significant community annoyance. Lower values at night would also lead to annoyance.

L1, L5, L10, etc.

When it comes to annoyance much shorter periods of intense sound can be the problem. For example noise from aircraft. As a plane, even near an airport, might pass by only once every few minutes measuring the average SPL (which we would normally do by measuring the Leq) will give a low number as it will be dominated by the much longer periods when a plane is not passing. The L1 value is the SPL not exceeded for more than 1% of the time. I.e it represents the loudest 1% of the noise.

This can be much more useful for gauging the level of sounds that vary a lot.

Most meters can also display L10 (i.e. the SPL not exceeded for more than 10% of the time) and other percentages. L10 is most often used when measuring traffic noise. A-weighting and the time period will be indicated as with Leq, for example: LA1,30min



LPEAK

When considering the siting of a building or a road it is worth reviewing the L10 of the site either by measurement or calculation, or by considering a similar site elsewhere, as many countries have compensation schemes for those exposed to excessive traffic noise, or may prohibit building in such a noisy environment. In the UK for example the value that might trigger compensation by a new or improved road is an LA10,18hr or 68dB.

Lpeak

Annoyance and hearing damage can also be function of the peak level of sound if the sound comes in very intense bursts. Examples being hammers in industrial or construction settings and drums in music rooms. For these noises the Leq might not be that high, but the peak level so high that it is almost impossible to keep the noise from spreading around a building or being transmitted across the neighborhood.

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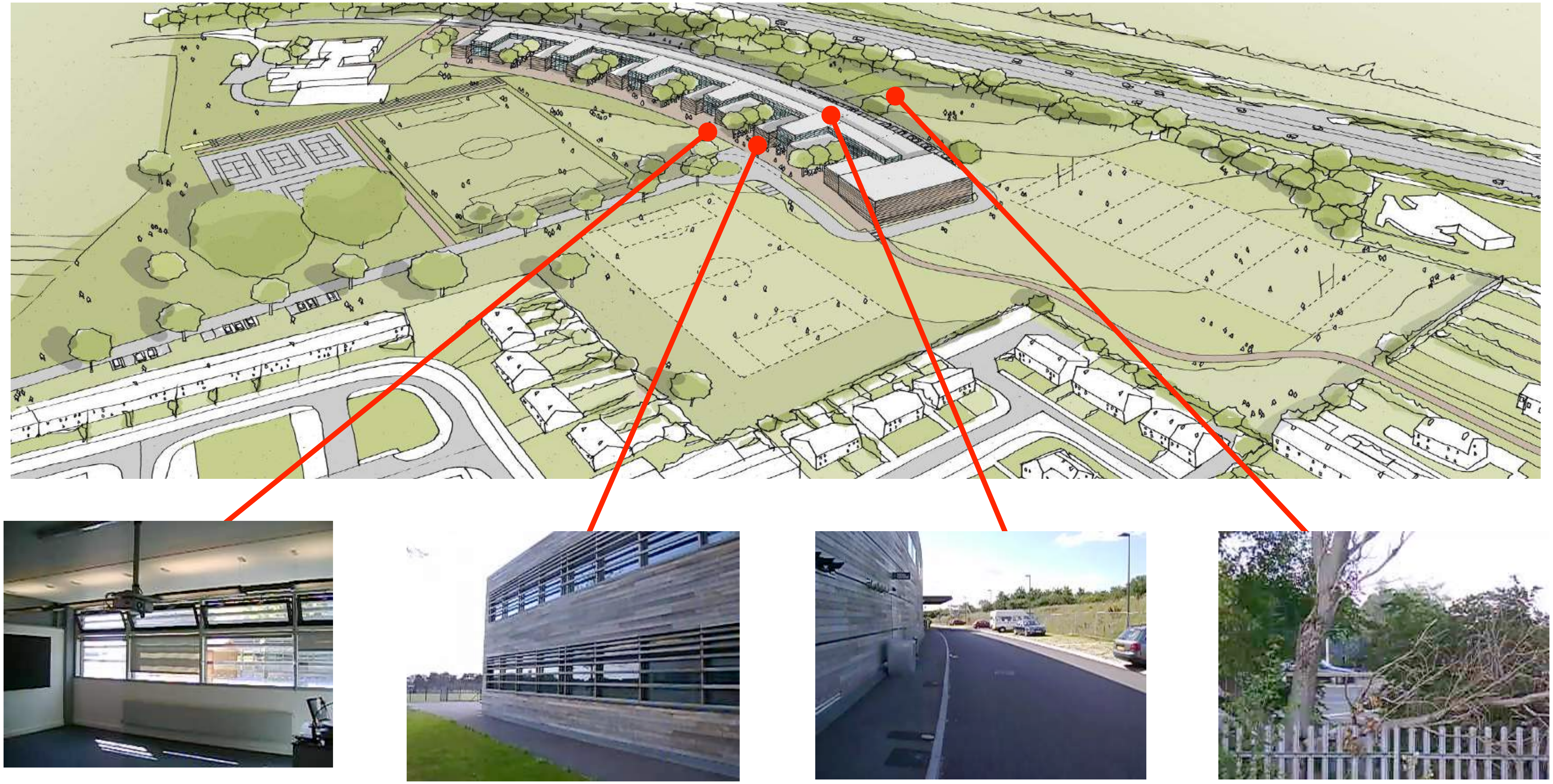
NOISE MAPPING

Facade Lecture Notes

CONTENTS

NOISE MAPPING

SOUND AROUND BUILDINGS



text

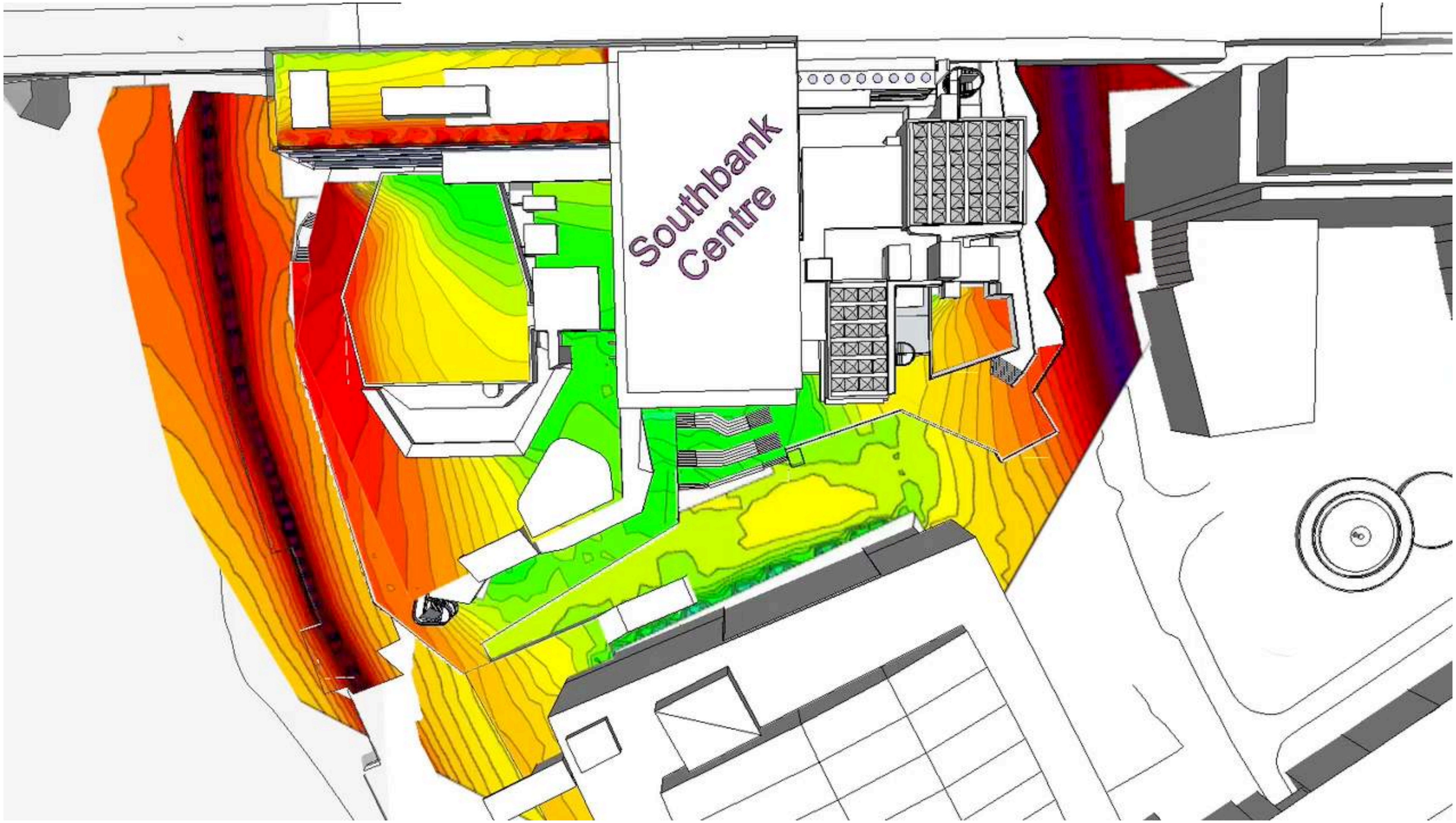
https://youtu.be/CV6RQ5Lr-Bk

https://youtu.be/7C4oI6otAfw

https://youtu.be/fyGdNwjfOnI

https://youtu.be/cnXMiOFjDIw

NOISE MAP



https://youtu.be/qOlXUdXIFNQ

text

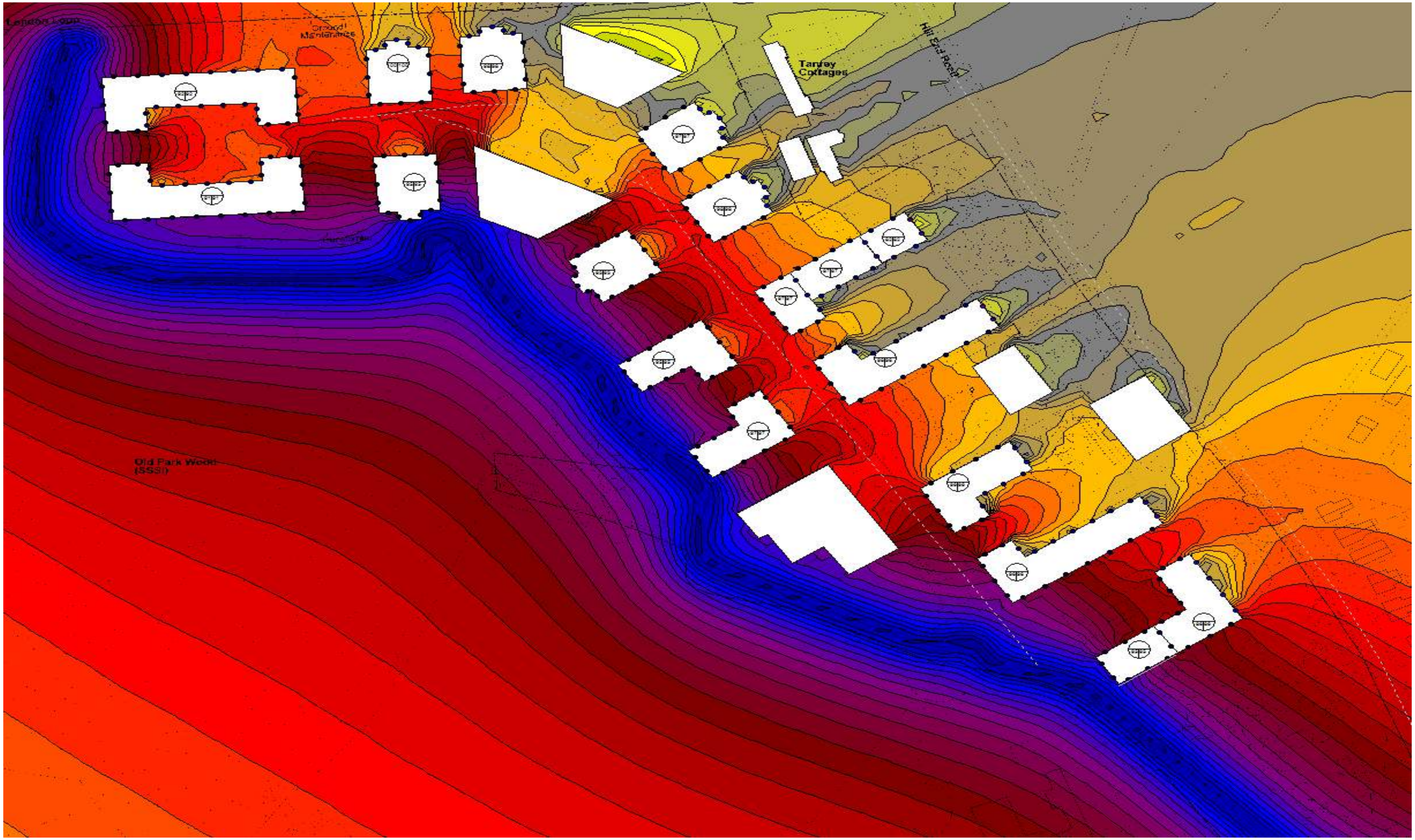
MASSING DRAWINGS & NOISE MAPPING

Massing is a technique crucial in site stage and allows us to model the sound around various structures. This is especially important to buildings in close proximity to busy roads.

CASE STUDY - MORRISTON COMPREHENSIVE

Morriston Comprehensive is a good example of a school in a noisy area lying next to the motorway. After carefully monitoring the direction the sound was coming from – only from one and not both ways as previous alternative acoustic consultancies had reported we were able to provide educated advice on less screening being required which resulted on cost saving.

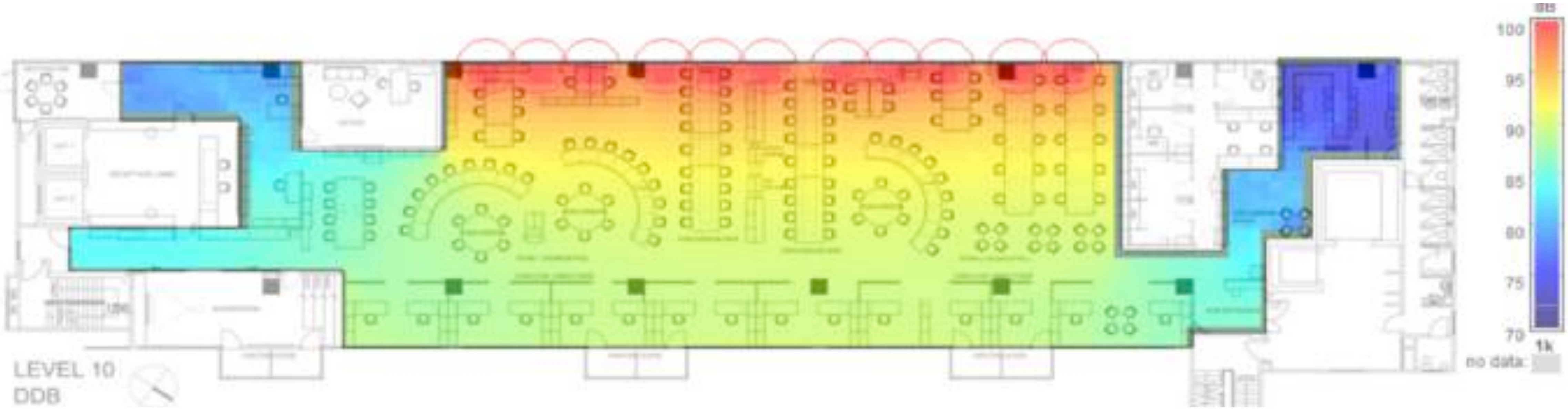
CASE STUDIES - THE VIEW RESIDENTIAL DEVELOPMENT



INTELEGENT LAYOUTS - FOR NATURAL VENTILATION

Sound decays over distance, it is therefore possible to mitigate noise ingress through a vented façade by space planning and considering the internal layout of a building.

Before: Noise break-in to an open plan office. Where the red circle represents the open vents



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ACOUSTICS FACADES DESIGN

Facade Lecture Notes

CONTENTS

ACOUSTICS FACADES DESIGN

BACKGROUND NOISE

Background noise is on of the key factors affecting the acoustics performance of a building. Background noise is defined as the sound level within the building, when the building is empty but fully operational, in other words fully ventilated.

Background noise has the effect of masking sound, meaning that in educational spaces, it is important to ensure that background noise levels sufficiently low to ensure that spoken voice can be heard.

Within auditoriums, the above principle is also true however, the spoken voice needs to travel over grater distances, meaning that background noise levels need to be reduced further. Important background noise in an auditorium effects the production taking paces, when the music come to an abrupt end, low background noise level are required to ensure that drama of these and similar events.

Within large open plan office it is important to ensure that noise levels are not too quite. If a degree of noise is not maintained then privacy and other issues can results in problems. Residential and Education/Health Care is about ensuring disturbance are control.

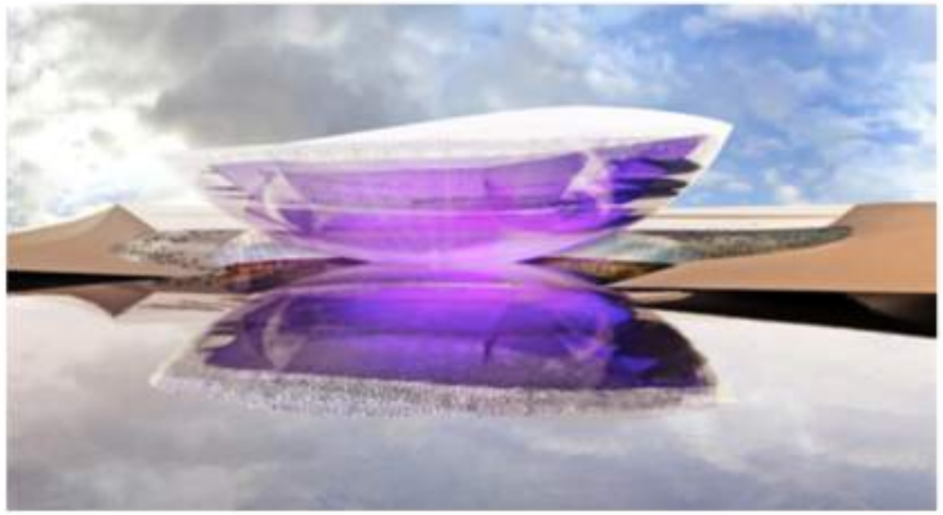
Noise from Entertainment is different in that it is more about containing noise than it is about keeping it out.

INTERNAL BACKGROUND NOISE REQUIREMENTS

Large office space

Education/Health Care

Residential



Entertainment

INTERNAL BACKGROUND NOISE REQUIREMENTS

Learning, studying and teaching

Sleeping

Healthcare and well being

Relaxing

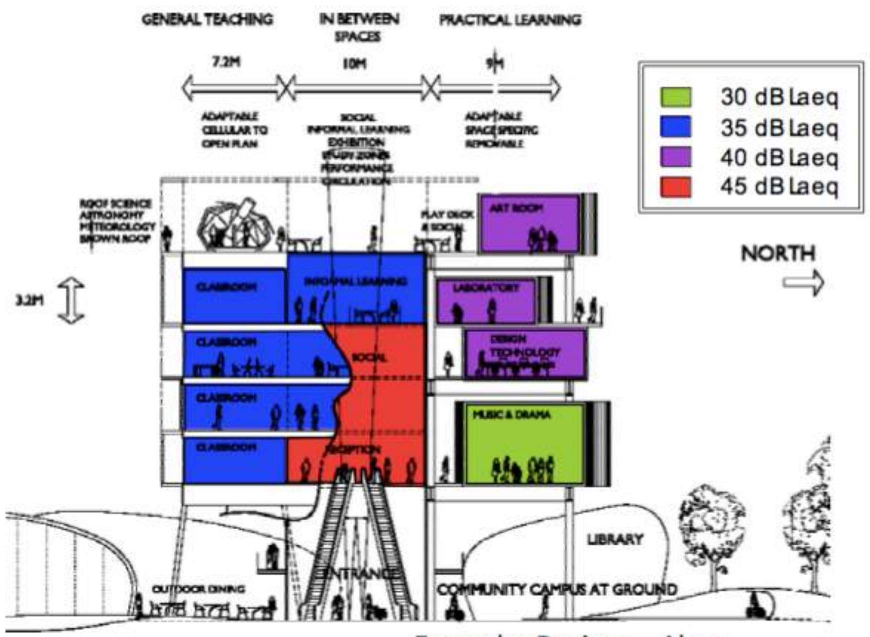
INTERNAL BACKGROUND NOISE REQUIREMENTS

Residential – PPG24 & BS8233

Criterion	Typical Situation	Design Range LAeq,T dB	
		Good	Reasonable
Reasonable resting/sleeping conditions	Living Rooms	30	40
	Bedrooms	30	35

A footnote to this table states that "*For a reasonable standard in bedrooms at night, individual noise events (measured with F time-weighting) should not normally exceed 45 dB LAmax*".

Schools - BB93



Exemplar Designs – Alsop

Health Care - HTM

FACADE TYPES

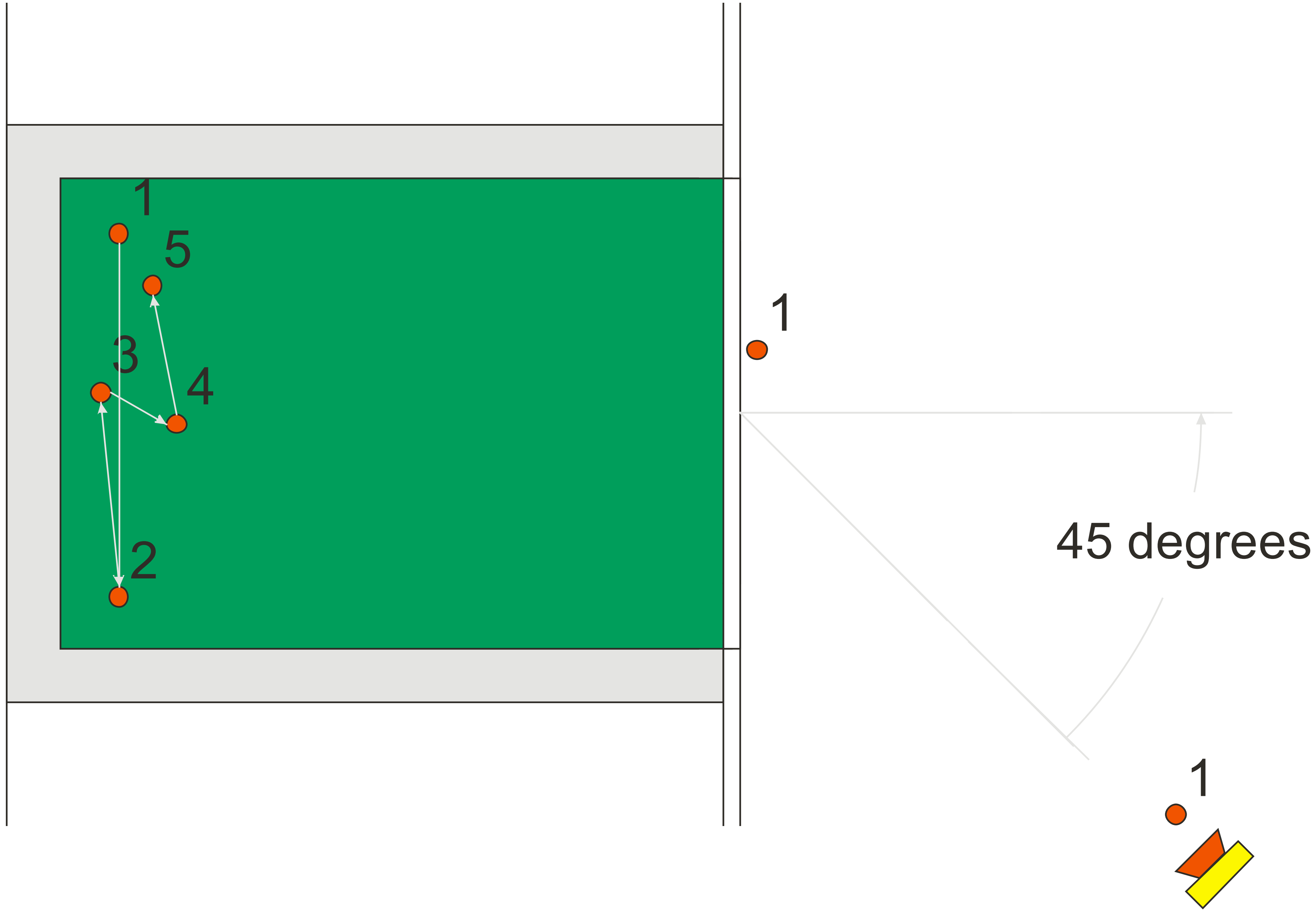
Vented Facades

Residential

Fully Glazed Facades

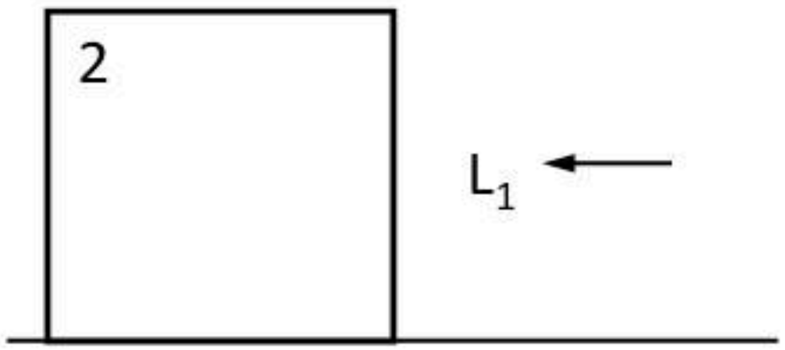
Double Facades

ACOUSTIC FACADE TEST



ACOUSTIC FACADE TEST

The external wall is an acoustic reflector. The complication here is whether the external sound level is what it would be with or without the external wall. The general value used is the level $\mathbf{L_1}$ at the wall as if the wall was not there !



Sound Pressure Level in the room,

$$\mathbf{L_2 = L_1 - R + 10.\log \frac{S}{A_2} + 6 \;\; dB}$$

Note: in front of the wall, the sound pressure includes both the incident and reflected pressure:

measured SPL 1m from the façade = L_1 + 2.5 dB

COMPOSITE FACADE

$$L_{eq,2} \approx L_{eq,ff} + 10\log_{10}\left[\frac{A_0}{S}10^{\frac{-D_{n.e}}{10}} + \frac{S_{wi}}{S}10^{\frac{-R_{wi}}{10}} + \frac{S_{ew}}{S}10^{\frac{-R_{ew}}{10}} + \frac{S_{rr}}{S}10^{\frac{-R_{rr}}{10}}\right] + 10\log_{10}\left[\frac{S}{A}\right] + 3 \quad (1)$$

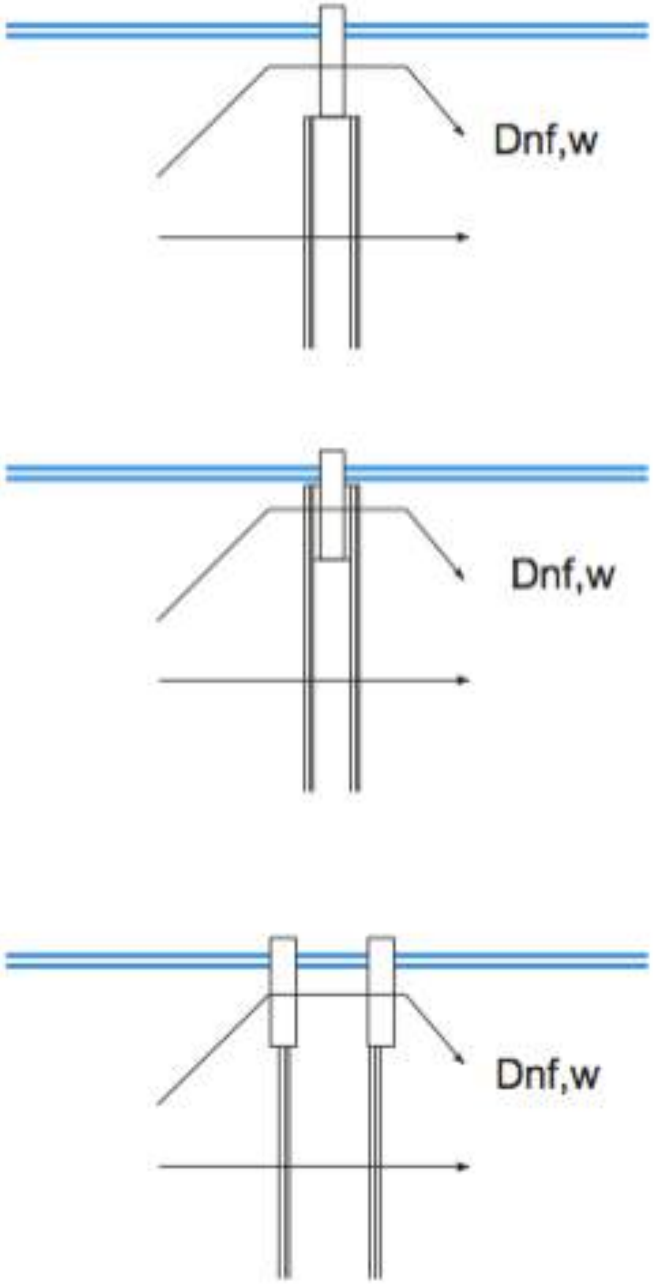
Where

$L_{eq,ff}$ is the equivalent continuous sound pressure level outside the room elements under consideration;
A_o is a reference absorption area of 10m^2 and is independent of frequency;
S is the total area of elements through which sound enters the room in square meters (m^2), i.e.S_r + S_m
D_{ne} is the insulation of the trickle ventilator measured according to BS EN 20140-10 [9];
S_{wi} is the area in square meters (m^2) of the windows in the room;
R_{wi} is the sound reduction index of the window;
S_{ew} is the area in square meters (m^2) of the external wall of the room;
R_{ew} is the sound reduction index of the external wall of the room;
S_{rr} is the area in square meters (m^2) of the ceiling of the room;
R_{rr} is the sound reduction index of the roof/ceiling;
A is the equivalent absorption area of the receiving room being considered.
S_f is the total facade area of the room in question in square meters (m^2);

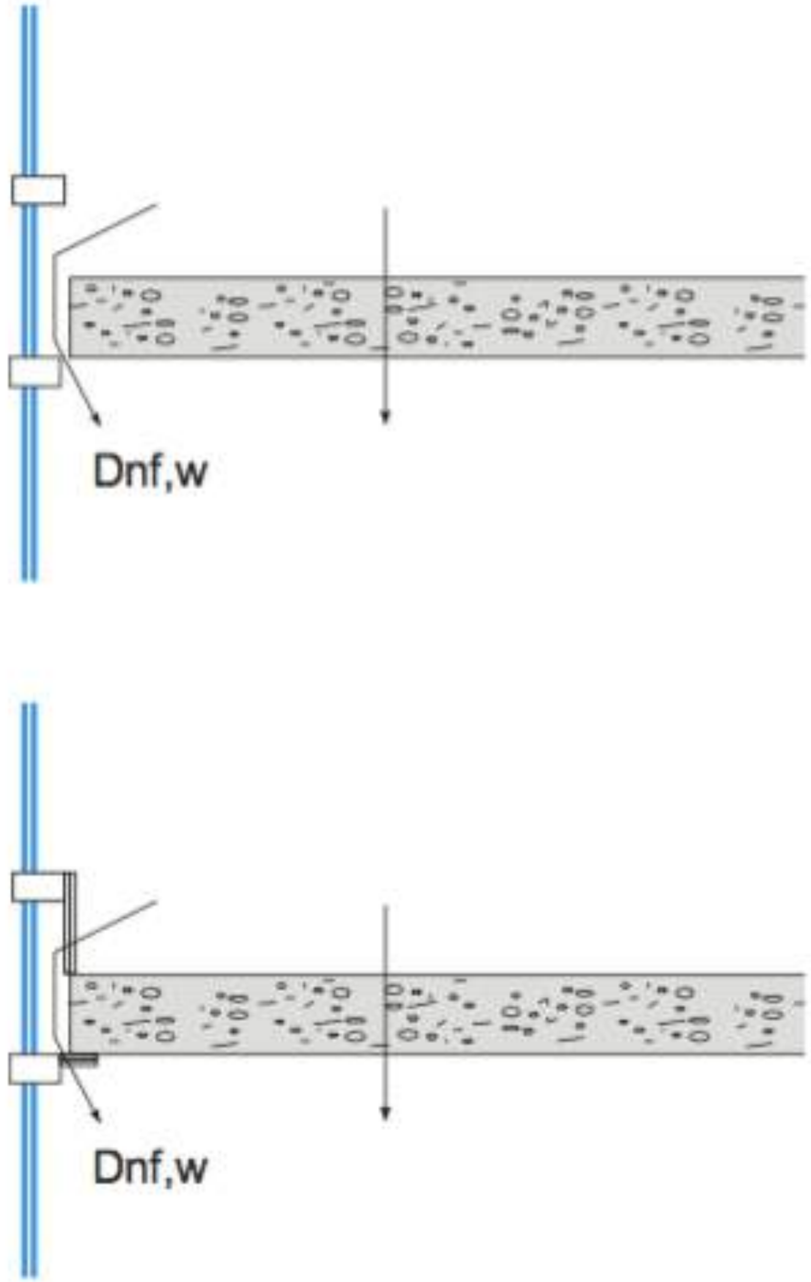
COMPOSITE FACADE

	BS8233 Facade Noise Break In Calculation		125	250	500	1000	2000	4000	dB(A)
	Noise Level at Façade		51.7	45.1	43.8	46.9	37.9	29.8	48.9
	Correction for Rooflight noise level	-6 dB							
	3dB Safety	3 dB	3.0	3.0	3.0	3.0	3.0	3.0	
	Calculation of enviromental noise break-in to hotel rooms								
	L2 = L0 - R + 10*log(S/A) + 3dB (Freefield version)								
	Calculated A = 0.16V/RT								
	Volume =	245 m3							
	RT		0.8	0.8	0.6	0.6	0.6	0.6	
	Absorption		49.9	49.9	66.6	66.6	66.6	66.6	
	10*log(A/S)		3.9	3.9	2.6	2.6	2.6	2.6	
	FAÇADE Elements								
	Façade Area	122.3 m2							
1	**Glazing Area, S**	7.2 m2	24	20	25	35	38	35	
G19	Double glazed 4/12/4		-36	-32	-37	-47	-50	-47	
	Predicted noise level in building from glazing		25.3	22.7	15.1	8.2	-3.8	-8.9	17.6
2	**Solid Façade 1**	46 m2	41	45	45	54	58	58	
W-EX1	Brick/block cavity wall		-45	-49	-49	-58	-62	-62	
	Predicted noise level through solid façade		16.4	5.8	3.2	-2.7	-15.7	-23.8	5.0
3	**Solid Façade 2 / Roof**	67 m2	21	26	33	33	35	35	
R1	Pitched, tiles on felf roof, 9mm pb ceiling		-24	-29	-36	-36	-39	-38	
	Predicted noise level through solid façade		38.0	26.4	16.9	20.0	9.0	0.9	25.4
4	**OPENING**	1.130 m2	0	0	0	0	0	0	
OPEN	Opening / no SI		-20	-20	-20	-20	-20	-20	
	Predicted noise level through solid façade		41.2	34.6	32.1	35.2	26.2	18.1	37.4
5	**Trickle Vent**								
W-V1	NO TRICKLE VENT	Dne	99	99	99	99	99	99	
		Ao/A	-10	-10	-10	-10	-10	-10	
	Predicted noise level through trickle vent	Lff-Dne+10log(A0/A)+K	-48.3	-54.9	-57.4	-54.3	-63.3	-71.4	-52.2
	Combined Noise Levels (1+2+3+4+5)		**43.0**	**35.5**	**32.3**	**35.3**	**26.3**	**18.2**	37.7
	Target dB(A) Level								40
									Pass
	Combined Noise Levels (1+2+3)		43.0	35.5	32.3	35.3	26.3	18.2	
	Target NR Level	NR 35	57	47	39	35	31	29	
	Difference		14.0	11.5	6.7	-0.3	4.7	10.8	
						Fail			

FACADE FLANKING DETAILS



Plan



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“MACH Acoustics takes time to analyze, consider and propose solutions, that promote an architectural approach. The sensitivity and technical performance capability is well respected by the practice.” Jo Bacon – Allies & Morrison Partnership

SOUND INSULATION-INTRODUCTION

Facade Lecture Notes

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SOUND INSULATION-INTRODUCTION

AN INTRODUCTION TO SOUND INSULATION

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, or receiver, room will be approximately 20 dB; barely audible. If sound levels are increased in the source room to 75 dB; a typical raised voice, sound levels within the adjacent room will also increase to 30 dB; audible. Sound insulation therefore, is a level difference, describing the level of sound lost across a partition and not the level of sound within the 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 Images 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 NR 35, and the second for background noise levels of NR 30.

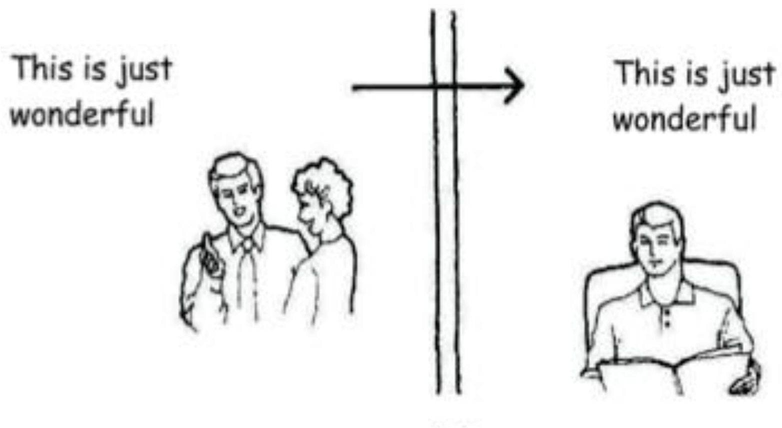


Figure 2.1 - Dw 30 dB, Background Noise NR 35 dB

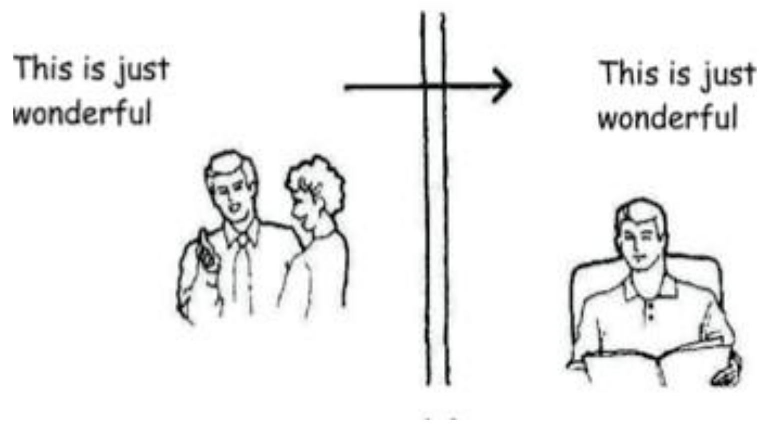


Figure 2.1 - Dw 30 dB, Background Noise NR 35 dB

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 i.e. the energy stored in the building frame, 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 embodied energy is to re-use an existing building. Demolition and rebuilding is often justified on the grounds of flexibility and acoustics. 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 or 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 acoustic performance. The advantage of lightweight framed buildings, is the considerable reduction in embodied energy, a sustainable building frame, and reduced levels of flanking between spaces.

As timber studs have less flexibility, they tend to offer lower levels of sound insulation than metal studs, however, this limitation can be overcome by means of a resilient bar within the partition make up.

Acoustic comparisons show block work does have a better low frequency performance, but this is easily remedied, meaning low frequencies are rarely problematic.

SUSTAINABILITY AND SOUND INSULATION

Damping within Partitions

Acoustic damping within stud walls is a cost effective, and sustainable, method of enhancing the performance of a partition. Mineral wool is conventionally used within partitions.

Mineral, or rock, wool 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 - from recycled plastic bottles, Jean fibre - from recycled jeans, Thermo fleece - sheep's wool, hemp, and Warmcell - from recycled newspapers, are just a few examples.

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 therefore 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.

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. 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 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, as the partition's performance will only ever be as good as that of its weakest element.

When designing green buildings, it is fundamental to ensure that the correct and most suitable performance requirements are used. 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, 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.

RW AND DW

A common confusion in specifying wall types for a building lies in the difference between Rw and DnTw. Misunderstanding this can lead to under or over performance, whilst grasping this simple difference could ensure a better result on-site, as well as present value engineering opportunities.

DnTw

DnTw is a term that relates to ON-SITE sound insulation. This is the target used to measure against in pre-completion testing, in line with BB93 specified DnTw values. Because it's on-site, it accounts for all sound transmission paths including through the separating partition and any flanking paths around it (i.e. through ceiling voids, ventilation paths, junction detailing).

Rw

Rw is defined as a LABORATORY-RATED sound reduction index. Wall constructions should be specified as this: Measured in isolation from any other sound flanking paths.

Why is this Important

The same construction measured in a lab will get the same result every time, but measured on-site will vary from room to room, project to project.

The conversion from Rw to DnTw has to account for the size of the separating partition, and the volume and reverberation time of the 'receiving' rooms. It must also incorporate a factor to account for potential flanking transmission on-site due to construction quality or inattention to junction detailing

Therefore it is not a simple case of Rw = DnTw + X dB. The R can vary significantly between partitions, even if they require the same DnTw. Figure 1 over leaf shows this.

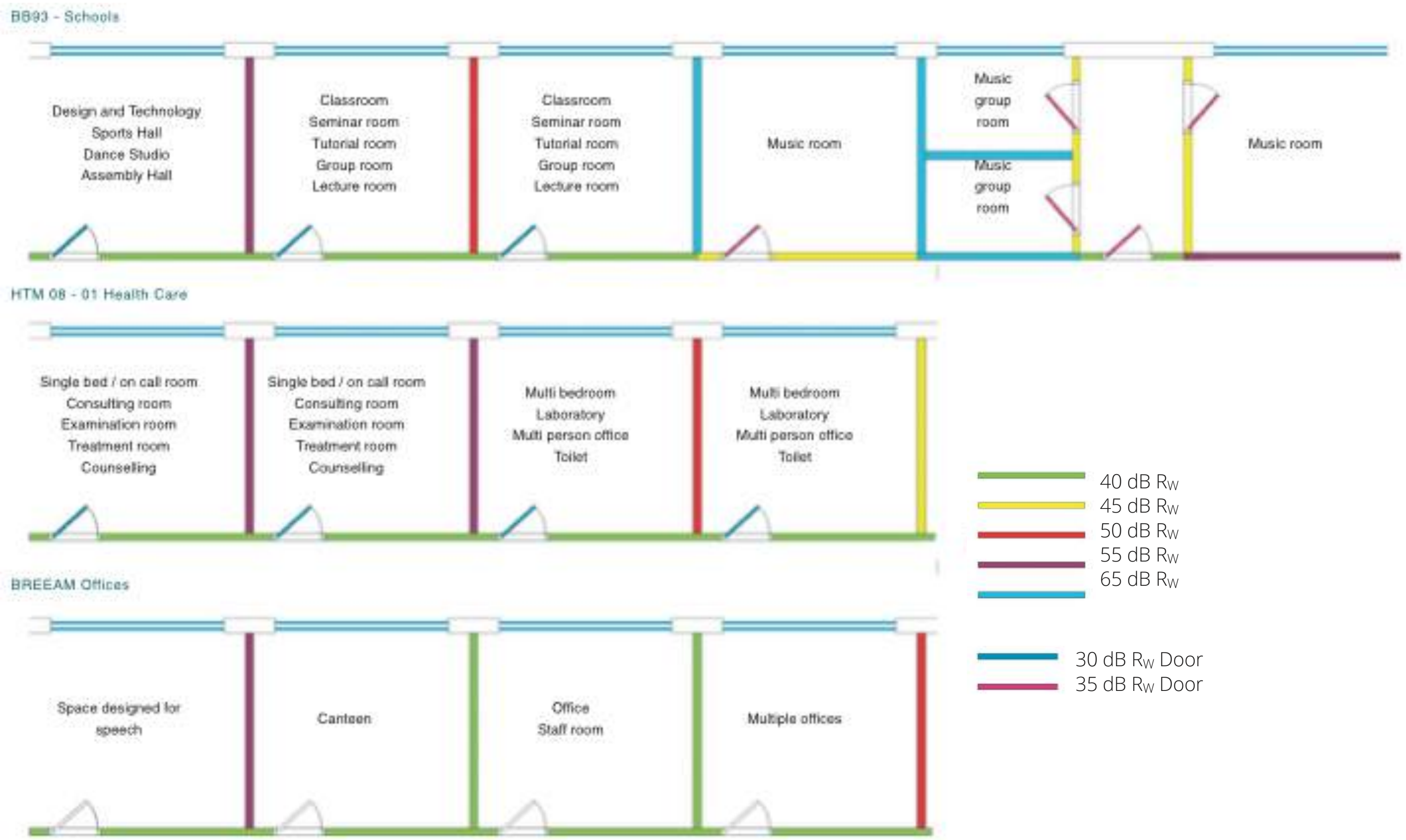
Why does the Rw vary when the DntW is the Same

Clearly, we see from the illustration above, if the same wall type Rw (say 45 dB) is used everywhere the DnTw is 40 dB, there will be rooms that fail. On the flip side, if the most onerous requirement of 53 dB Rw is used for all 40 dB DnTw walls, then some areas will exceed the required performance by a considerable margin.

PERFORMANCE SPECIFICATIONS

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

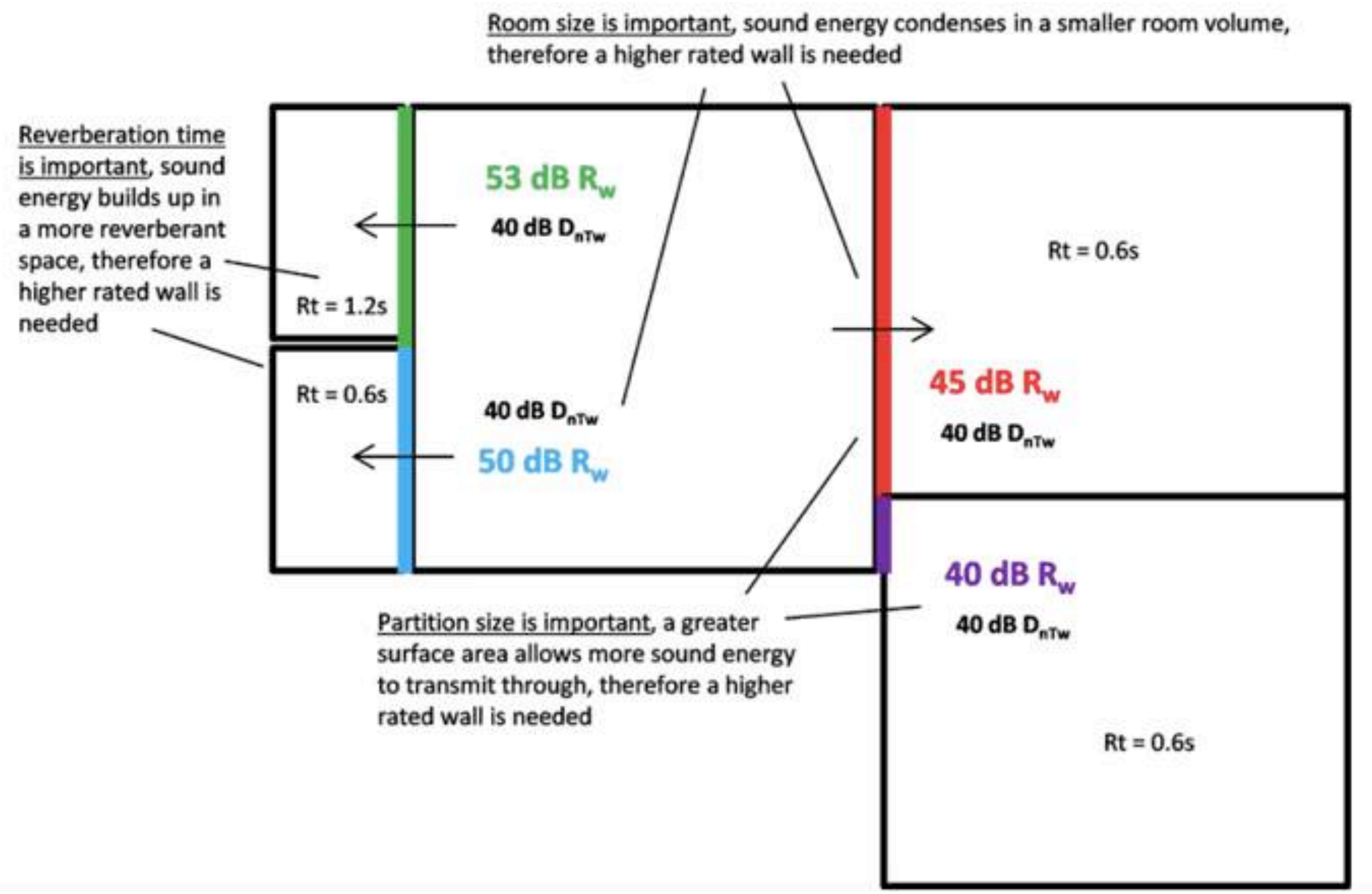
The provided performance targets are given in terms of R_W levels, to achieve appropriate D_W levels once installed. Assumptions relating to room sizes, floor to ceiling height, room acoustic finishes, and other factors, have been made during the conversion between D_W and R_W levels as specified by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



CONVERSION BETWEEN RW AND DW

Of the two scenarios, it is usually the latter that will occur within a design. Therefore, clear cost savings could be made by assigning wall types to partitions based on the required Rw, not simply the DnTw.

This can all be done whilst retaining the same number of wall types. In fact, by careful design and attention to construction details, the build ups of wall types can be engineered to reduce unnecessary overspend on thicker or denser plasterboard products and still maintain the on-site acoustic performance. Reducing every dB of over design quickly sums up when applying over projects, schemes and larger frameworks, particularly those with common shared constructions.



CONVERSION BETWEEN RW AND DW

R_W Lab Tested Sound Insulation

D_W On Site Sound Insulation level

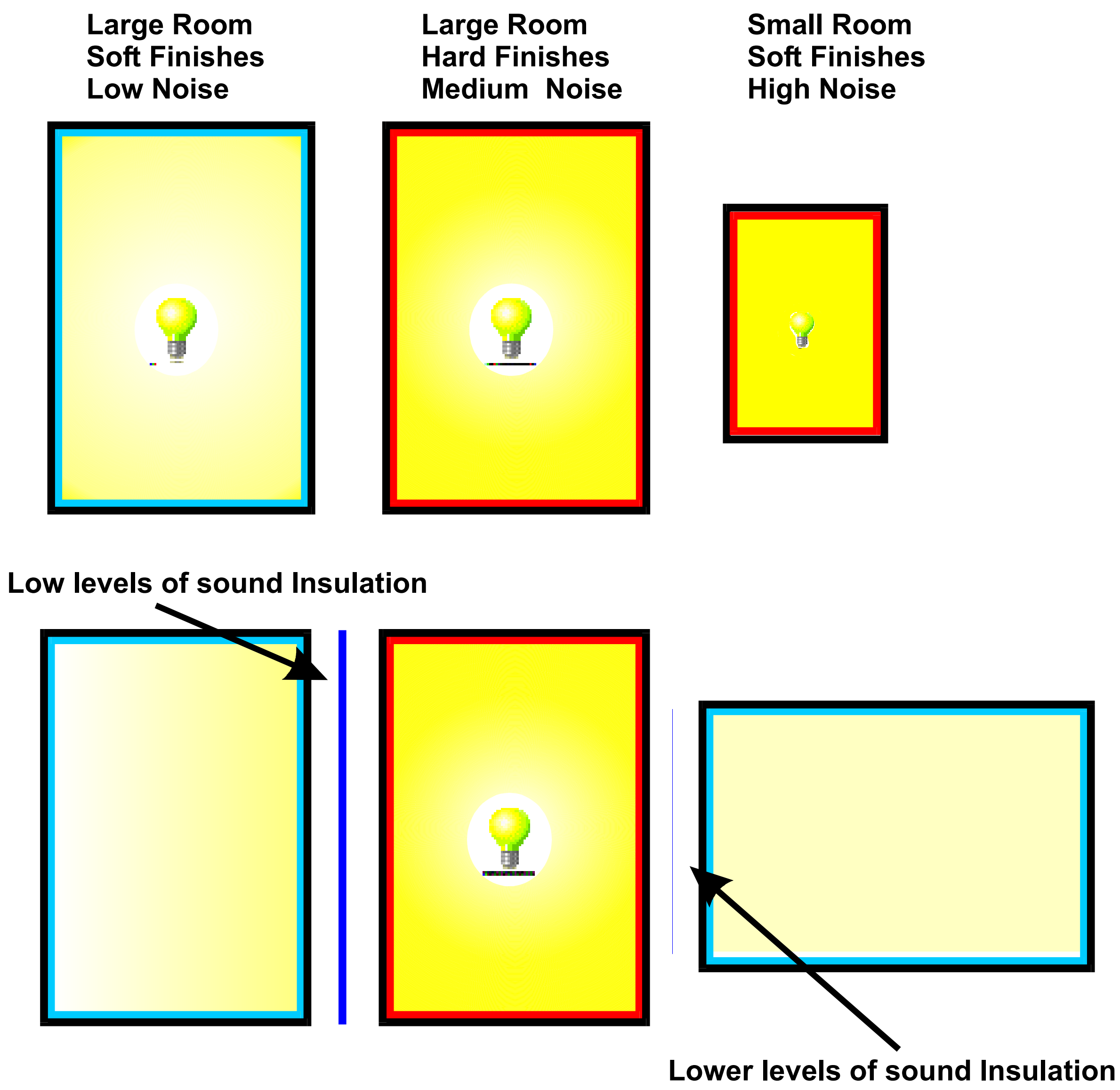
V is the receiving room volume,

S is the partition area

T is the room finishes

X is a safety factor

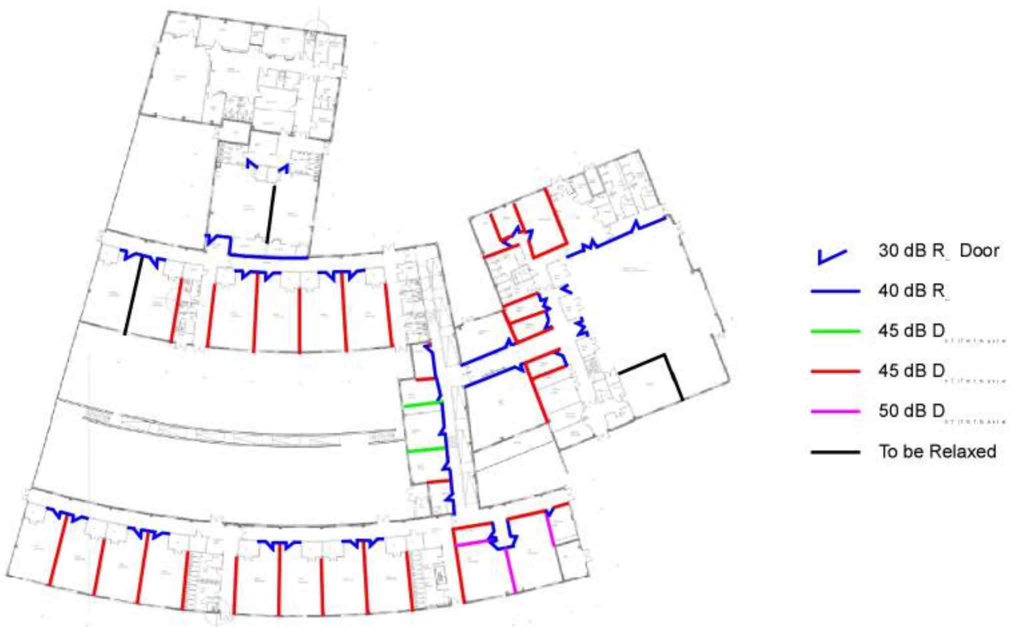
(typically 5 dB and 12 dB fo a folding partition)



$$D_W = R_W + 10\log(3TS/V) + X\ (dB)$$

PERFORMANCE SPECIFICATIONS - IN DETAIL - BB93

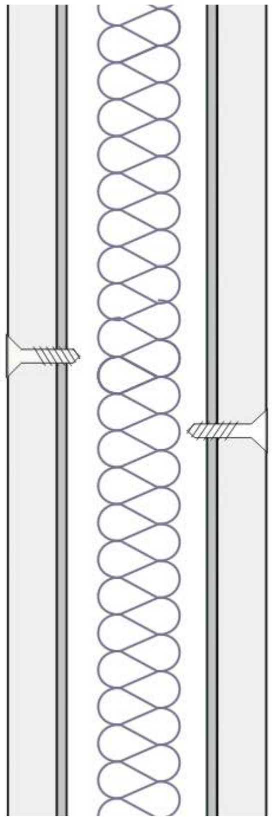
Type of room	Room classification for the purpose of airborne sound insulation in Table 1.2: Activity noise (Source room)	Room classification for the purpose of airborne sound insulation in Table 1.2: Noise tolerance (Receiving room)	Upper limit for the indoor ambient noise level, dB $L_{Aeq,30min}$
Nursery school playrooms	High	Low	35[1]
Nursery school quiet rooms	Low	Low	35[1]
Primary school: classrooms, class bases, general teaching areas, small group rooms	Average	Low	35[1]
Secondary school: classrooms, general teaching areas, seminar rooms, tutorial rooms, language laboratories	Average	Low	35[1]
Open-plan[2]			
Teaching areas	Average	Medium	40[1]
Resource areas	Average	Medium	40[1]
Music			
Music classroom	Very high	Low	35[1]
Small practice/group room	Very high	Very Low	30[1]
Ensemble room	Very high	Very Low	30[1]
Performance/recital room	Very high	Very Low	30[1]
Recording studio[3]	Very High	Very Low	30[1]
Control room for recording	High	Low	35[1]



Minimum $D_{nT\,(T_{mf,max}),w}$ — Noise tolerance in receiving room *(see Table 1.1)*	Activity noise in source room *(see Table 1.1)*: Low	Average	High	Very high
High	30	35	45	55
Medium	35	40	50	55
Low	40	45	55	55
Very Low	45	50	55	60[1]

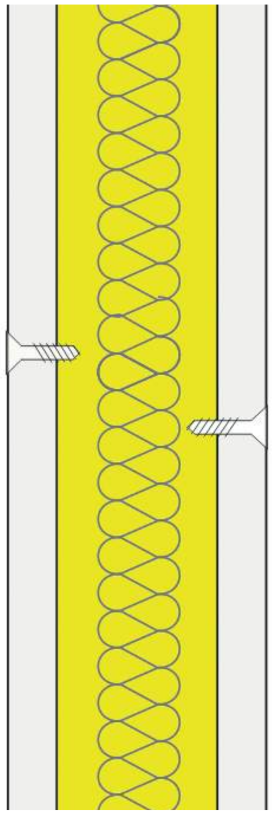
LIGHT AND HEAVY WEIGHT WALL EXAMPLES - PARTITIONS

Metal Studs



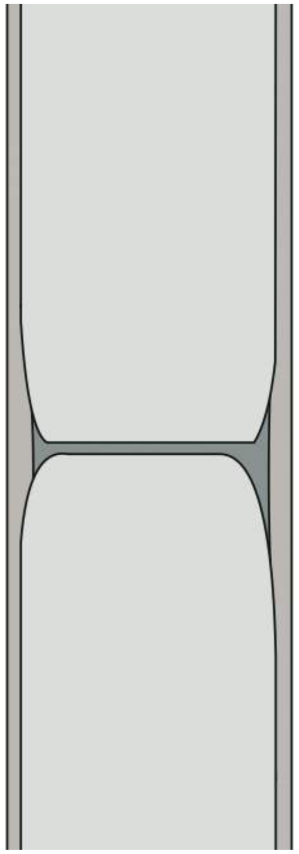
Rw = 42dB, Width = 73mm - One 12.5mm WallBoard, a 48mm 'C' stud at 600mm centres, 25mm Isowool

Timber Studs



Rw = 39dB, Width = 75mm - One 12.5mm WallBoard, a 50mm timber stud at 600mm centres, 25mm Isowool

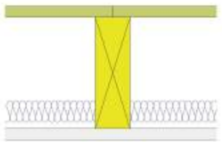
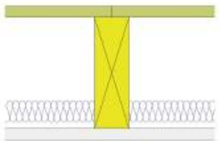
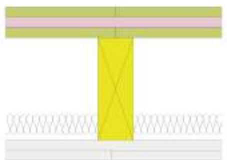
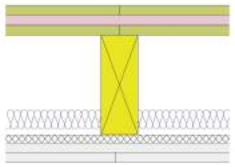
Block Wall

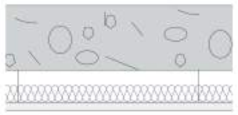
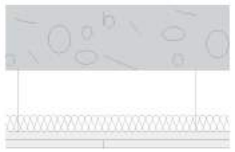


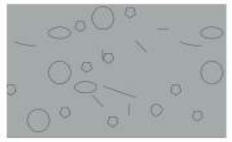
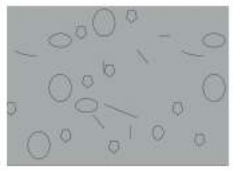
Rw Fair Faced = 39dB, Rw Plastered = 45 dB, Width = 75mm, Density = 1475 kg/m^3

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

LIGHT AND HEAVY WEIGHT WALL EXAMPLES - FLOORS

R_w	Timber Floor	Description
39dB		18mm T&G board, 250mm Joist, 12.5mm Wall Board, 50mm Iso Wool Thickness: 280mm
42dB		18mm T&G board, 250mm Joist, 2*12.5mm Wall Board, 50mm Iso Wool Thickness: 293mm
48dB		2*18mm T&G board, 19mm plan, 250mm Joist, 2*12.5mm Wall Board, 50mm Iso Wool Thickness: 330mm
62dB		2*18mm T&G board, 19mm plan, 250mm Joist, 2*12.5mm Wall Board, 50mm Iso Wool Thickness: 330mm

R_w	Light weight concrete floor	Description
44dB		Density: 1400 Kg/ m3 Mass: 140 Kg/ m3 Thickness: 100mm
54dB		Slab as above: 50mm void, 25mm mineral wool, 1*12.5 Wall Board on MF system. Thickness: 162.5mm
59dB		Slab as above: 50mm void, 25mm mineral wool, 2*12.5 Wall Board on MF system. Thickness: 150mm
63dB		Slab as above: 100mm void, 25mm mineral wool, 2*12.5mm SoundBlockon MF system. Thickness: 162.5

R_w	High Mass Floor	Description
49dB		Density: 2200 Kg/ m3 Mass: 220 Kg/ m3 Thickness: 100mm
55dB		Density: 2200 Kg/ m3 Mass: 330 Kg/ m3 Thickness: 150mm
59dB		Density: 2200 Kg/ m3 Mass: 440 Kg/ m3 Thickness: 200mm
63dB		Density: 2200 Kg/ m3 Mass: 550 Kg/ m3 Thickness: 250mm

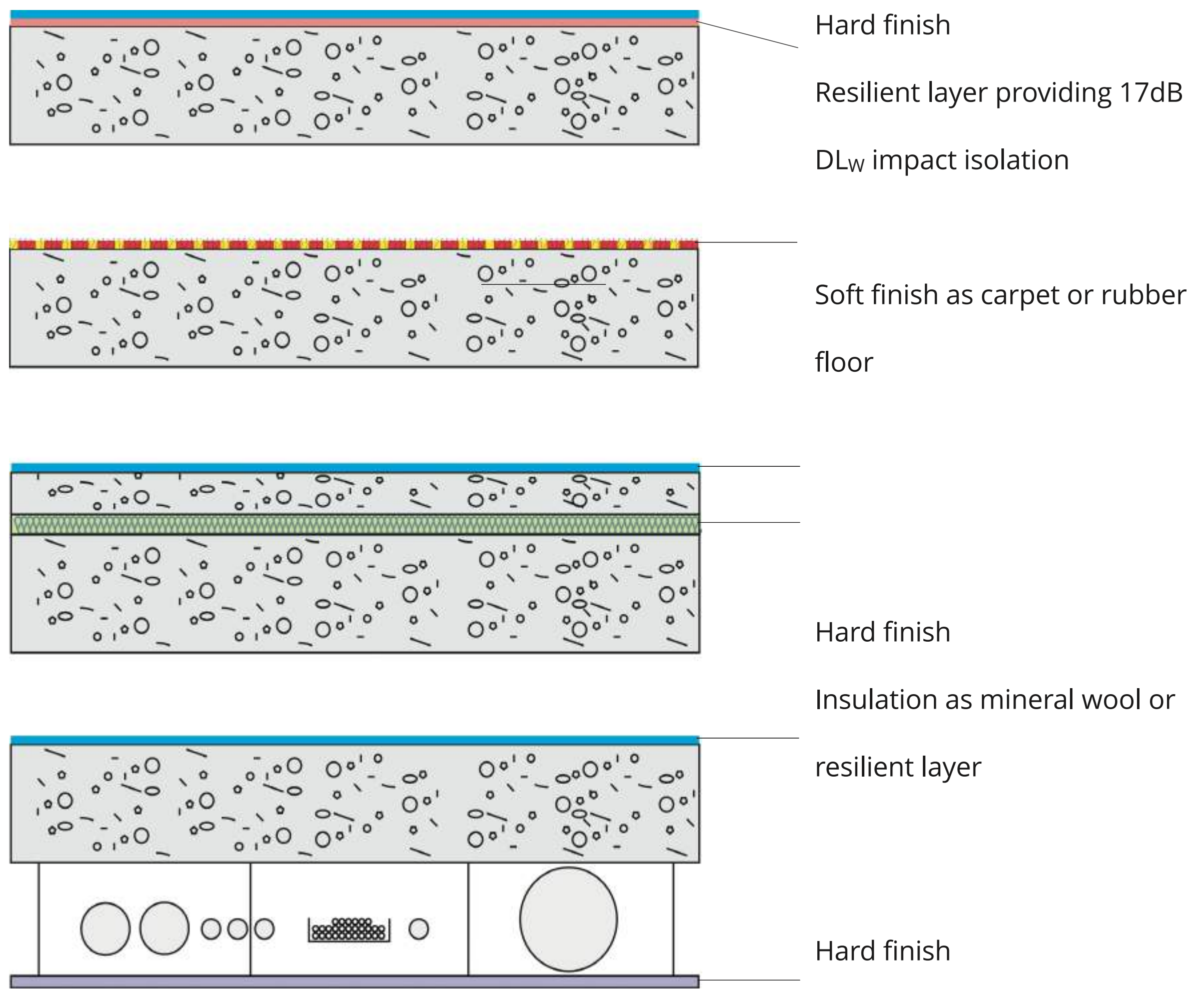
Indicative Sound Insulation Levels - Based on INSUL Composite Sound Insulation Calculations

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.



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THE PHYSICS BEHIND SOUND INSULATION

Facade Lecture Notes

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THE PHYSICS BEHIND SOUND INSULATION

THE PHYSICS BEHIND SOUND INSULATION

Previously covered sound insulation in terms of its principle and the application of these principles to building acoustics. This section looks at the physics behind sound insulation; providing an insight into how sound passes through structures.

Particle Movement and Sound Insulation - Going back to the start, we have seen that sound is in effect oscillating air molecules, moving backward and forwards. These molecules have a mass and, since they are moving, they contain kinetic energy. When this energy is met by a solid structure, part of this energy is transferred into that structure, forcing the structure to move. It is this movement that allows sound to pass through a structure, as the molecules on the far side of the structure will undergo compression and expansion, resulting in a new sound wave being propagated.

Put another way, sound can only pass through a structure , providing it does not contain holes, by moving the structure itself; the harder the structure is to move, the more energy is lost and less sound can pass through the structure.

The video shown here on the right, demonstrates how the window of a car moves back and forth, with every beat of the bass. Outside the car bass frequencies can clearly be heard, as a result of this movement.

https://youtu.be/L823C8l1vwo

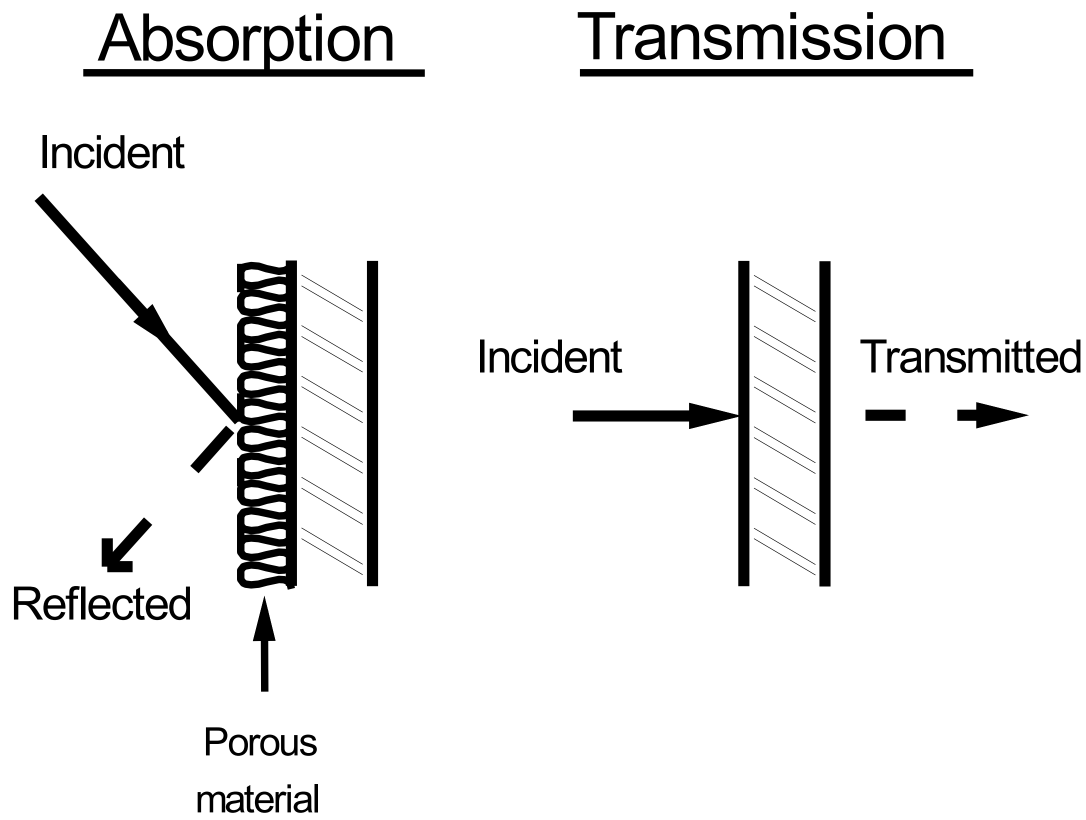
INSULATION VS ABSORBTION

Insulation vs Absorption

Insulation and ***absorption*** are two very different things, yet can be confused by many.

In the prevention of noise transmission, through a wall, floor, or ceiling, sound must be either absorbed by the partition, or reflected back into the room. In practice the former is difficult to achieve, whilst the latter means sound ***insulation*** is not likely to reduce the amount of sound within the source room; rather, it may well increase it.

Absorbers can only absorb sound if the sound passes through them multiple times, and a sound wave passing though a wall need strike the wall only once to be transmitted. Applying sound ***absorption*** in the source room will help to 'mop up' the sound, but, due to this 'one strike transmission', this does nothing to stop the transmission into the next room.



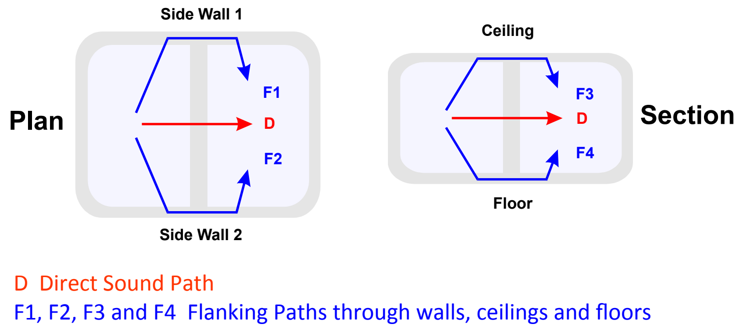
SOUND INSULATION - TYPES AND PATHS - FLANKING

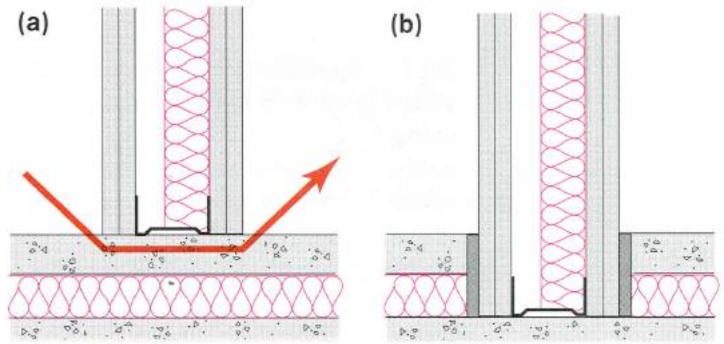
The following figure shows examples of the various paths that sound can take between two rooms. Paths are typically grouped into direct and flanking paths.

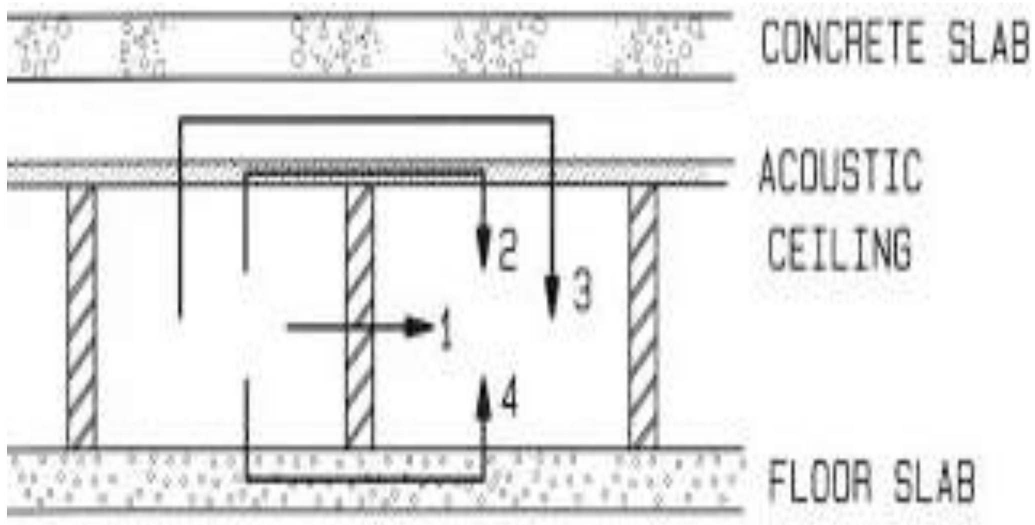
A **direct path** is sound transmitted through the partition which connects the two rooms. This is denoted by D in the image, and F . Below

Flanking paths account for all other transmission paths, denoted by F below, and might be via the floor or shared external wall of two rooms on the same story, for some examples. The estimation of the sound transmitted through these routes is a difficult task without specialist software.

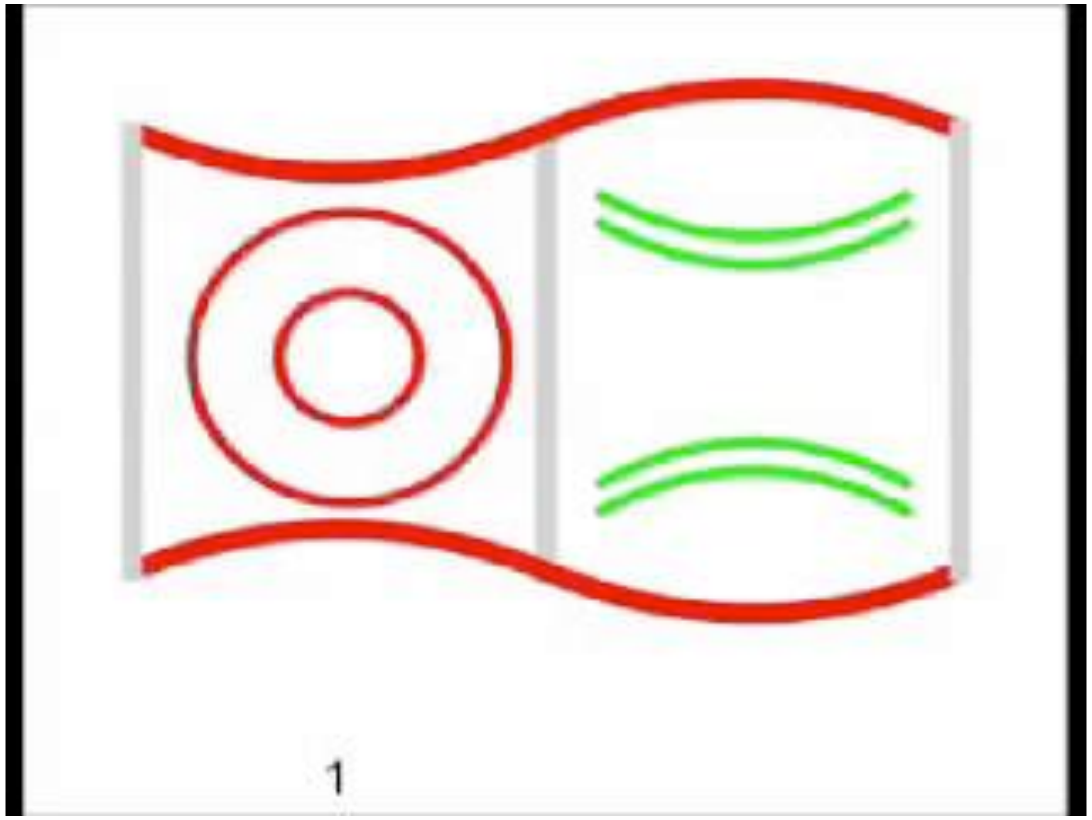
Luckily, the transmitting of sound through direct paths normally dominates. This means that, unless a very high degree of acoustic isolation is required, flanking paths can often be left out of calculations, instead using good design to minimize the effectiveness of such paths.







SOUND INSULATION - TYPES AND PATHS - FLANKING



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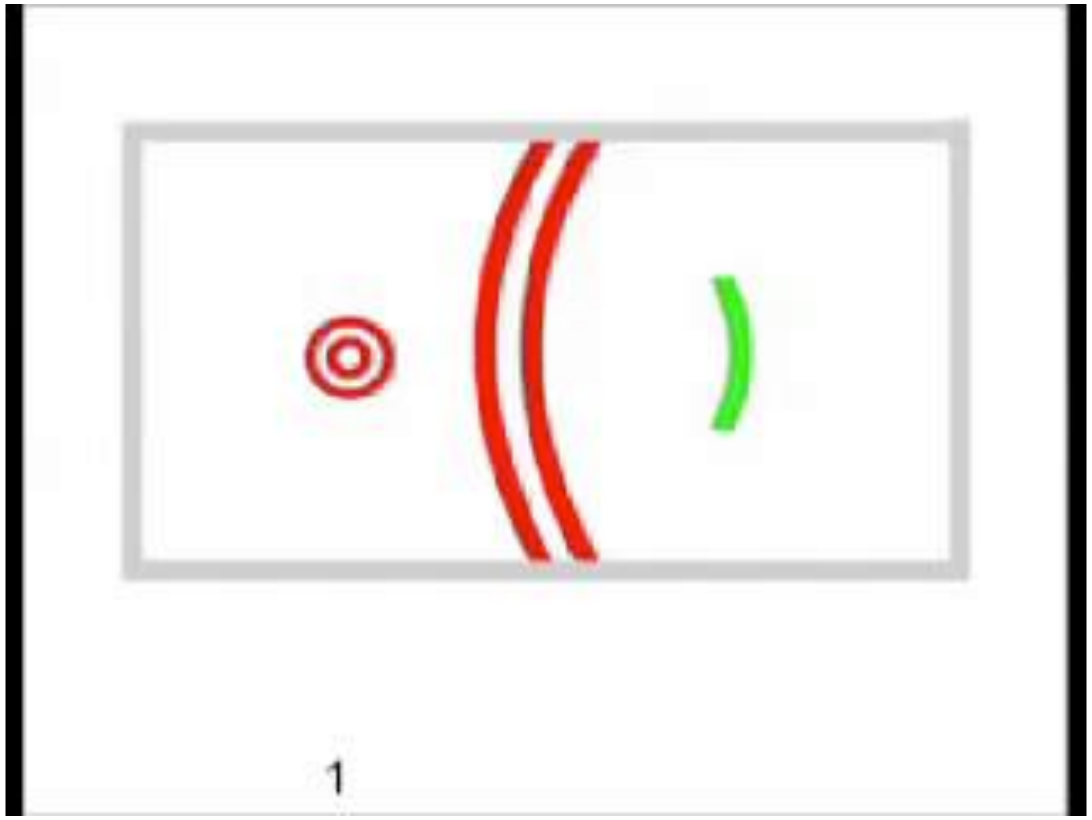


https://youtu.be/brwhRSsOR2A

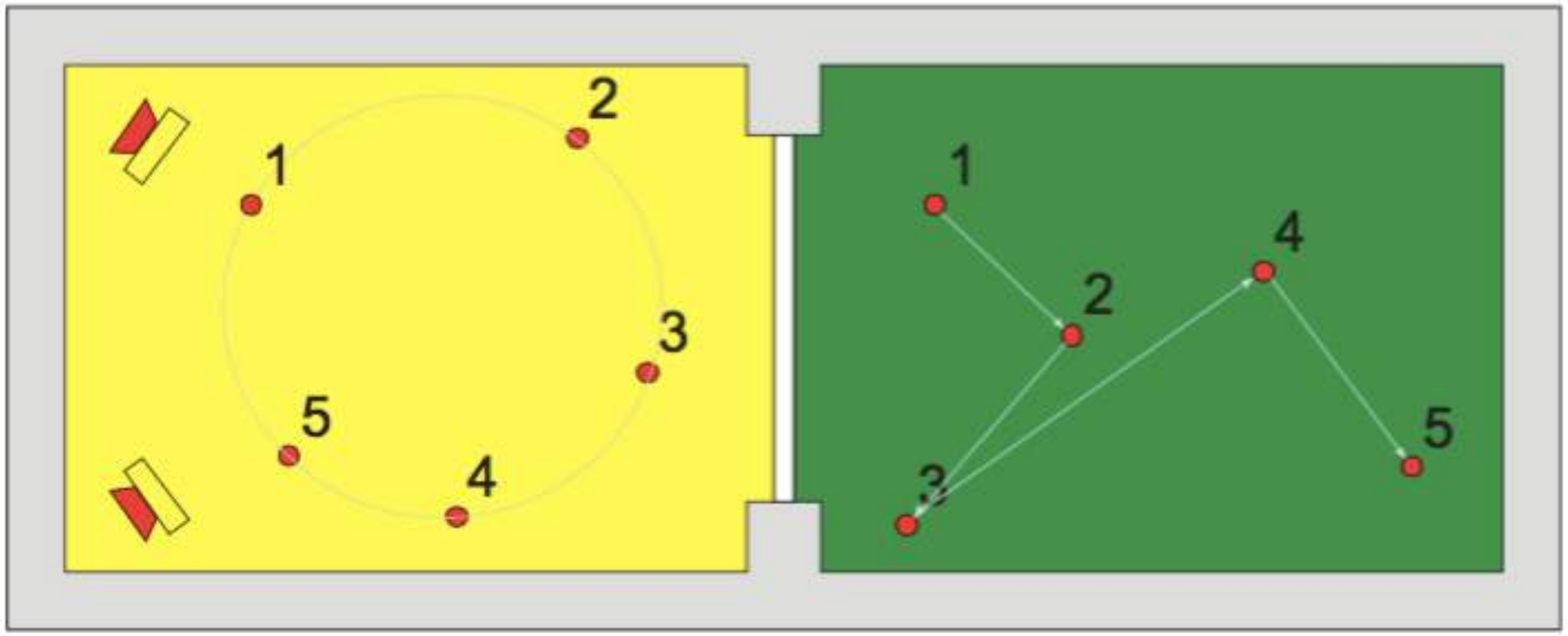
SOUND REDUCTION INDEX

The ability of a separating element, i.e. a wall, floor, window or another object, to attenuate airborne sound is represented by its sound reduction index (SRI). SRI is denoted as ***R***, with ***R*** representing the number of decibels a source is reduced by, given the presence of the partition. ***R*** is also often referred to as the transmission loss, ***TL***, in some countries.

R ≈ SPL in source room – SPL in receiving room

SRI is frequency dependent, so the sound attenuation of a construction is normally presented within a table, see the figure to the right, with a different value for R at each octave or each 1/3 octave.

It is worth considering how effective typical constructions are at removing sound energy, and how, despite this, people can still be affected by any energy which gets through the partition, though this is usually a minuscule amount.



CALCULATING SOUND TRANSMITION

The transmission of sound across a separating structure is described as sound insulation provided by the structure and is a measure of sound power difference across the separating element.

When a separating structure is made up of more than one element, the over all sound insulation of the separating structure is dependent upon the logarithmic sum of the sound power transmitted through both elements.

The sound power of an element is defined as the sound pressure on a source multiplied by its area. If the sound pressure, or the area of an element, is increased, the total energy the element is exposed to is also increased, hence sound reduction levels are also affected.

The sound pressure level in any receiving room is calculated using the known sound pressure level in the source room, the sound reduction index of the partition and the total absorption of the receiving room, using the following;

$$SPL_2 = SPL_1 - R + 10\log S_p - 10\log A.$$

where:

SPL_1 = Sound Pressure Level in Source Room

SPL_2 = Sound Pressure Level in Receiver Room

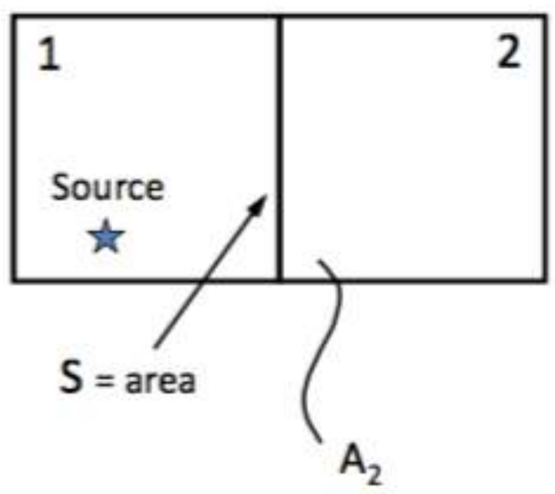
R = Sound Reduction Index

S_p= Surface Area of Partition

A= Total Absorption within the Receiving Room, $\alpha_m S$

S =Total Surface Area of Receiving Room

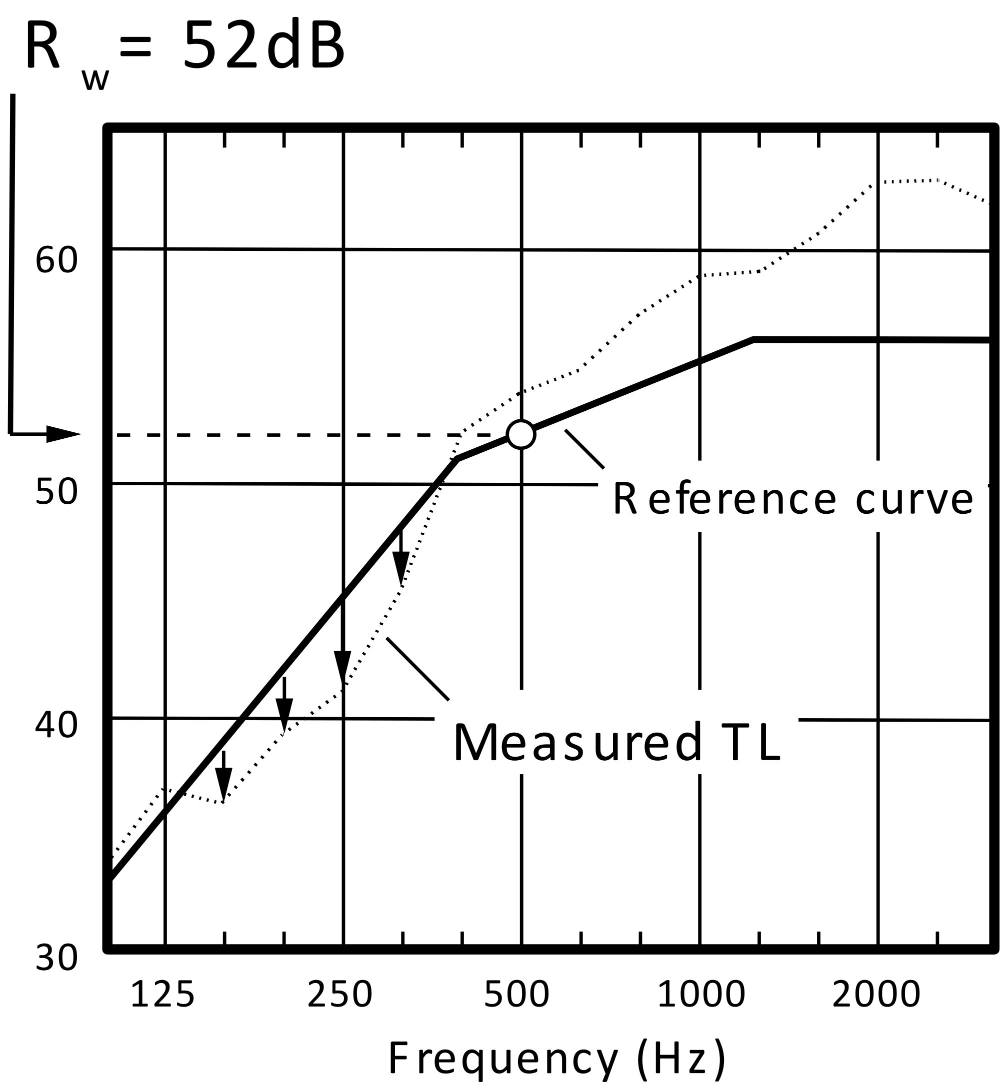
It is worth noting that neither the volume, nor reverberation time, of the source room appear within the equation, as these are accounted for in the value of A, which is frequency dependent. The sound reduction indices of various constructions can be found in most text books, or from manufacturers' websites.



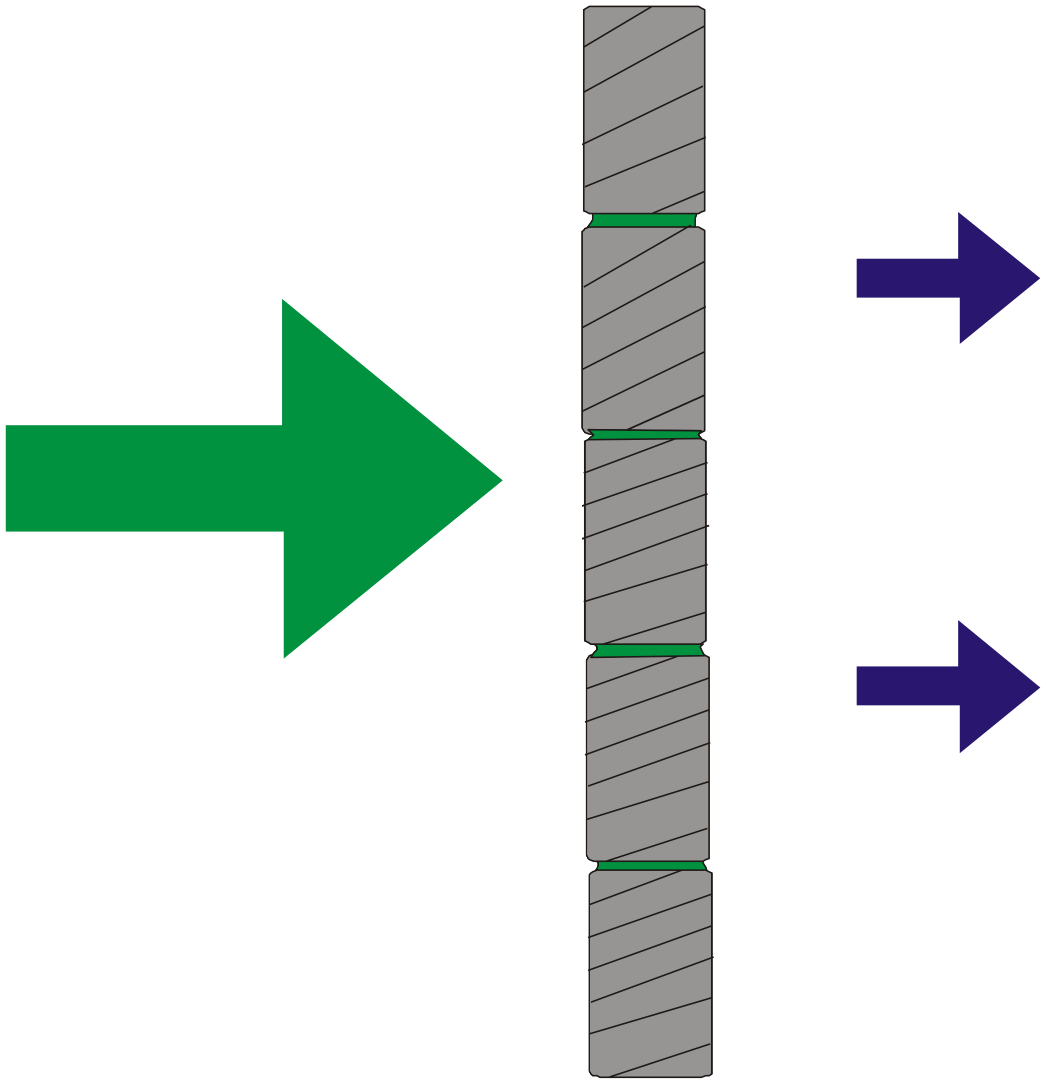
WEIGHTED SOUND REDUCTION INDEX

In order to compare different constructions, it is useful to have a single representative value for SRI, rather than a range of frequency dependent values. To create a single value SRI, an approach similar to A-weighting can be applied, which results in the **Weighted Sound Reduction index, R_w,** which weights different frequencies with greater or less importance.

Note, in the USA the equivalent of Rw is the sound transmission class, STC. This is calculated much the same as R_w, but uses a different range of frequencies. The final rating will, however, be almost the same.



SOUND REDUCTION OF MONOLITHIC STRUCTURES

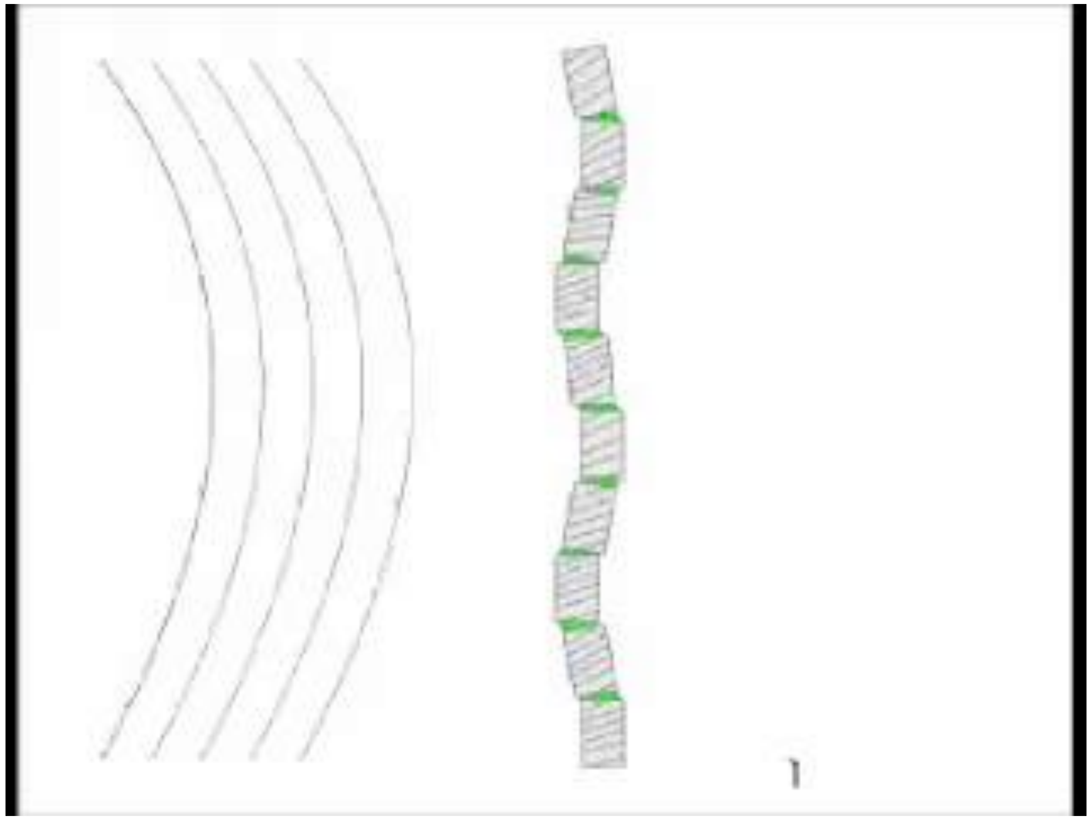


Doubling of mass adds 6 dB to sound insulation of a wall

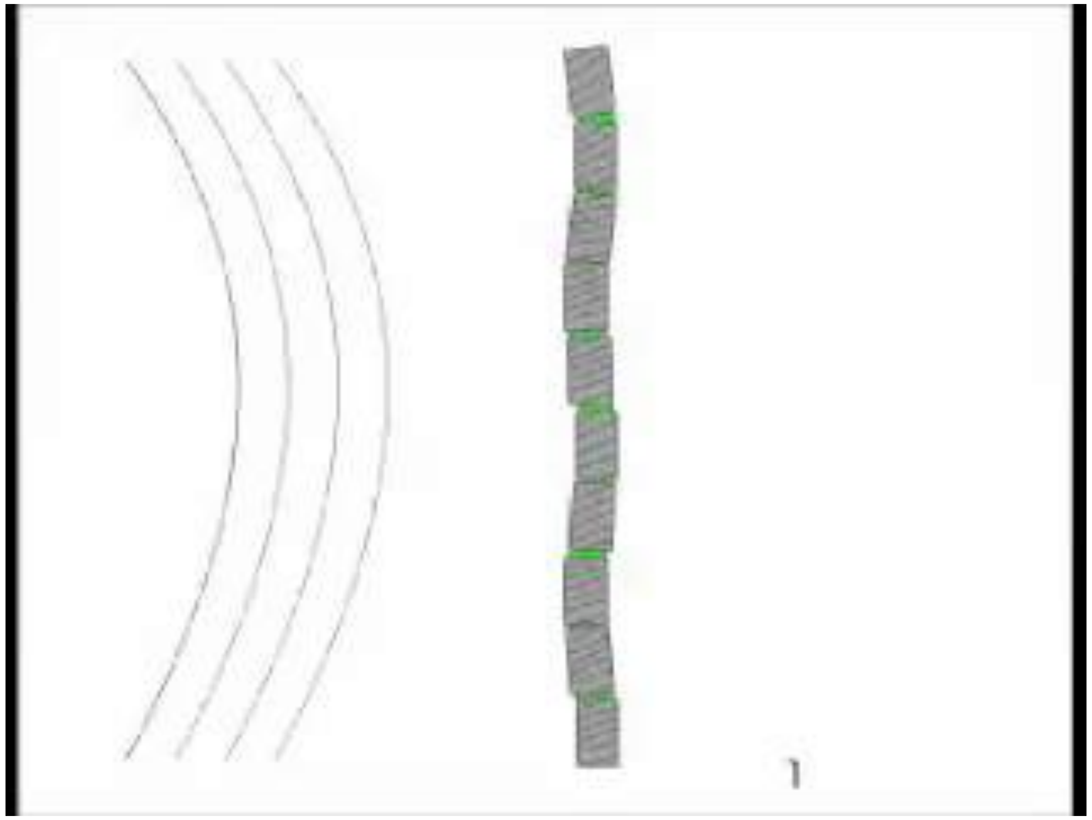
SOUND REDUCTION OF MONOLITHIC STRUCTURES

The sound reduction across a simple monolithic structure, such as concrete, is simply dependent upon the mass of the structure. The heavier the structure; the harder it is to move.

The two videos below illustrate the sound reduction through light weight and dense block walls. It can be seen the light weight wall offers significantly less sound reduction, as a result of considerably more movement, due to the fact that it is lighter and, therefore, easier to move.



https://youtu.be/lqs-xw-Frok



https://youtu.be/tW5HODhvelQ

MASS LAW

For a partition, how much sound it will pass to a receiving room will depend on how easily sound energy can move the partition.

The sound reduction of a monolithic separating structure such as block work, concrete, glass, without any holes or weak spots, is simply down to the mass of the structure. The mass of the wall makes it harder for sound to move the partition and therefore the greater the level of sound reduction. Hence, heavyweight partitions can be expected to provide good levels of sound reduction.

The relationship between mass and frequency is as follows;

R = 20logMf – 43 dB

where;

M = mass of the partition per unit area (kg.m^{-2}),

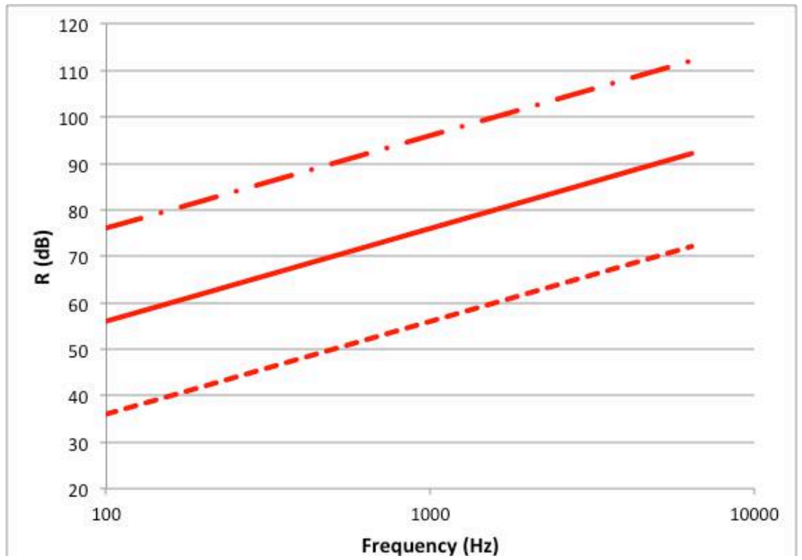
f= frequency (Hz)

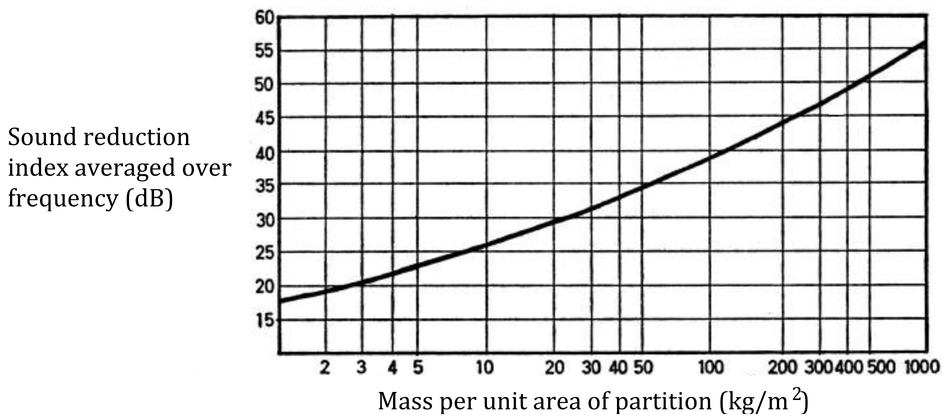
R = sound reduction index.

Alternatively, a single value can be obtained from

R (average 125 to 4K) = 20log*1312*f – 43 dB

A useful rule is that doubling the mass of a partition increases its sound insulation, R, by 6 dB. Note, R, as mentioned previously, is frequency dependent, so manufacturer's data will provide a value for R for each octave band. The mass law in frequency for partitions weighing 1 (dotted), 10 (solid) and 100 (chain) kg.m^{-2}.

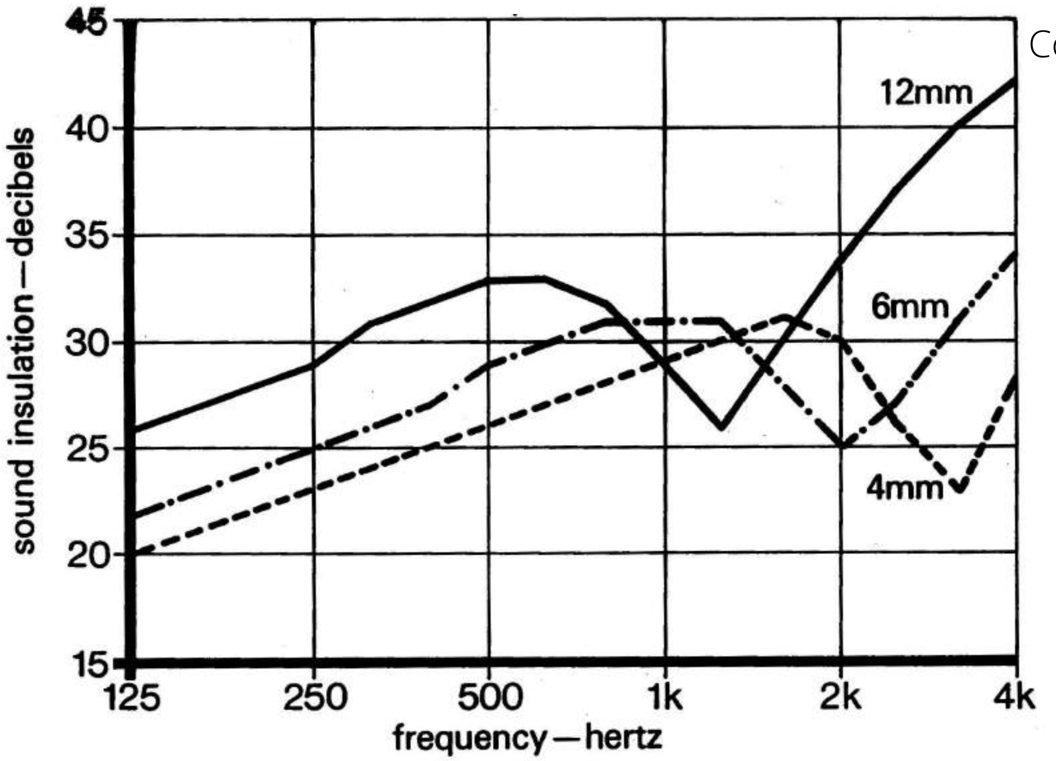




COINCIDENCE FREQUENCY

Another strong characteristic in the frequency response of the partition is its Coincidence Frequency. This is similar to the natural frequency, however, this characteristic occurs high in the frequency range of the partition since it is a function of the wavelength, stiffness of the material, levels of damping in the material, but above all the thickness of the material.

The coincidence frequency is therefore seen to be the flexing of the partition, resulting in different parts of the partition moving independently of each other, resulting in peaks and troughs appearing across the surface of the partition, which in turn compromises the overall performance of the partition at high frequency.

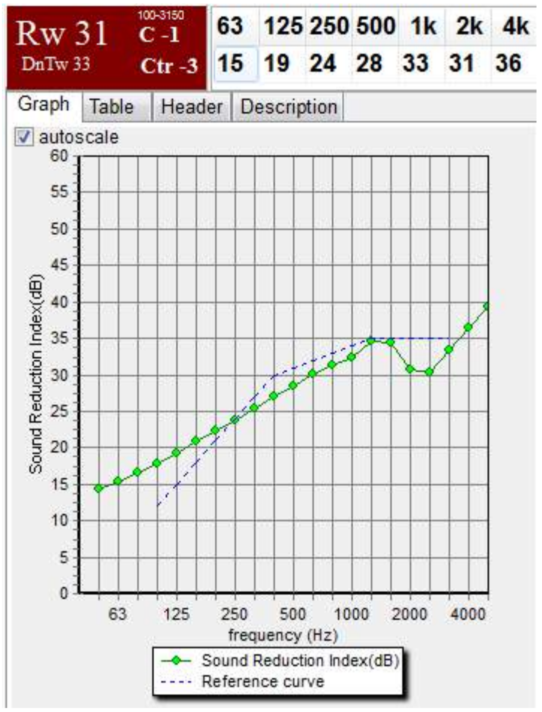


Coincidence. [1]

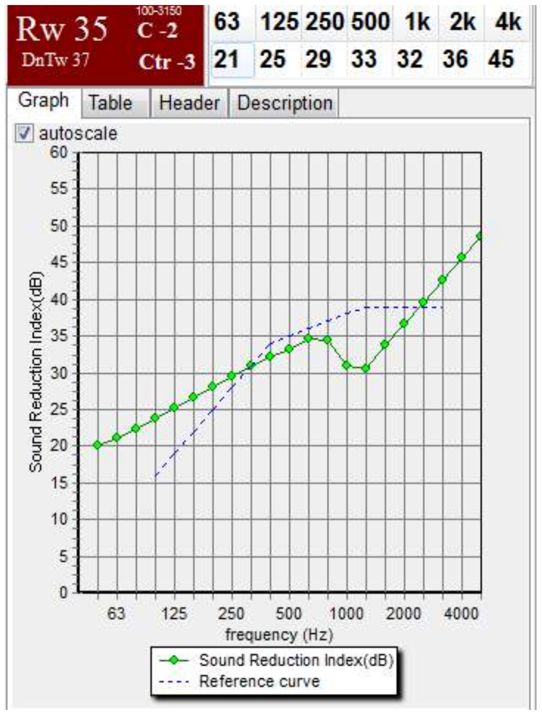
COINCIDENCE FREQUENCY

The graphs to the below show the modeled sound reduction for a series of glass panels. Note the effects of the coincidence frequencies for each panel at the top end of the frequency spectrum.

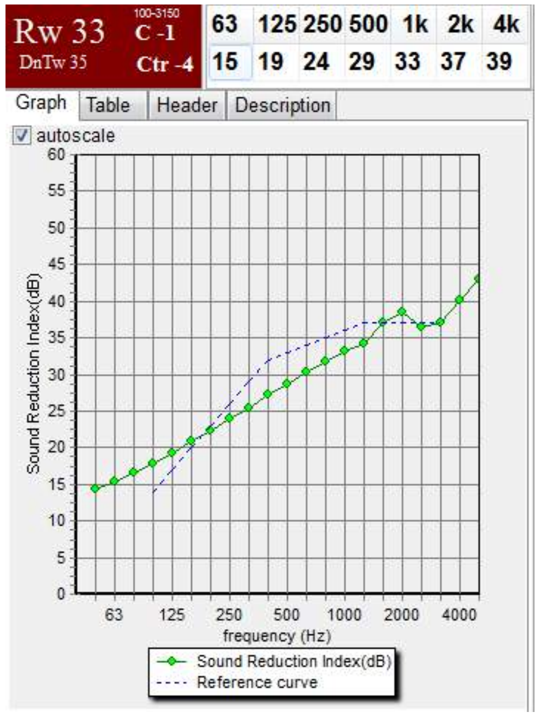
The graphs to the below show the modeled sound reduction for 6 and 12mm glass panels. Comparing these graphs shows how the overall sound insulation of the glazing increases by 6dB per octave, with a doubling of mass. It can also be seen that due to the increase in thickness in the glass, the coincidence frequency has dropped.



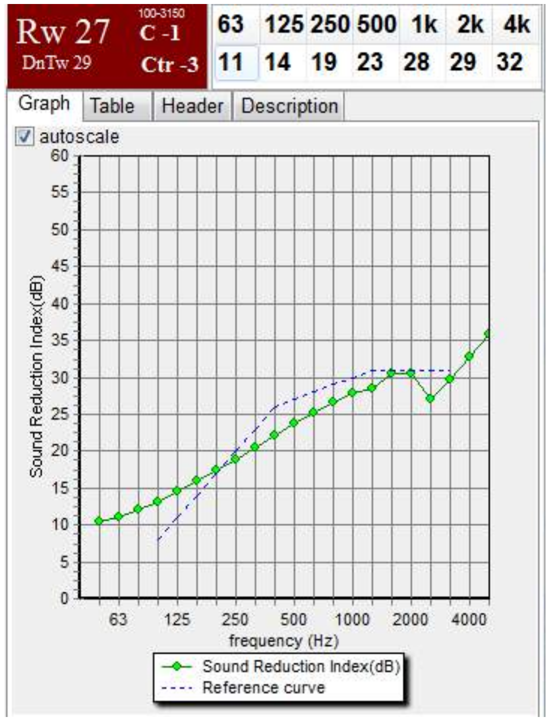
6mm Glass



12 Glass



6mm Laminated Glass



12mm Plasterboard

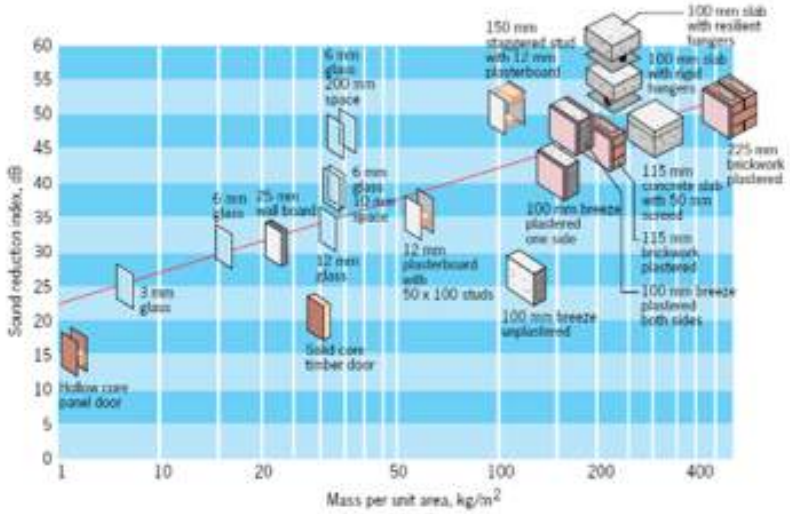
SOUND REDUCTION OF TWIN SKIN CONSTRUCTIONS

The graph to the right, provides a visual summary of the Mass Law. Comparing 3mm glass to 6mm glass; an improvement of 6dB, with a further 6 dB improvement, when increasing the thickness from 6 to 12mm.

However, when comparing the performance of a monolithic 12mm glass plane to a double sink; 6mm, 200mm air space, and 6mm glass; for the same mass the double glazed unit has an increased performance of an additional 20 dB, without increasing the overall mass of the structure. This increase in performance is due to the fact that double leaf systems perform better than single leaf structures, due to the air gap between the two panels.

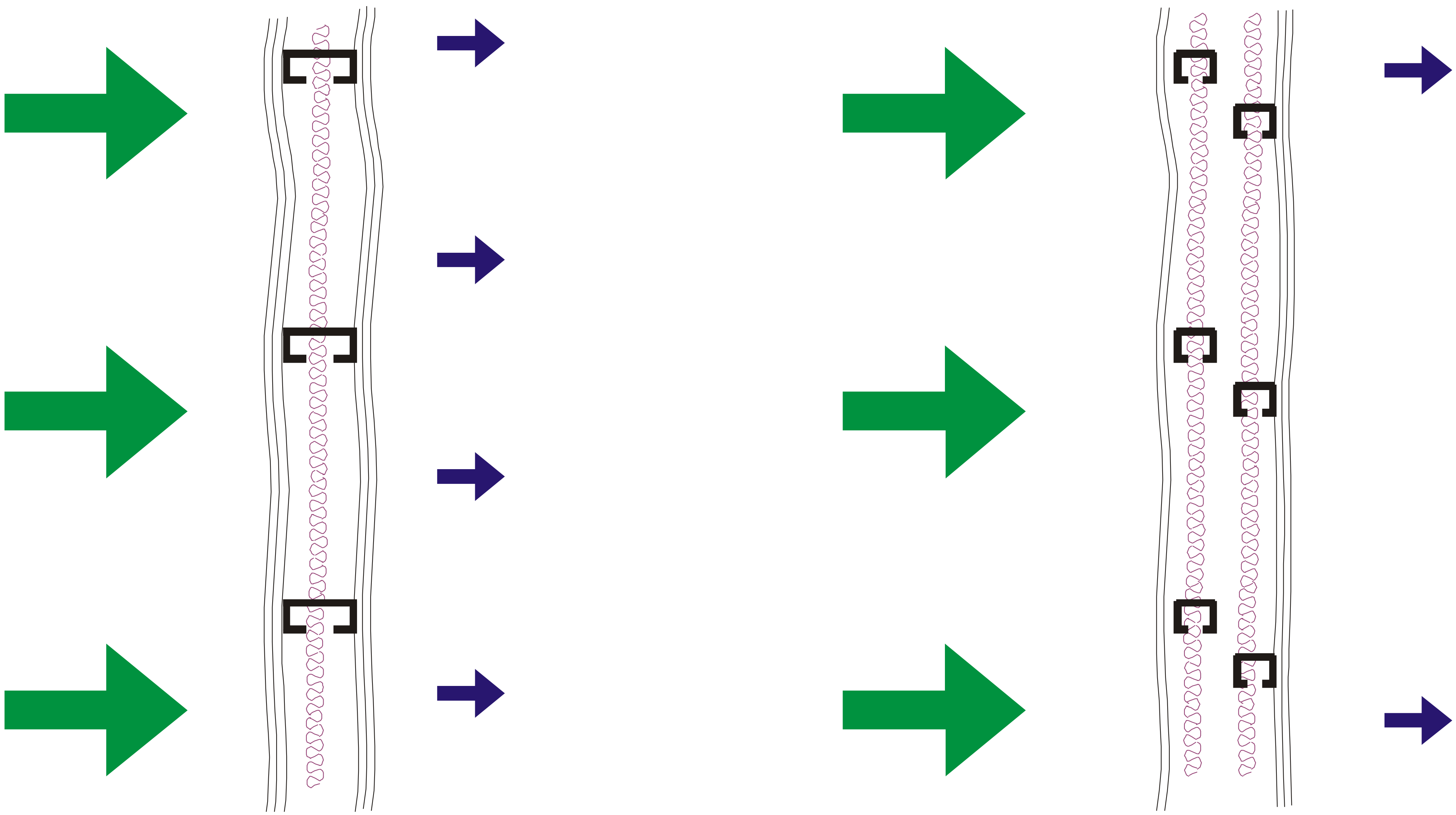
Comparing 6mm float glass and 6mm laminated glass shows that laminations within the glass provide damping, reducing the effects of the coincidence frequency. This can be seen in the illustration above. Since the mass of the glass is not significantly changed by the additional damping the overall performance of the glazing is not affected. This can, however, be useful if there are problem frequencies associated with a development as the glazing can be specified, such to reduce the problem frequencies, without over specification occurring

.



Monolithic Structure - blockwork

SOUND REDUCTION OF TWIN SKIN CONSTRUCTIONS



TWIN SKIN CONSTRUCTIONS

The sound reduction through a composite construction is similar to the sound transition through a monolithic construction, but, in this instance, the sound is required to pass through multiple, interconnecting structures and mediums; air.

Composite Structure – Stud Wall, Double Glazing

The passage of sound through a twin skin partition is proportional to the mass of the two skins making up the partition, plus the sound insulation of the interconnecting element.

As in the case of a monolithic structure, the mass of each skin governs the levels of movement and, therefore, the propagation through these two structures, with a higher mass offering improved separation.

The benefit of composite construction is that sound must also pass through the connecting structure; where a structure with high levels of flexibility will reduce the levels of vibration, or movement, resulting in enhanced levels of separation.

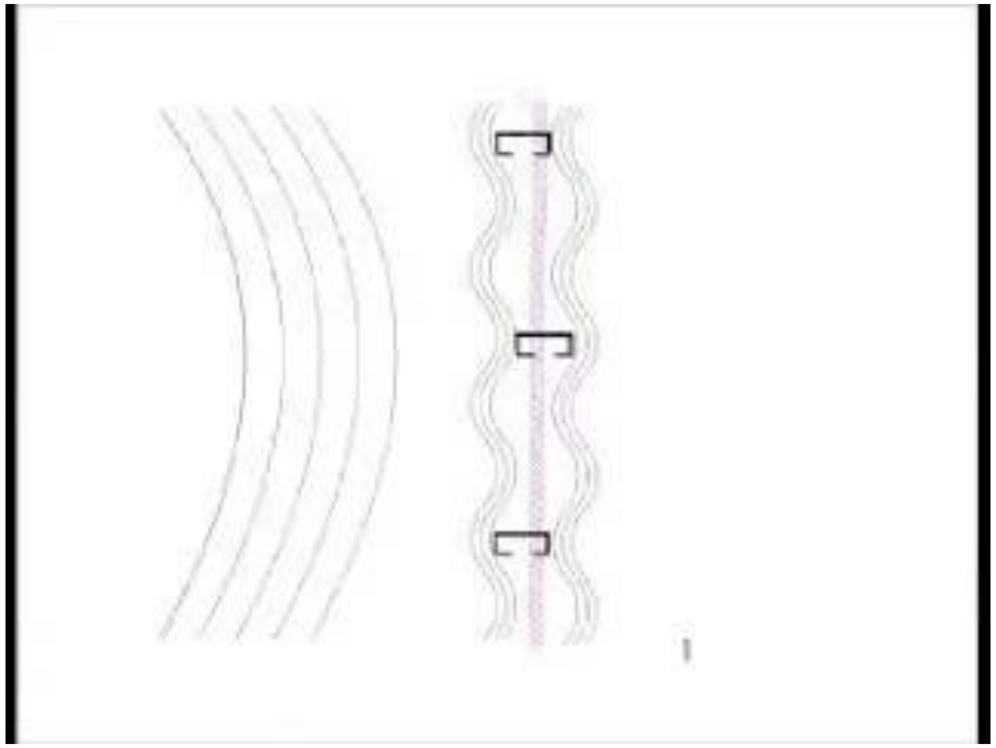
As noted previously, the sound reduction across a composite structure is dependent upon the ease with which the first skin , the skin exposed to the sound, moves, the ease with which the sound/ vibration then passes to the connecting structure between the skins, and the ease with which the second skin can be moved.

It is worth noting that the addition of acoustic absorption to the void within a composite construction has the benefit of adding damping to low frequency resonance, somewhat negating its effects.

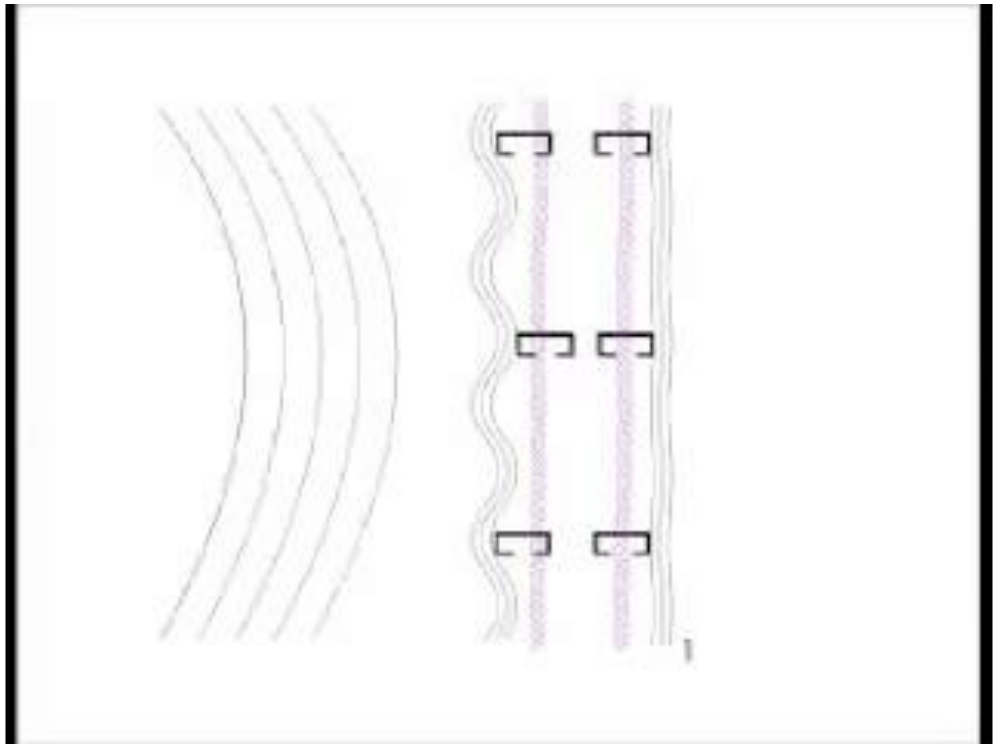
TWIN SKIN CONSTRUCTIONS

For simplicity, if we keep the mass of the skins equal, it can be seen that two layers of plasterboard on either side of a single stud wall, will not perform as well as the same sound passing through a twin stud wall. This is simply due to the connectivity between the two studs.

The videos below demonstrate this effect; Video 1 shows the sound reduction through a single stud wall and Video 2 illustrates the sound reduction through a twin stud wall.



https://youtu.be/ZtbVv6Io--w



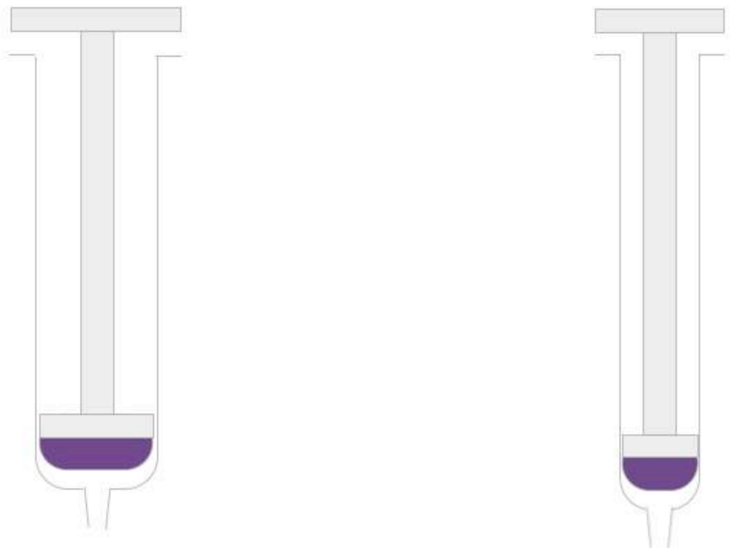
https://youtu.be/Cg-ph6B99Lw

AIR CAVITIES - TWIN SKIN CONSTRUCTIONS

One of the key factors affecting the performance of a twin skin construction is the air cavity between the two leaves. The illustrated video below demonstrates this effect as plungers are extracted from different sized syringes.

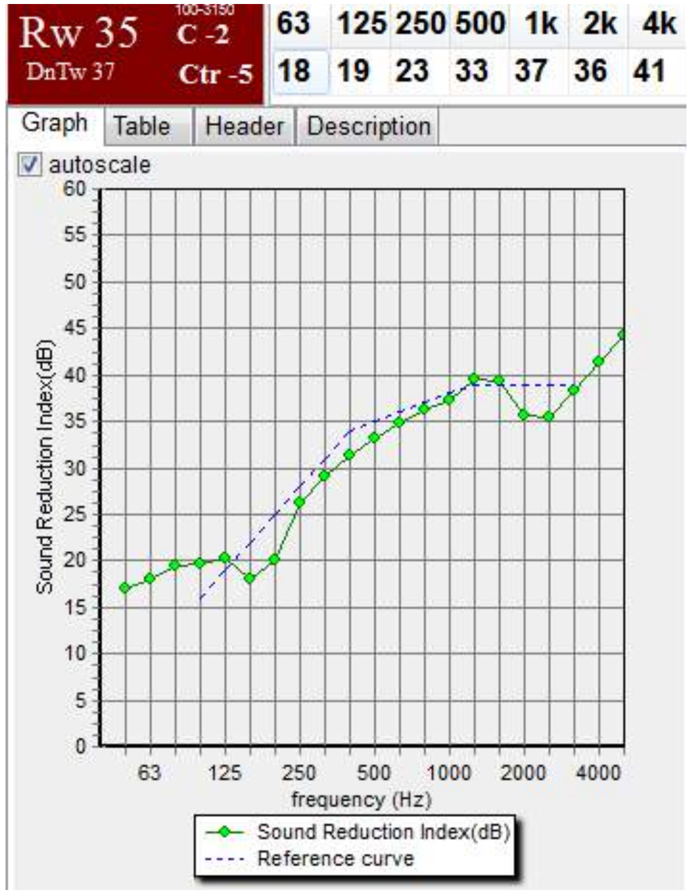
As can be seen from this video, both syringes return back to their original positions. However, the larger of the two takes longer to reach its starting position. This is due to the increased air volume in the larger syringe, resulting in the air being under less of a vacuum, hence there is less pressure to return the plunger.

In the case of a twin skin construction, the air between the leaves acts as a coupler, in a similar manner to that as shown in the illustrated videos. As such, if the air void between the two skins is not being dominated by mechanical structures, the air coupling increases the levels of acoustic separation provided by these structures.

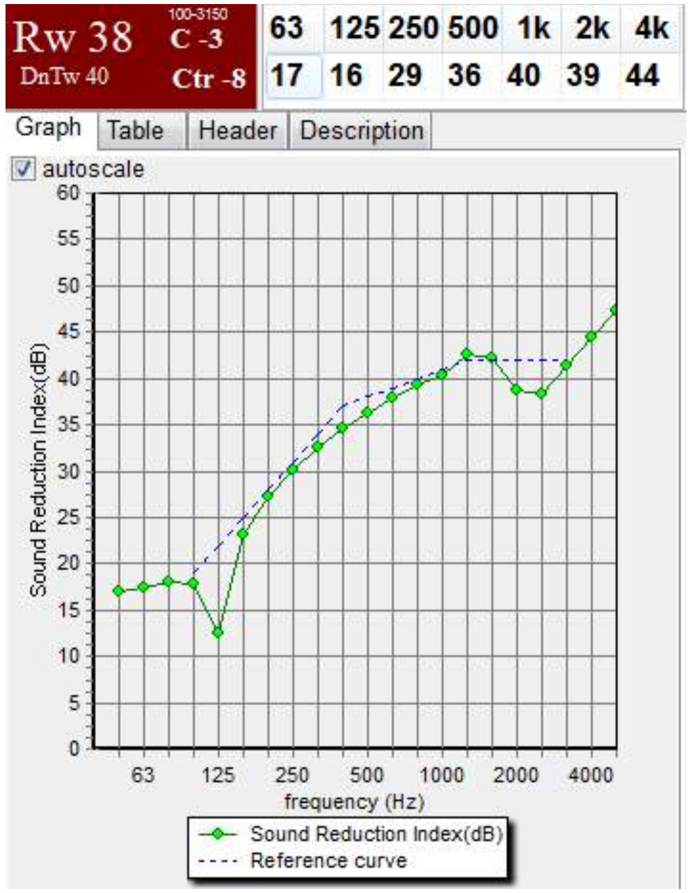


https://youtu.be/psI8j3gY3W0

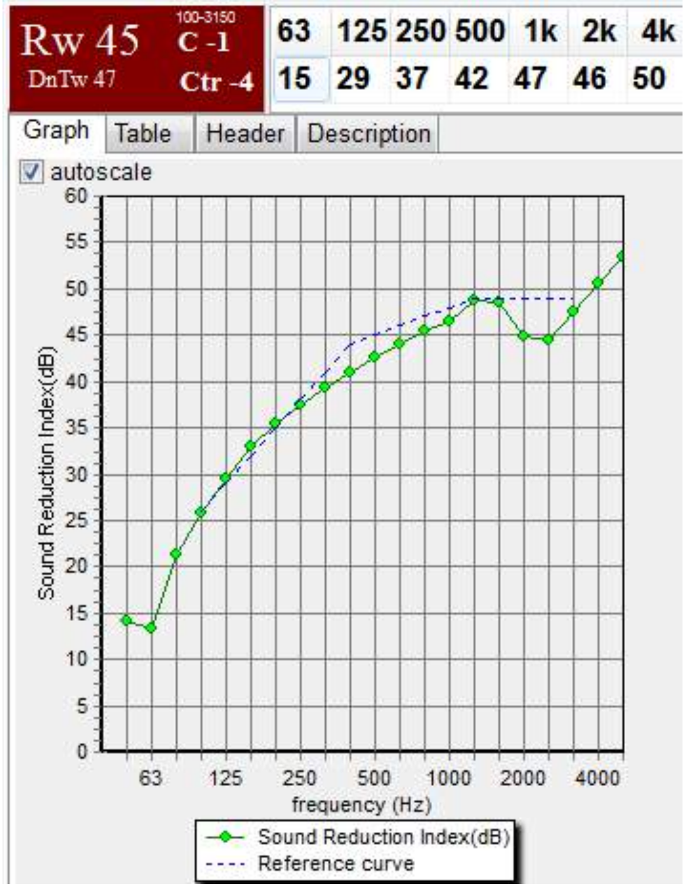
SOUND REDUCTION OF DOUBLE GLAZING



6 / 12 / 6mm Glass



6 / 24 / 6mm Glass



6 / 100 / 6mm Glass

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MACH ACOUSTICS

Presented By Ze Nunes
Founder of MACH Acoustics
Lecturer At the University Of Bath

"MACH Acoustics takes time to analyze, consider and propose solutions, that promote an architectural approach. The sensitivity and technical performance capability is well respected by the practice." Jo Bacon – Allies & Morrison Partnership

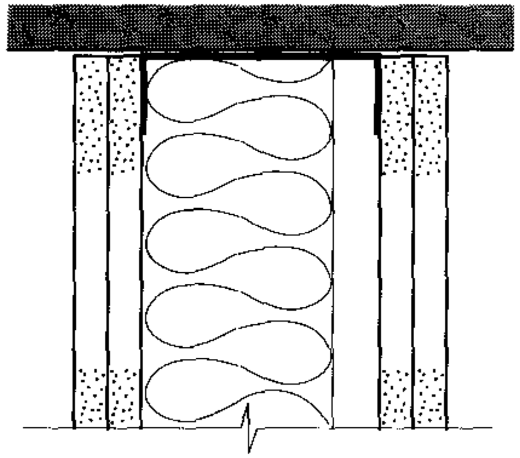
ACOUSTICS AND CONSTRUCTION DETAILS

Facade Lecture Notes

CONTENTS

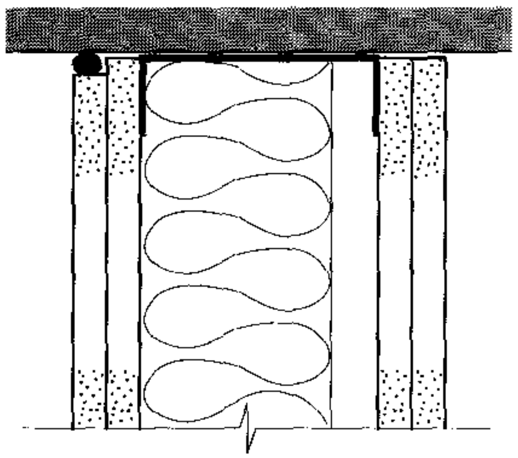
ACOUSTICS AND CONSTRUCTION DETAILS

THE AFFECTS OF DEFECTS



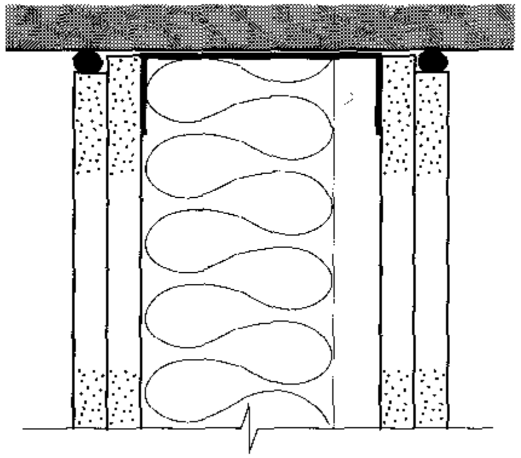
Unsealed

STC 29



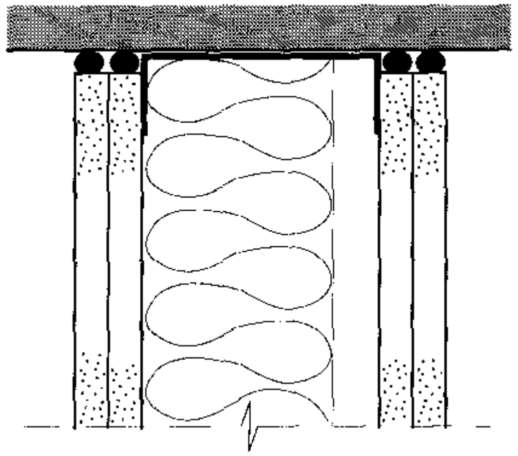
One sealing bead

STC 49



Two sealing beads

STC 53



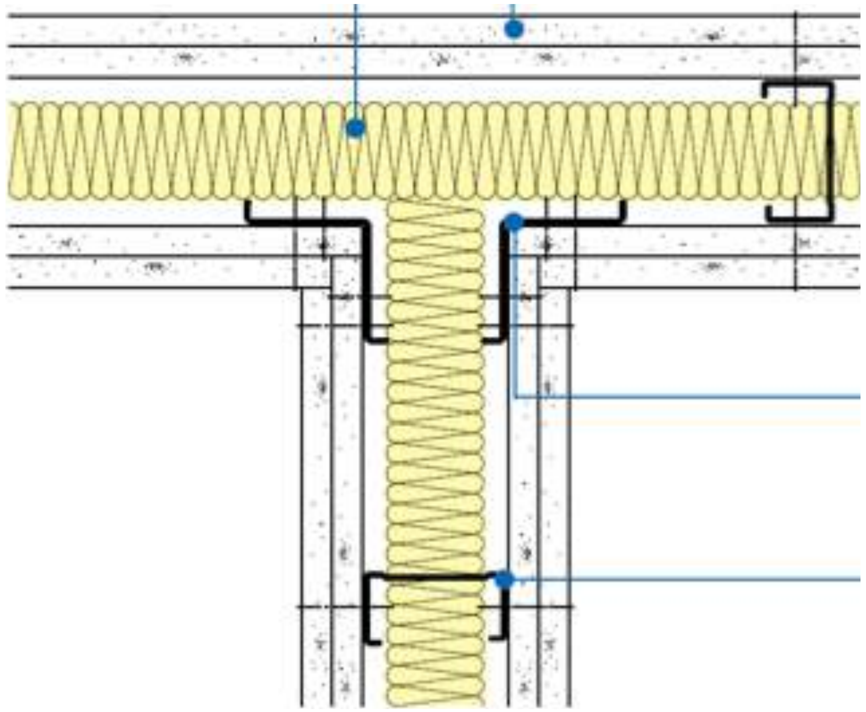
Four sealing beads

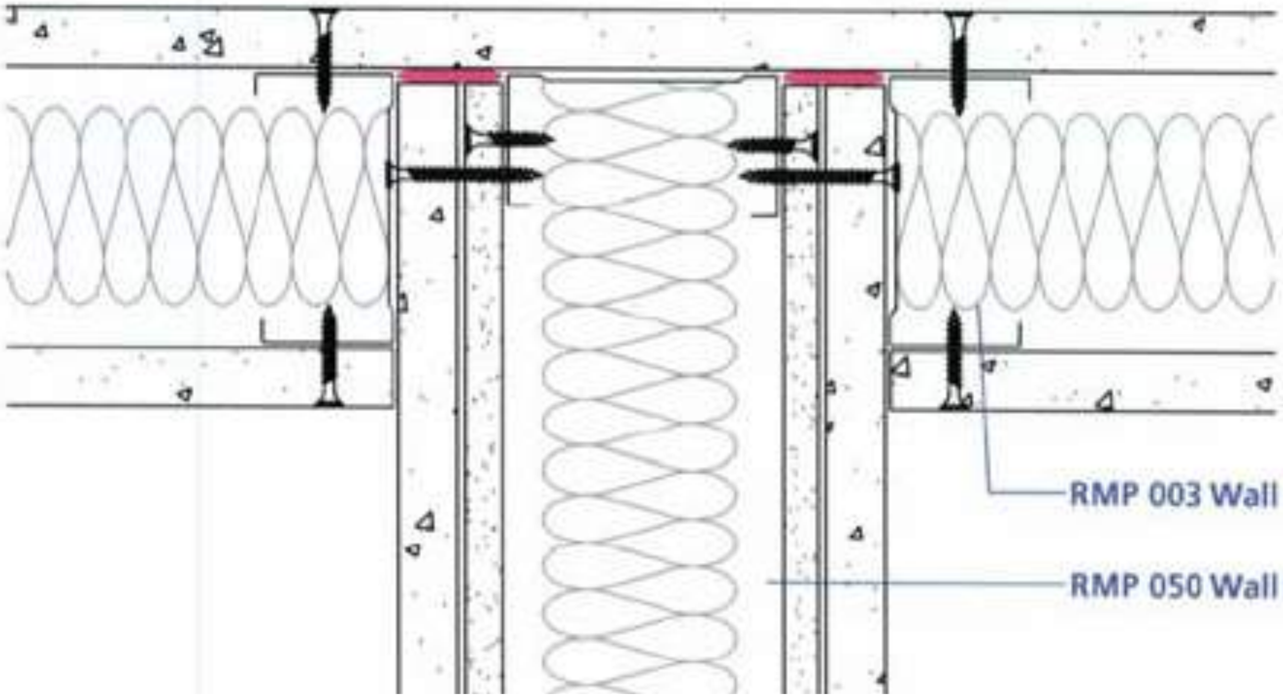
STC 53

THE AFFECTS OF DEFECTS

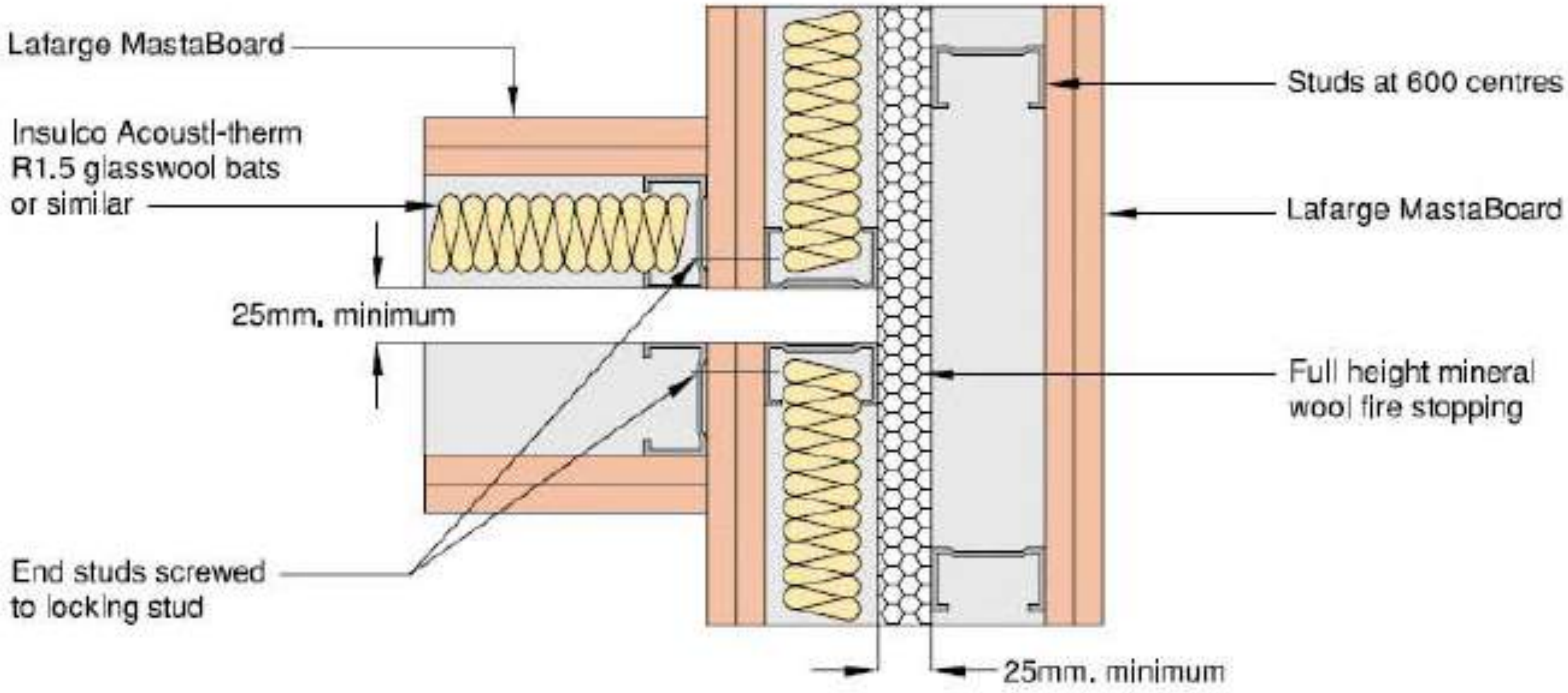
https://youtu.be/9ksxJ3i1KbA

T JUNCTIONS - SINGLE LEAF

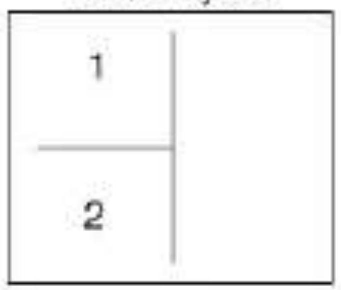




T JUNCTIONS - DOUBLE LEAF

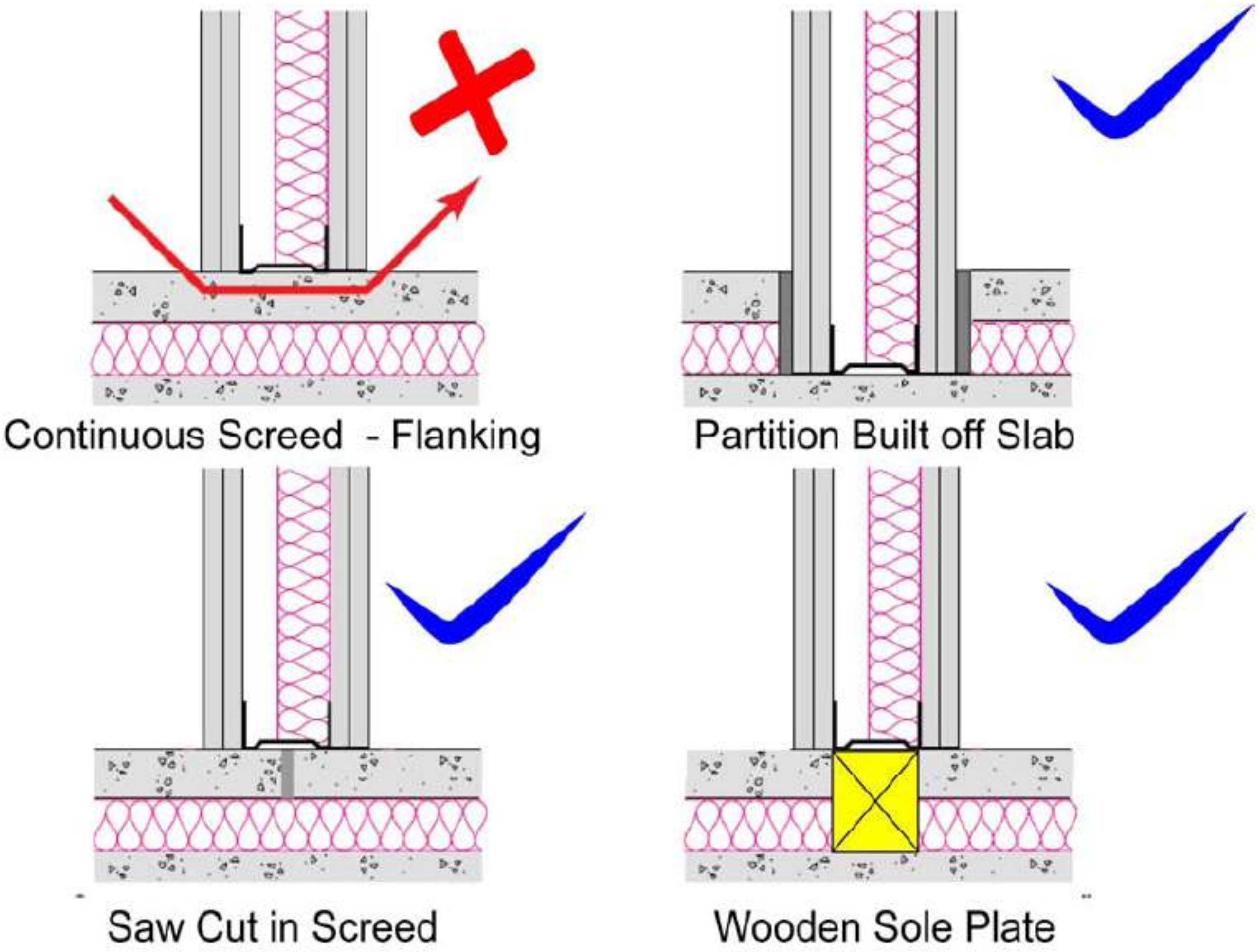


Unit Layout

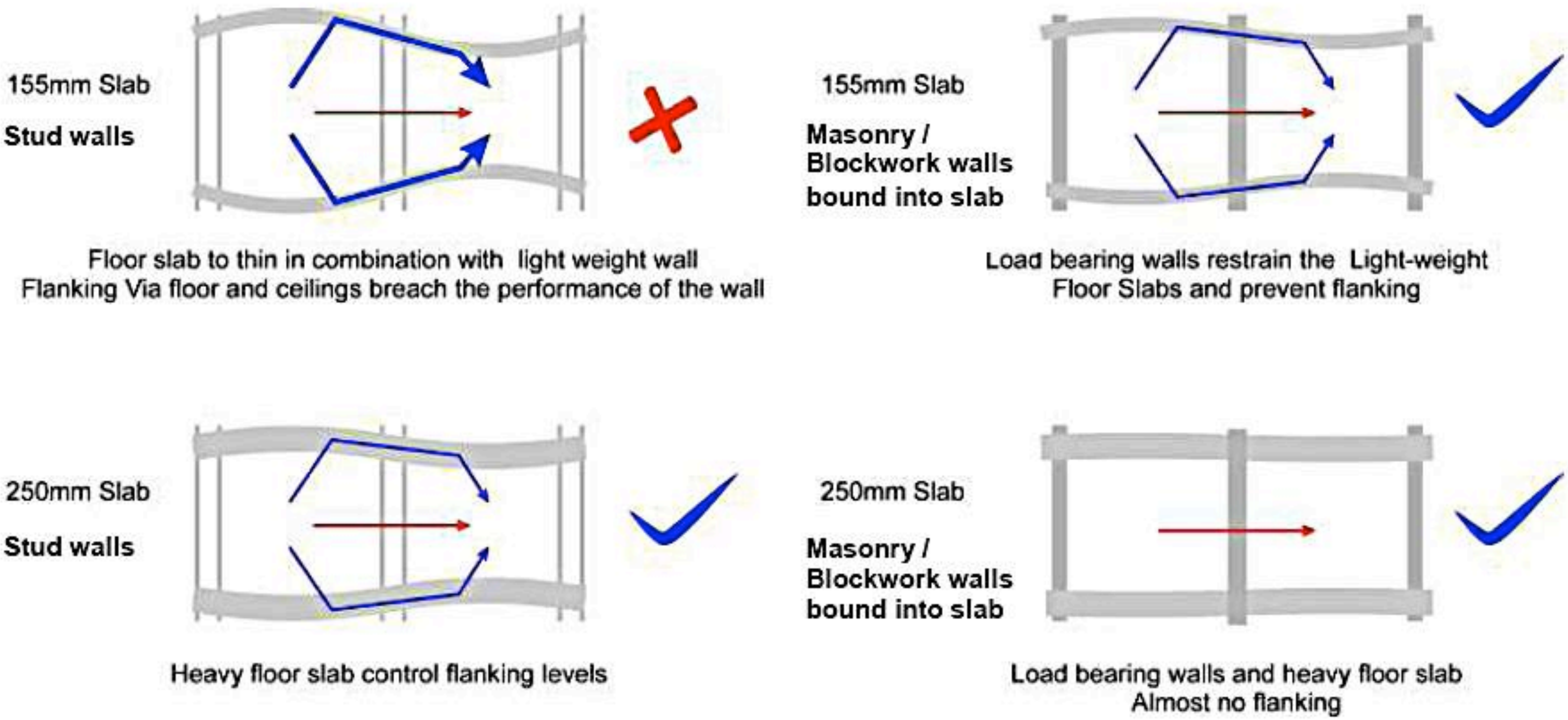


LINING AS SPECIFIED
FOR SPECIFIC SYSTEMS

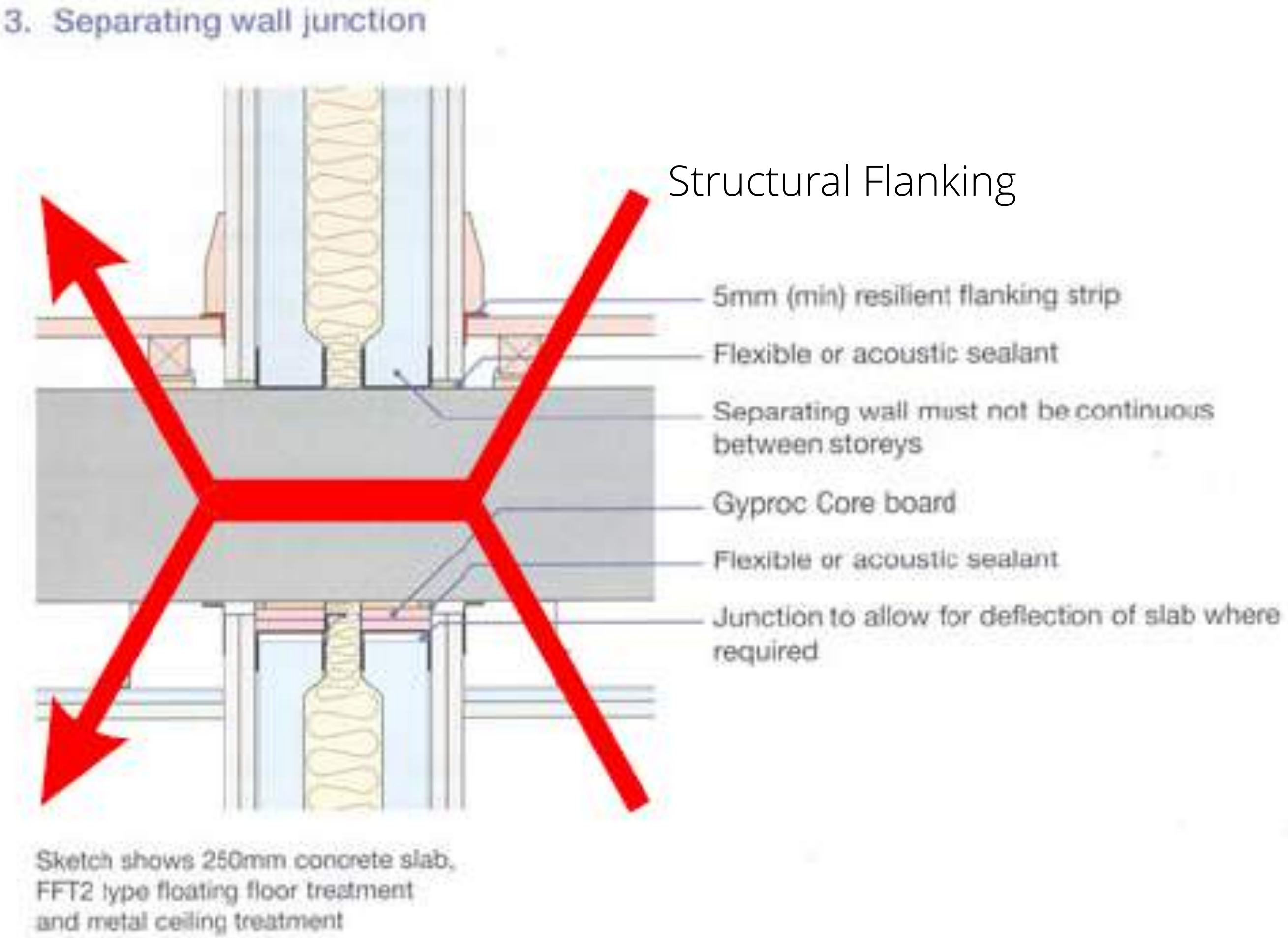
FLOOR SCREEDS

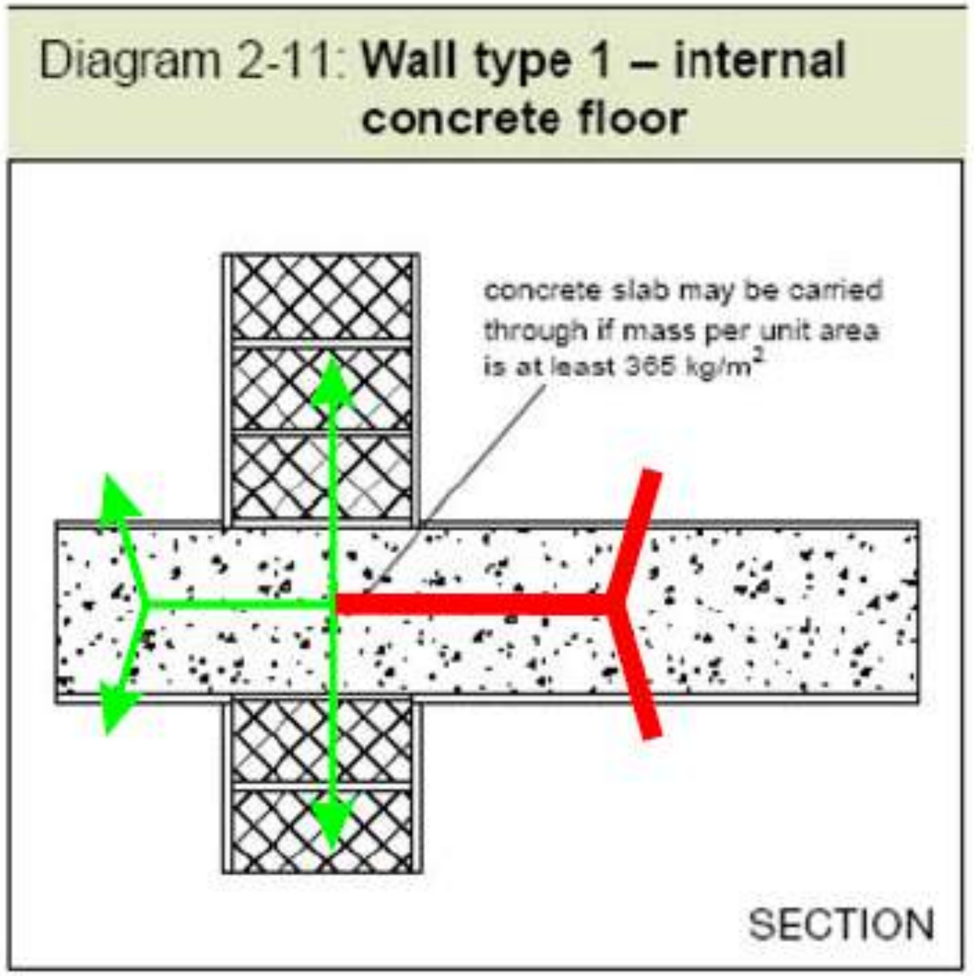


STRUCTURAL FLANKING - BUILDING STRUCTURE



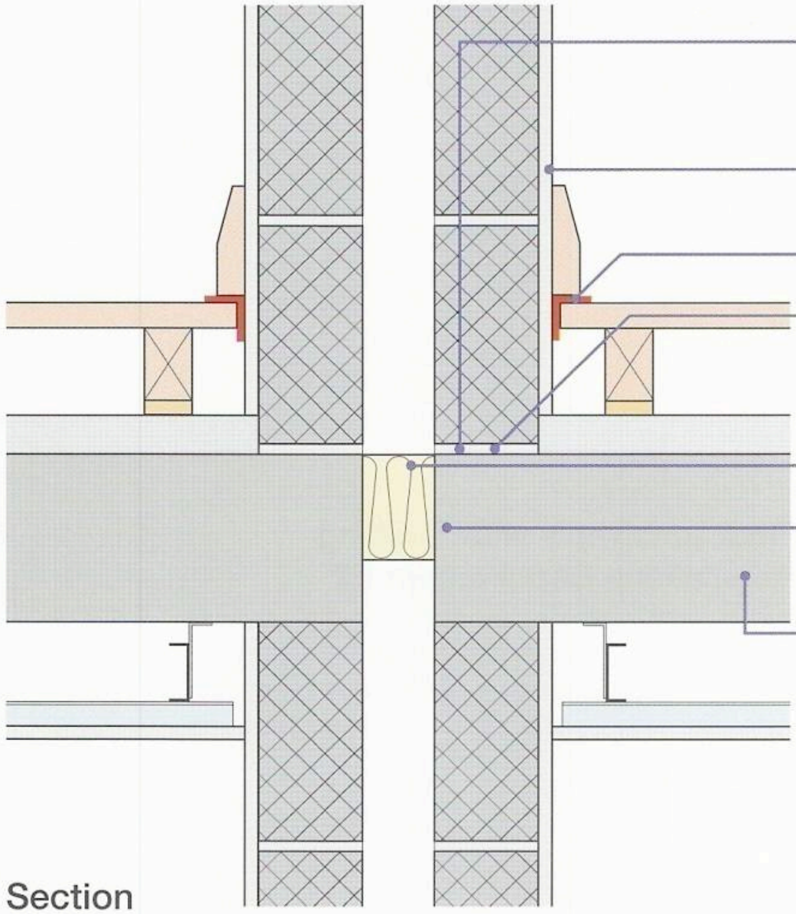
STRUCTURAL FLANKING - LOAD AND NON-LOAD BEARING WALLS





STRUCTURAL FLANKING - CONTINUES SLABS

5. Separating floor junction



Sketch shows E-FC-1 type separating floor, FFT1 type floating floor treatment and CT3 type ceiling

STRUCTURAL FLANKING - INTERNAL FACADE LININGS

Diagram 2-6: **Wall type 1 – bonded junction – masonry inner leaf of external cavity wall with solid separating wall**

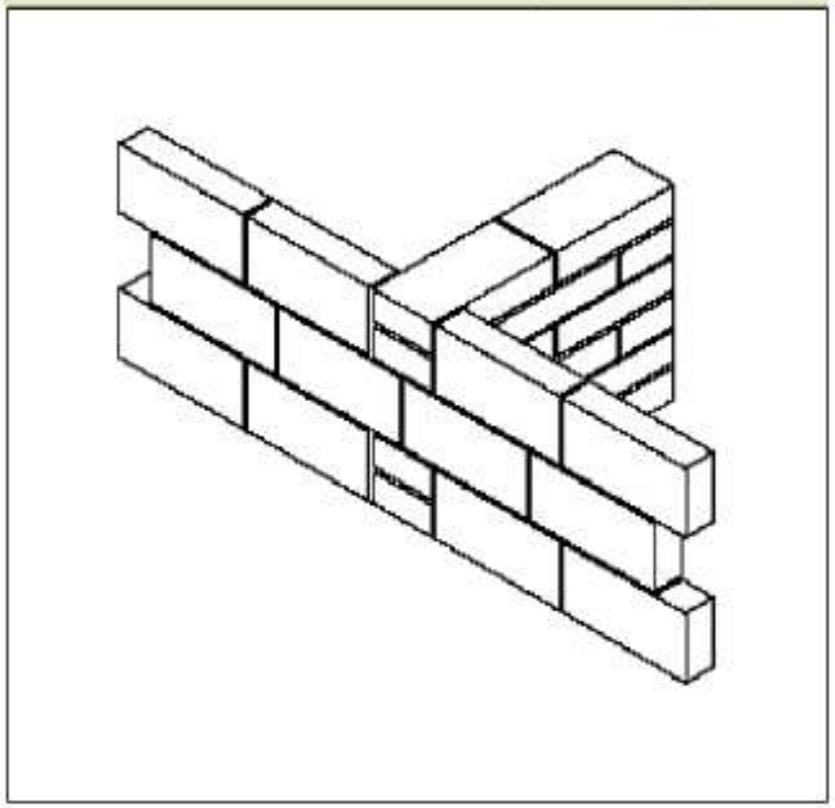


Diagram 2-5: **Wall type 1 – external cavity wall with masonry inner leaf**

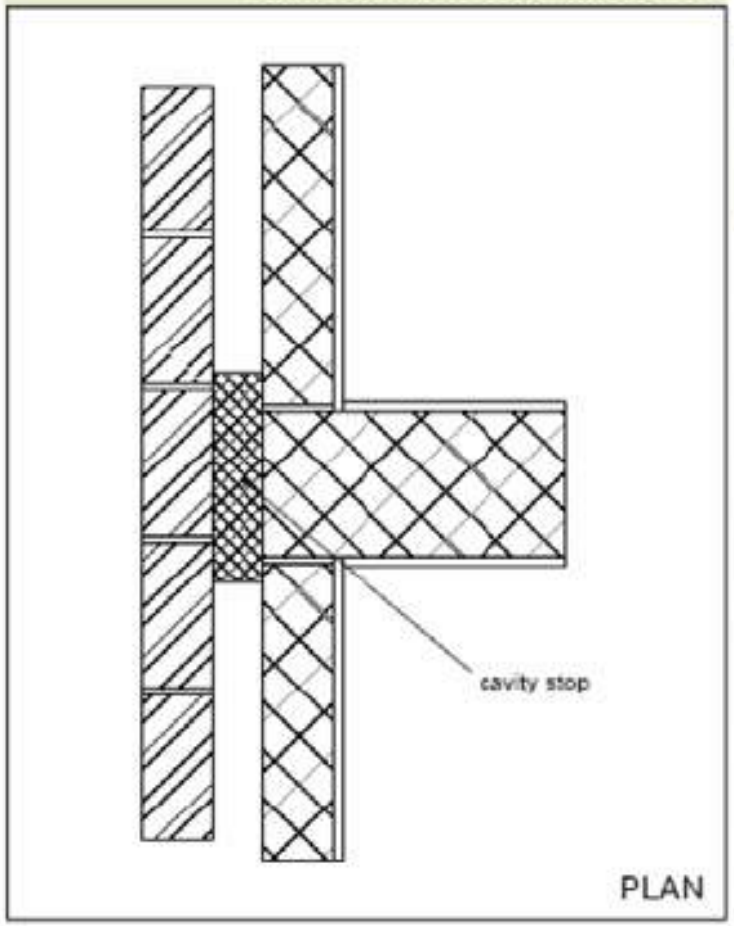
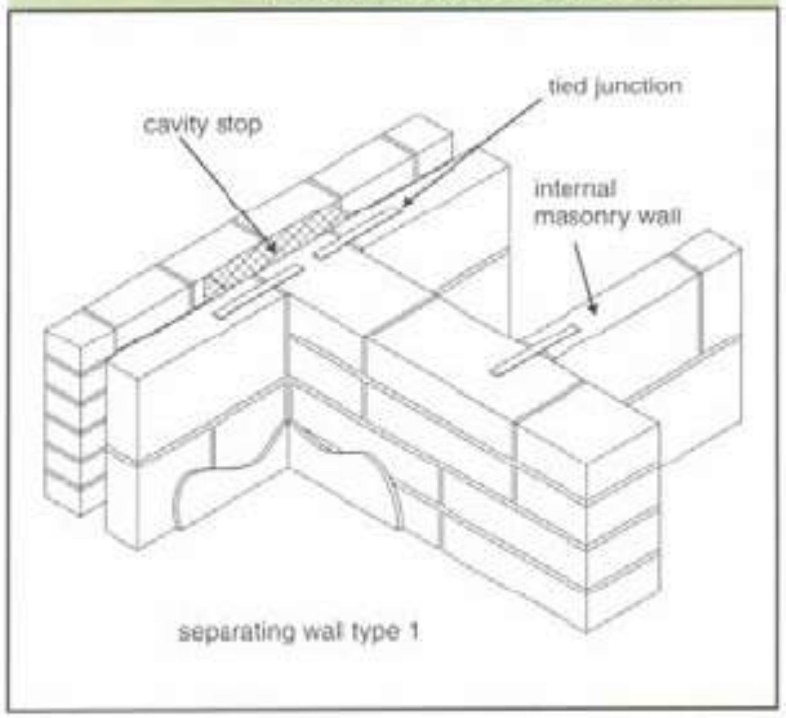
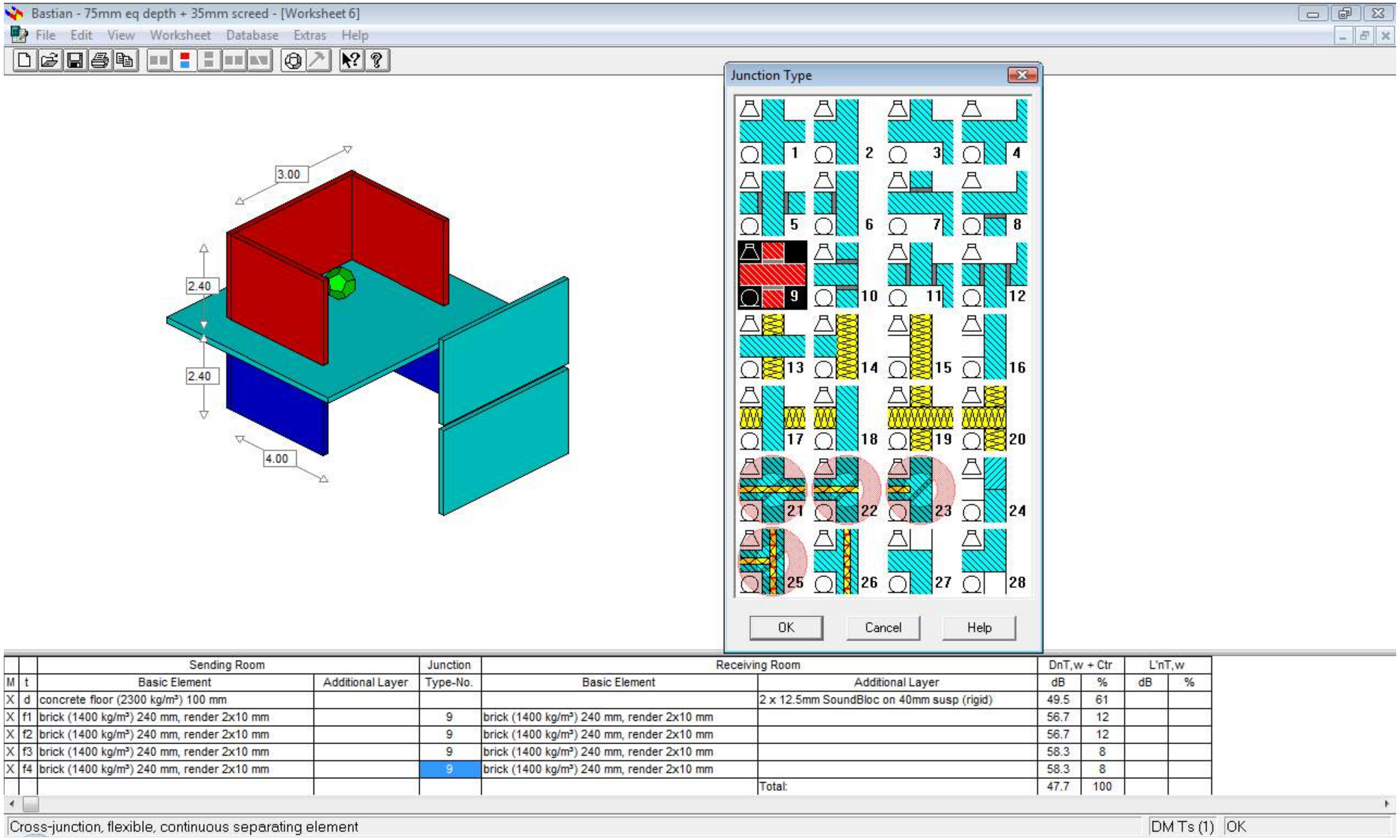


Diagram 2-7: **Wall type 1 – tied junction – external cavity wall with internal masonry wall**

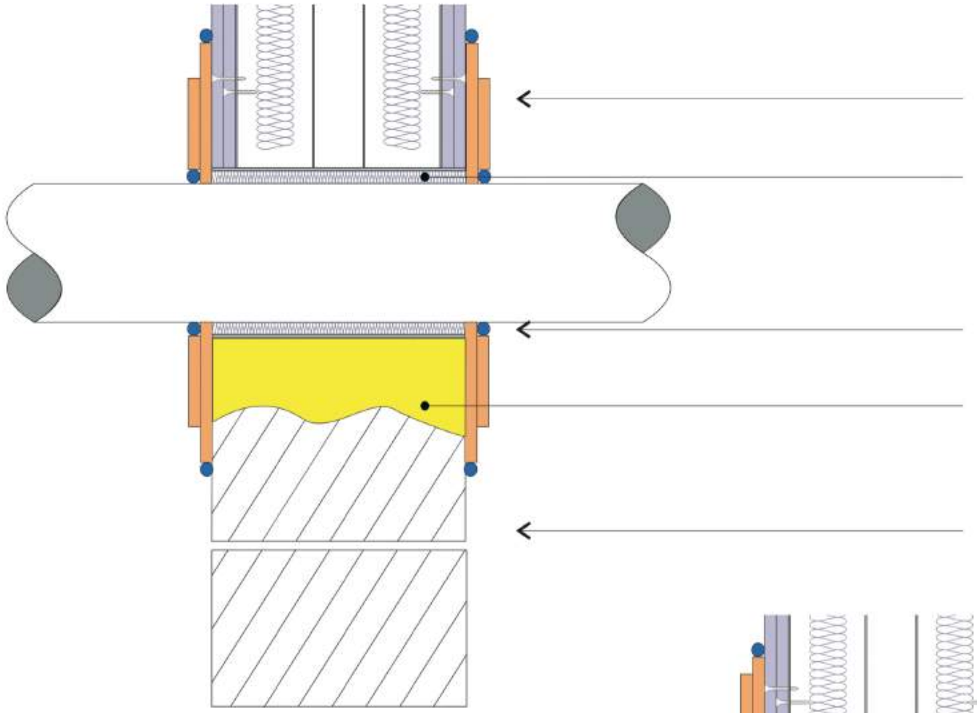


STRUCTURAL FLANKING - ASSESSMENTS



		Sending Room		Junction	Receiving Room		DnT,w + Ctr		L'nT,w	
M	t	Basic Element	Additional Layer	Type-No.	Basic Element	Additional Layer	dB	%	dB	%
X	d	concrete floor (2300 kg/m³) 100 mm				2 x 12.5mm SoundBloc on 40mm susp (rigid)	49.5	61		
X	f1	brick (1400 kg/m³) 240 mm, render 2x10 mm		9	brick (1400 kg/m³) 240 mm, render 2x10 mm		56.7	12		
X	f2	brick (1400 kg/m³) 240 mm, render 2x10 mm		9	brick (1400 kg/m³) 240 mm, render 2x10 mm		56.7	12		
X	f3	brick (1400 kg/m³) 240 mm, render 2x10 mm		9	brick (1400 kg/m³) 240 mm, render 2x10 mm		58.3	8		
X	f4	brick (1400 kg/m³) 240 mm, render 2x10 mm		9	brick (1400 kg/m³) 240 mm, render 2x10 mm		58.3	8		
						Total:	47.7	100		

SOUND INSULATION DETAILS & SERVICES PENETRATIONS



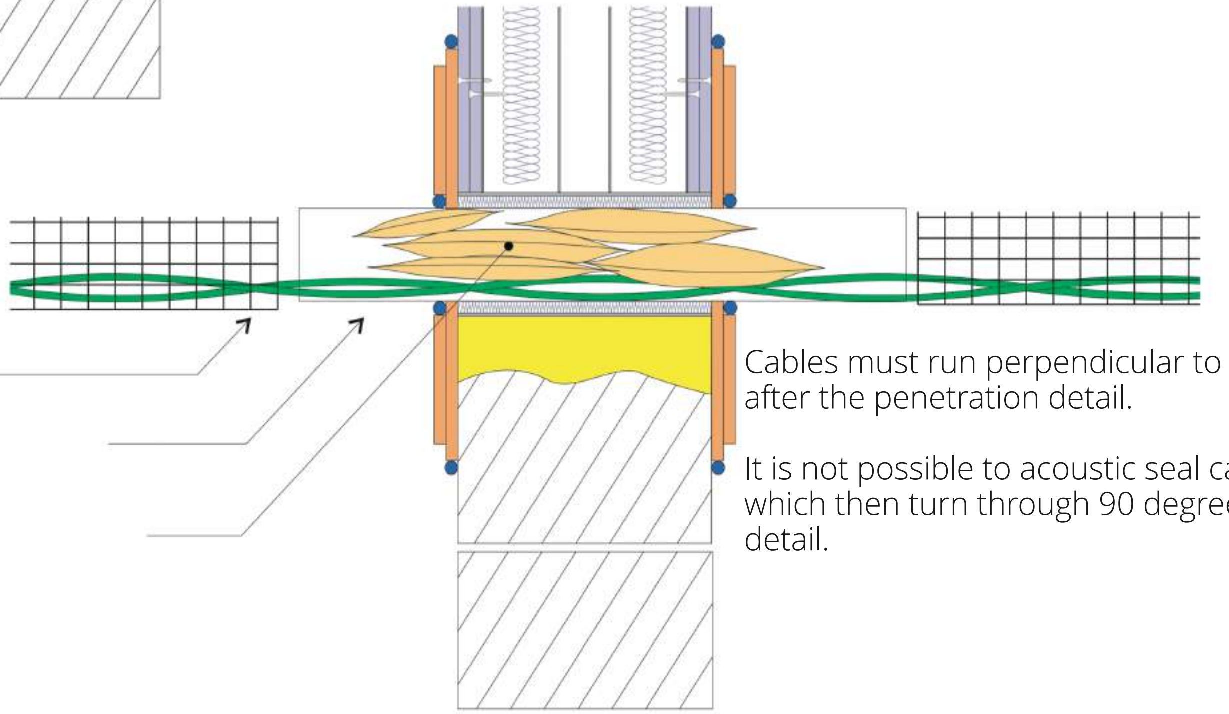
2*12.5mm Plasterboard or 2*12.5mm MDF Pattress set on continuous bead of Mastic

Gap between pipe or duct to be sealed with densely packed mineral wool

All Gaps Less than 5mm sealed with non hardening Mastic

Hole made good with a similarly dense material

Blockwork/Concrete Wall



Cable Tray

Metal electrical trunking 0.5 metres in length

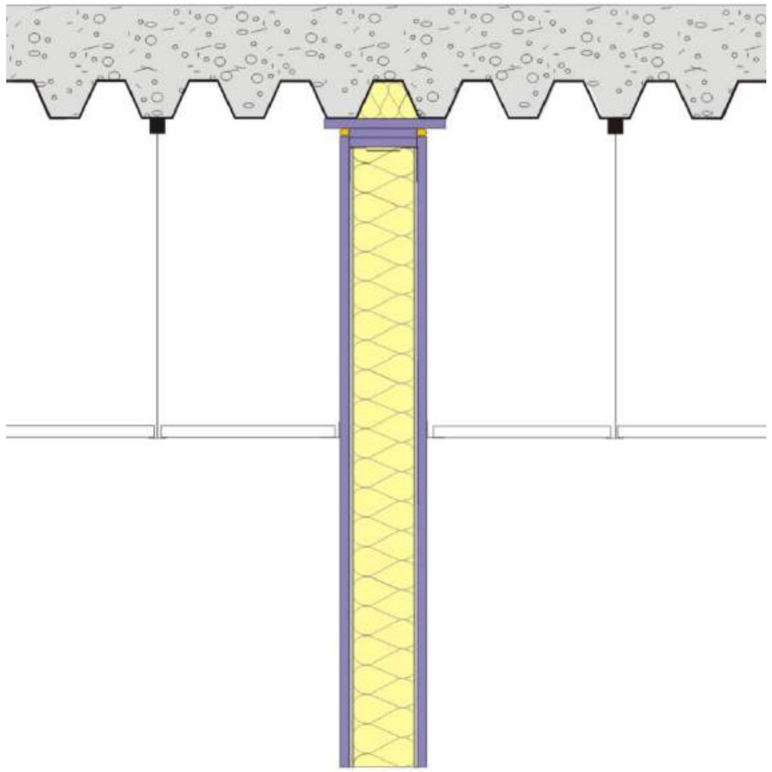
Gaps above cables to be packed tight with sand-filled pugging bags to full depth

Cables must run perpendicular to wall at least a metre before and after the penetration detail.

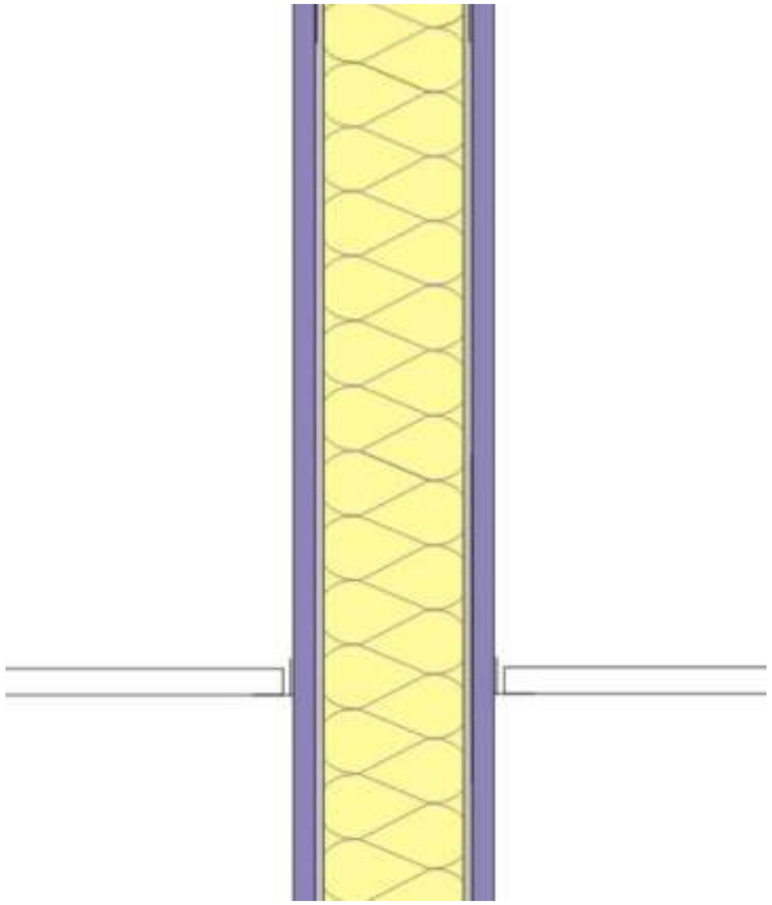
It is not possible to acoustic seal cables passing up or along a wall, which then turn through 90 degrees and enter the penetration detail.

SOUND INSULATION DETAILS - STANDARD DETAILS

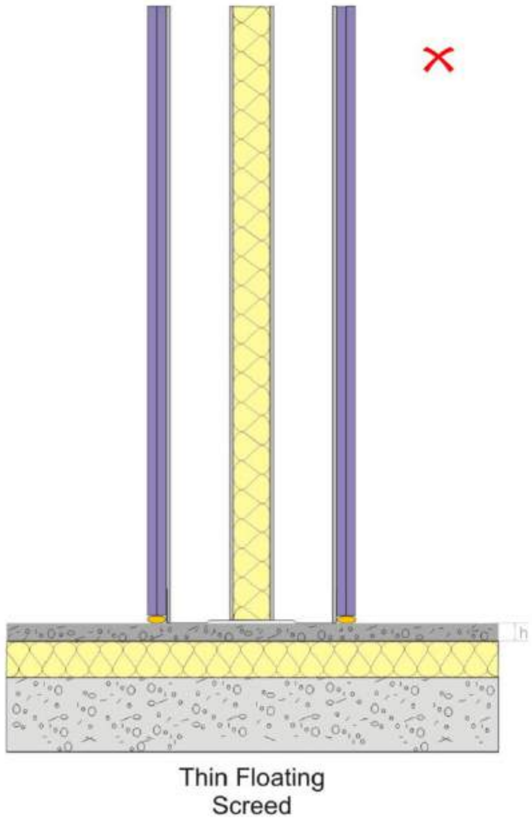
Metal Studs



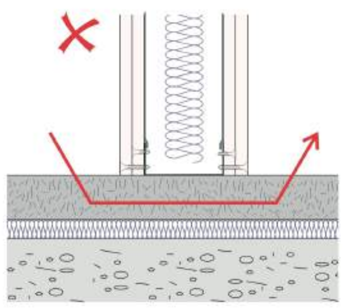
Timber Studs



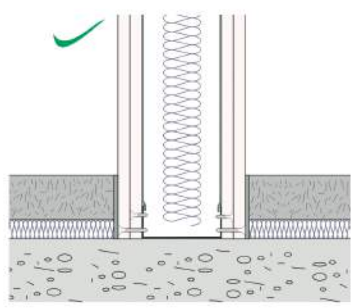
Block Wall



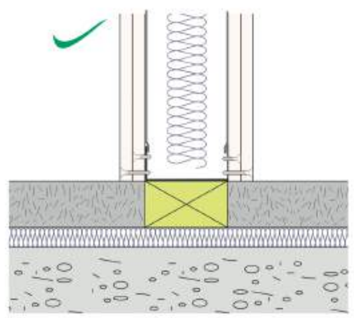
SOUND INSULATION DETAILS - CONCRETE ELEMENTS



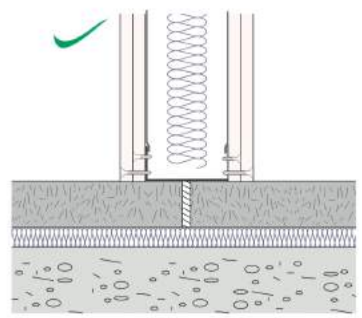
Flanking through a floating screed breaching the sound insulation of the wall



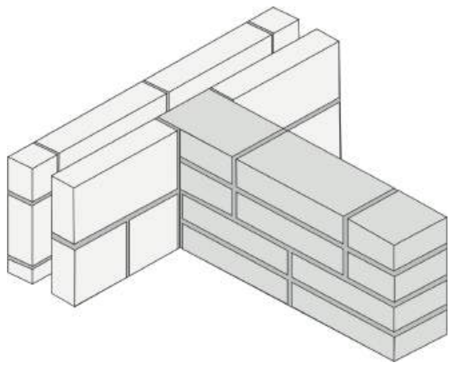
Flanking through a floating screed prevented by building the partition off the floor slab.



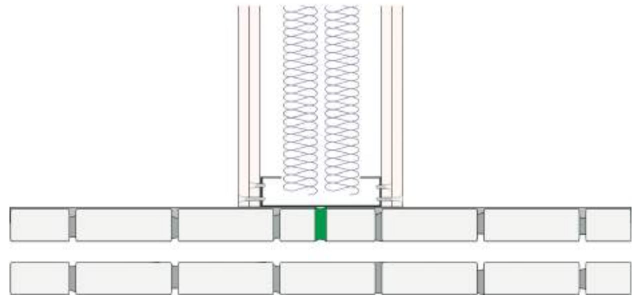
Flanking through a floating screed prevented by timber sole plate.



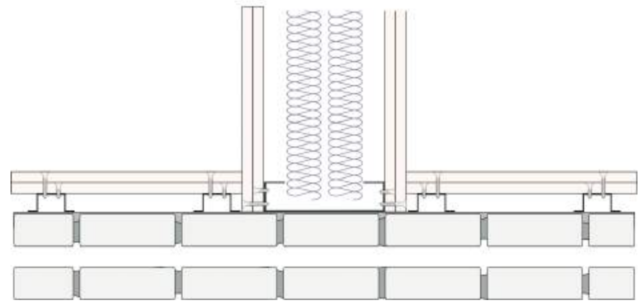
Flanking through a floating screed prevented by saw cut in screed.



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

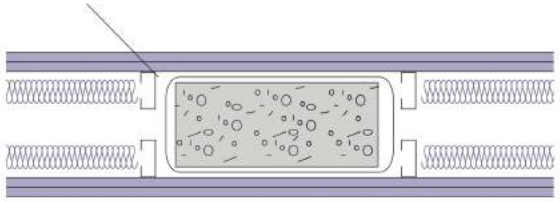


Separating wall must be built into the inner skin of the facades



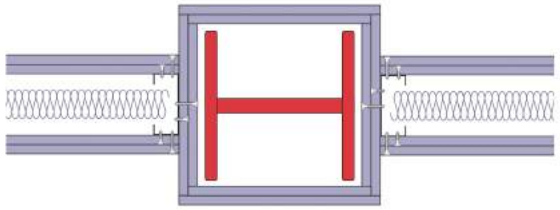
Alternative detail, where flanking is prevented by an independent wall lining.

SOUND INSULATION DETAILS- JUNCTIONS AND PENETRATIONS

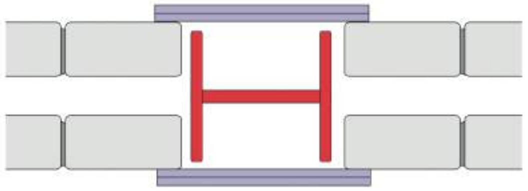


text

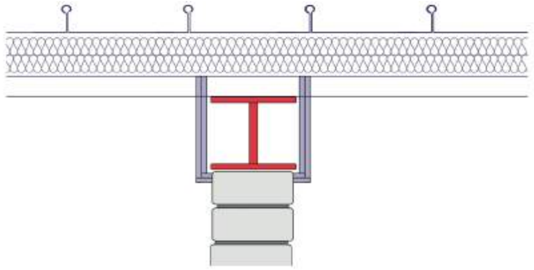
Plasterboard enclosing a concrete column should not be conventionally connected to the column.



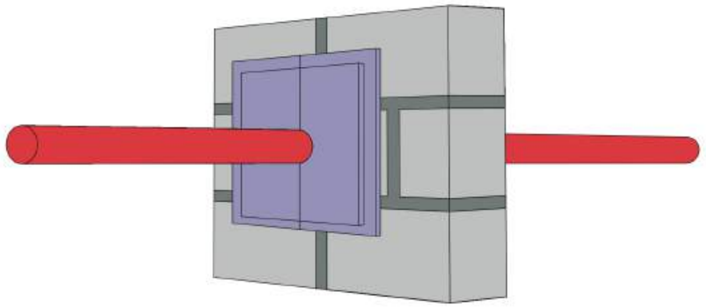
The boxing around steels should equal that of the partition type.



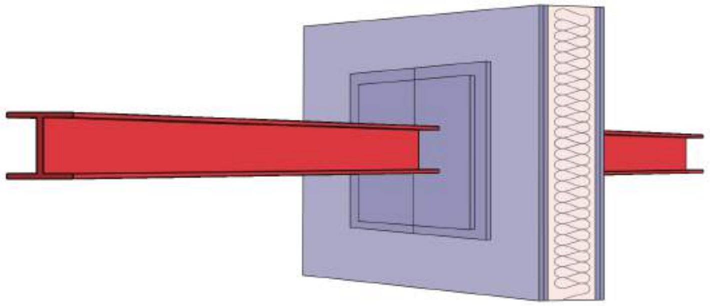
Steels should not make contact with cavity walls in any way.



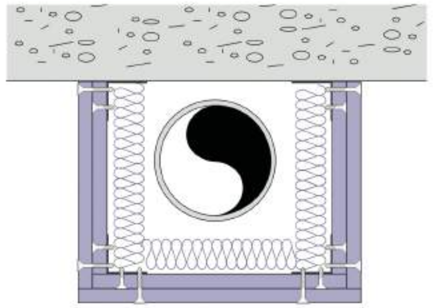
Steels above block walls are always advised to be enclosed with plasterboard.



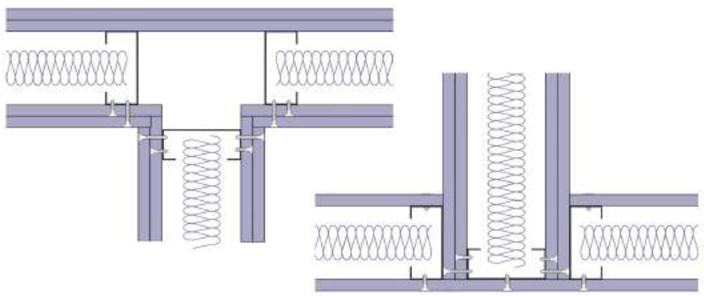
Steels passing through a separating block wall should be sealed with two layers of plasterboard. All joints should be sealed with mastic.



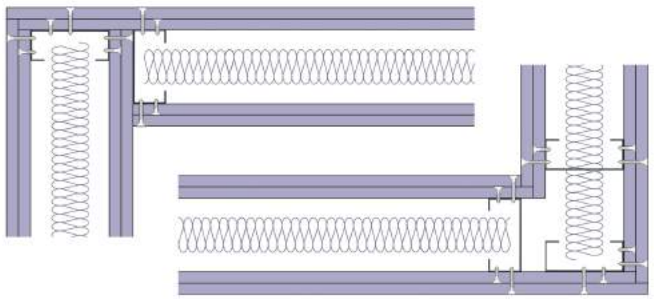
Steels passing through a separating stud wall, should be sealed with two layers of plasterboard. All joints should be sealed with mastic.



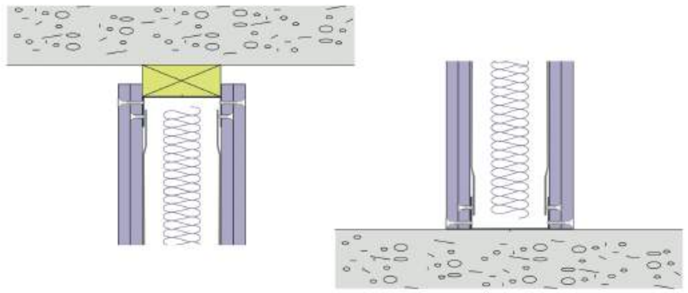
All waste pipes within sensitive rooms are recommended to be enclosed with two layers of plasterboard.



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

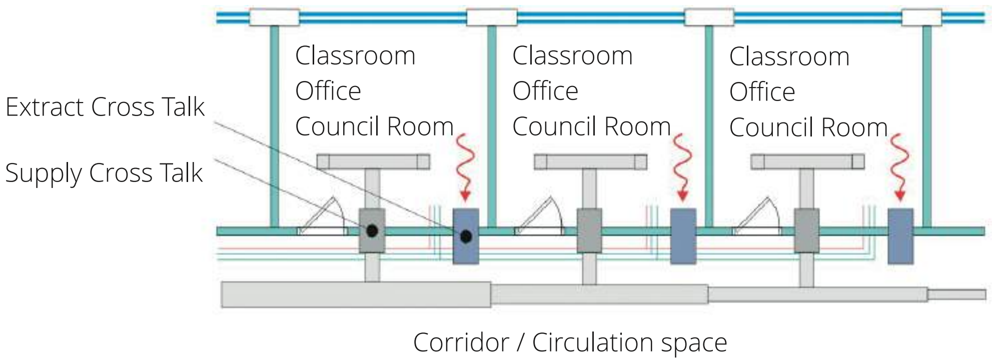


Two equally performing details. The selection of this detail is down to build-ability.

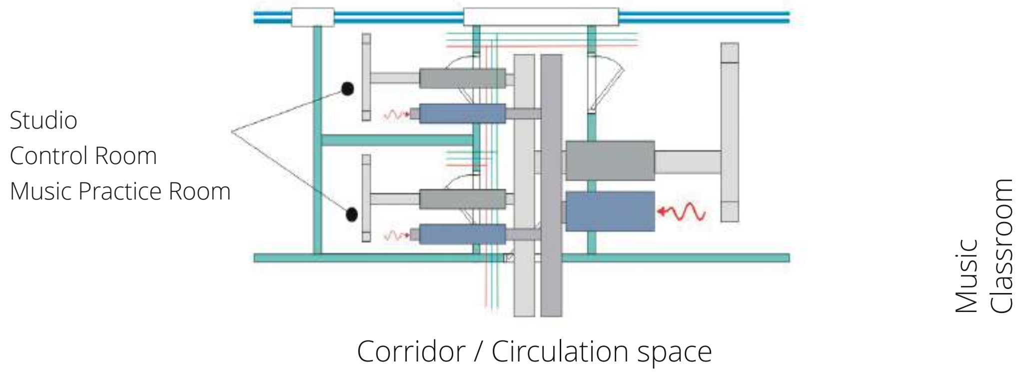


Base and head deflection details. Note that all joints and junctions are required to be sealed with mastic.

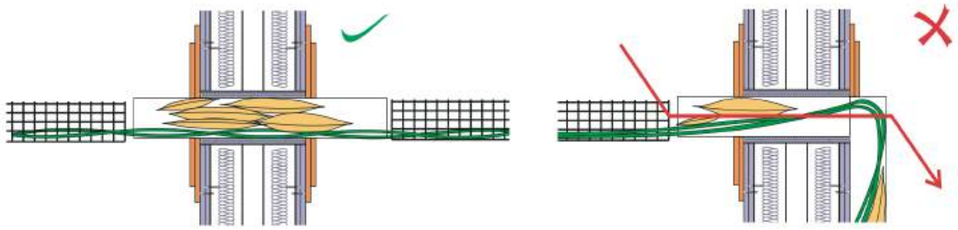
SOUND INSULATION DETAILS & SERVICES PENETRATIONS



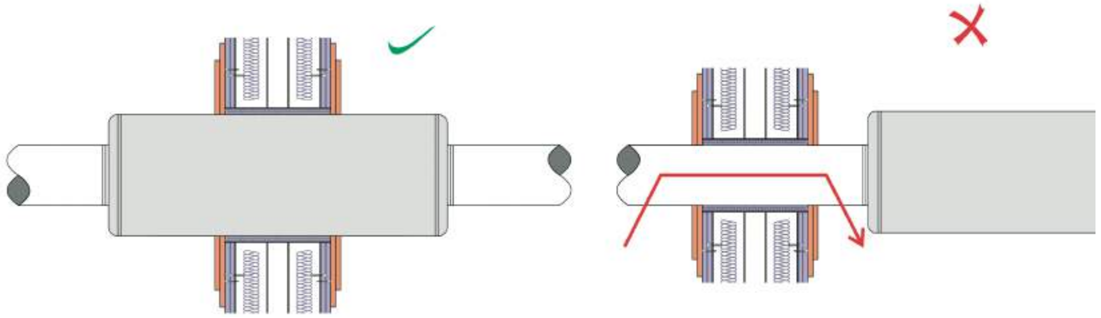
Electrical services should always run down the circulation zones and enter sensitive spaces though the corridor wall. This prevents penetration within high performance walls.



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. This 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 in this image 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.

Junction between mullion and floor slab. The sealing between different constructions needs to be considered carefully to avoid large or awkward gaps which can be difficult to make good

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

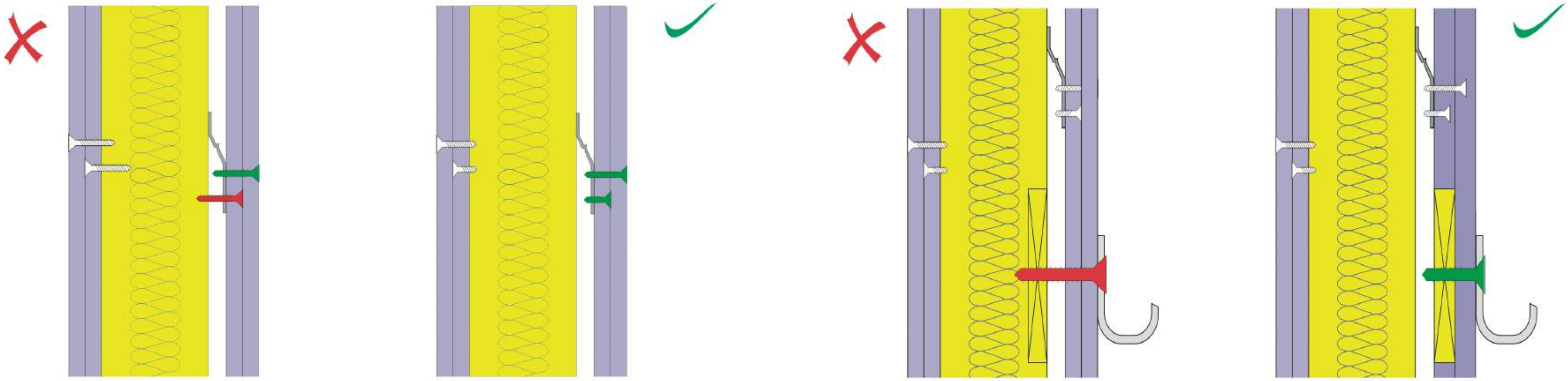
Incorrect screw size breaching the flexibility of the resilient bar and hence compromising the performance of this partition.

SOUND INSULATION DETAILS - RESILIENT BARS

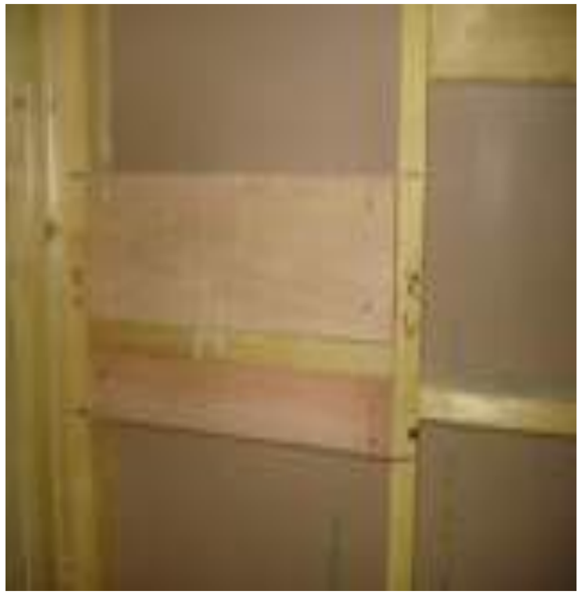
https://youtu.be/ESqw-zmAnTg

https://youtu.be/9c9oHMUcVTA

SOUND INSULATION DETAILS - RESILIENT BARS



Resilient bars with red screws are seriously compromised by screws which are too long. This is likely to downgrade the partition by 5 to 10 dB.



REFURBISHMENTS – UPGRADING A BUILDING

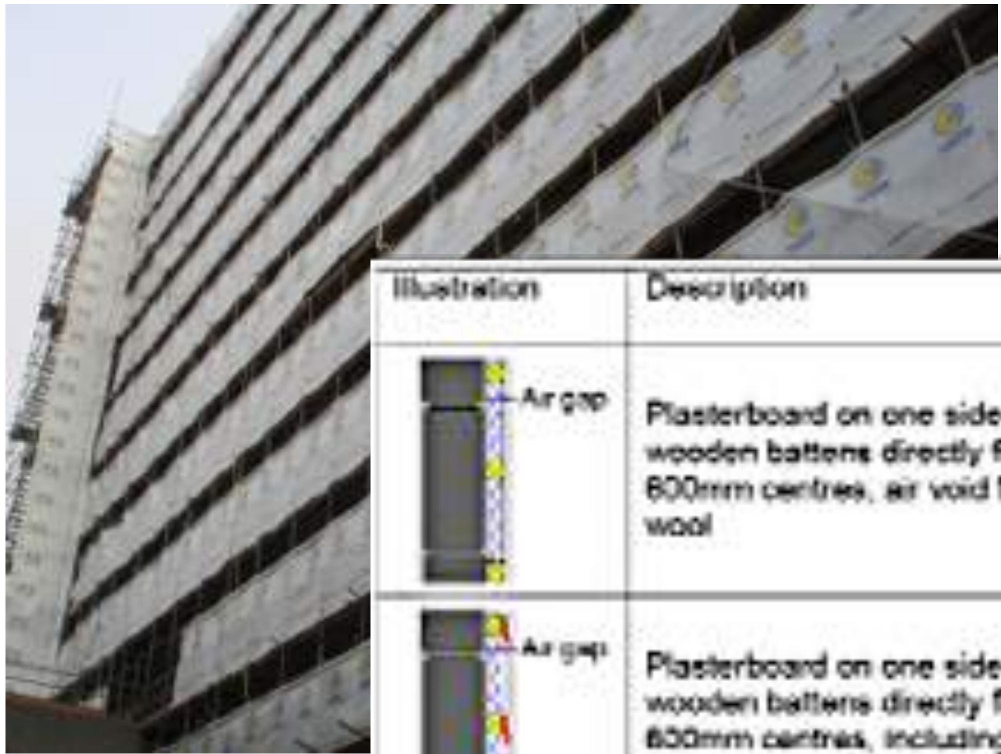


Illustration	Description	Plasterboard	Air gap - See Drawing 25mm	50mm	100mm	150mm
Air gap	Plasterboard on one side of block wall, wooden battens directly fixed to wall at 600mm centres, air void filled with mineral wool	1 layer of 12.5mm plasterboard	7 dB	8 dB	10 dB	-
		2 layers of 12.5mm plasterboard	8 dB	10 dB	11 dB	-
Air gap	Plasterboard on one side of block wall, wooden battens directly fixed to wall at 600mm centres, including a resilient bar, air void filled with mineral wool	1 layer of 12.5mm plasterboard	9 dB	10 dB	15 dB	-
		2 layers of 12.5mm plasterboard	11 dB	17 dB	18 dB	-
Air gap	Plasterboard on one side of block wall, steel stud independent from block wall at 600mm centres, air void filled with mineral wool	1 layer of 12.5mm plasterboard	-	13 dB	19 dB	22 dB
		2 layers of 12.5mm plasterboard	-	19 dB	24 dB	27 dB
Air gap	Plasterboard on both side of block wall, wooden battens directly fixed to wall at 600mm centres, air void filled with mineral wool	1 layer of 12.5mm plasterboard	14 dB	18 dB	20 dB	-
		2 layers of 12.5mm plasterboard	16 dB	20 dB	22 dB	-

Table 4 Possible upgrade solutions to existing walls

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Correspondence:
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Bristol

LONDON MACH Acoustics
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TEL: 0117 944 1388
EMAIL: info@machacoustics.com

Presented By Ze Nunes
Founder of MACH Acoustics
Lecturer At the University Of Bath

"MACH Acoustics takes time to analyze, consider and propose solutions, that promote an architectural approach. The sensitivity and technical performance capability is well respected by the practice." Jo Bacon – Allies & Morrison Partnership

ROOM ACOUSTICS AND REVERBERATION

Facade Lecture Notes

CONTENTS

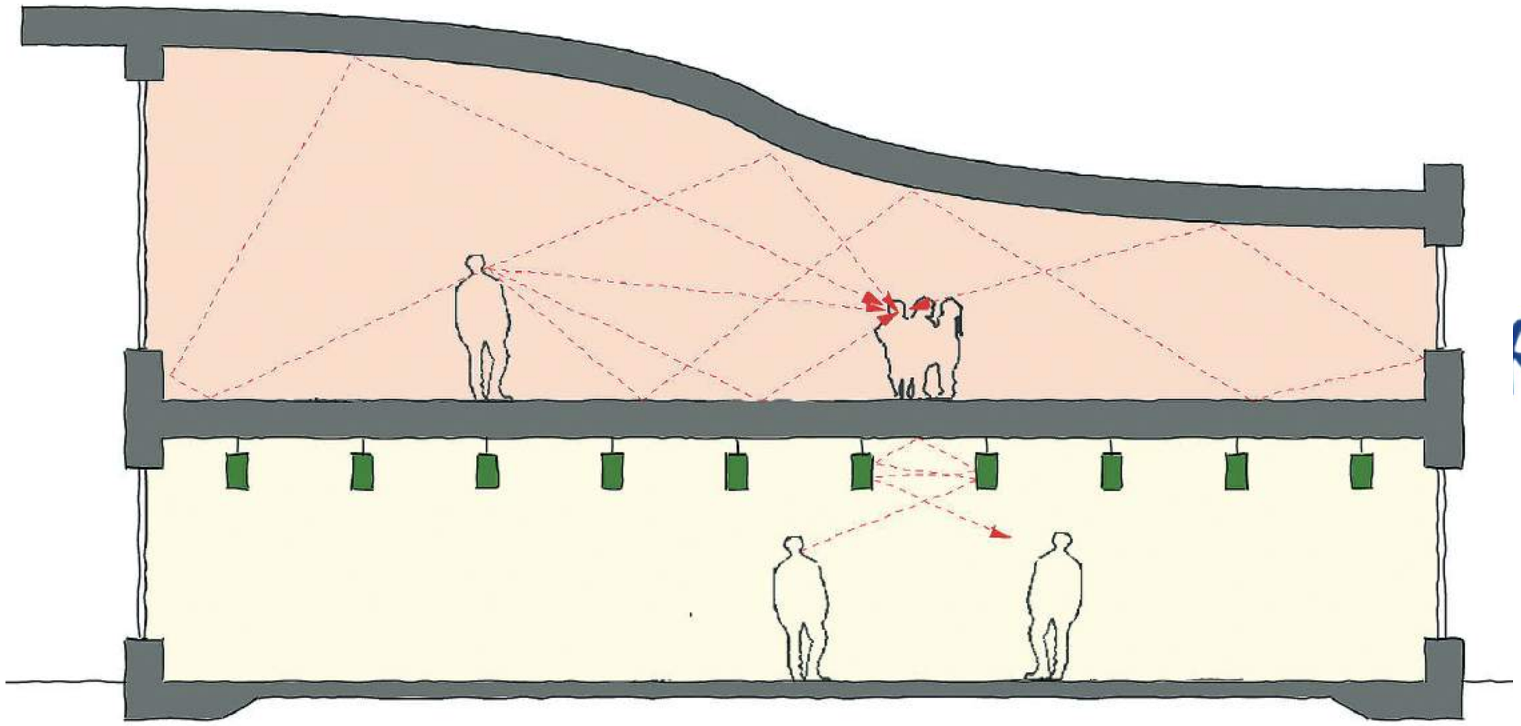
ROOM ACOUSTICS AND REVERBERATION

INTRODUCTION TO REVEBERATION

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.

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;

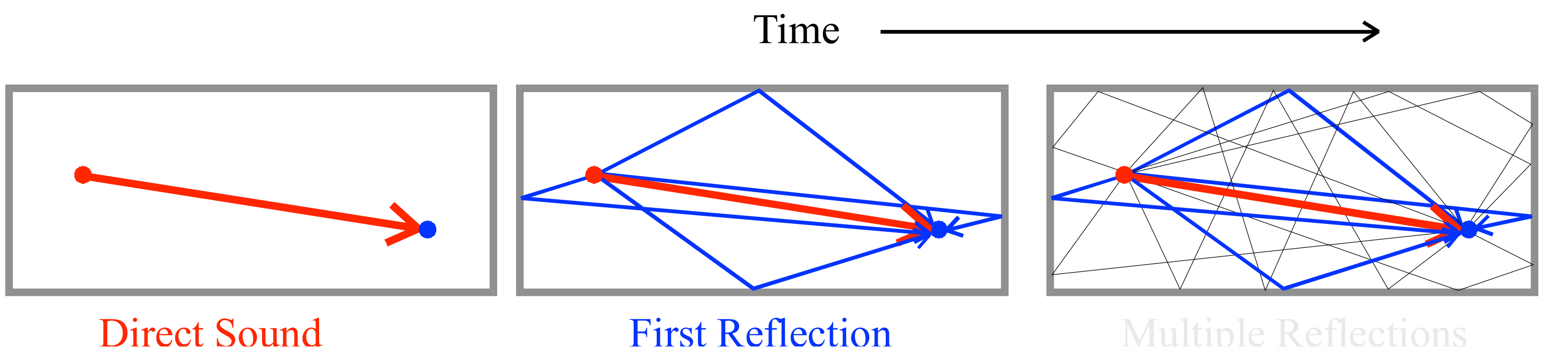


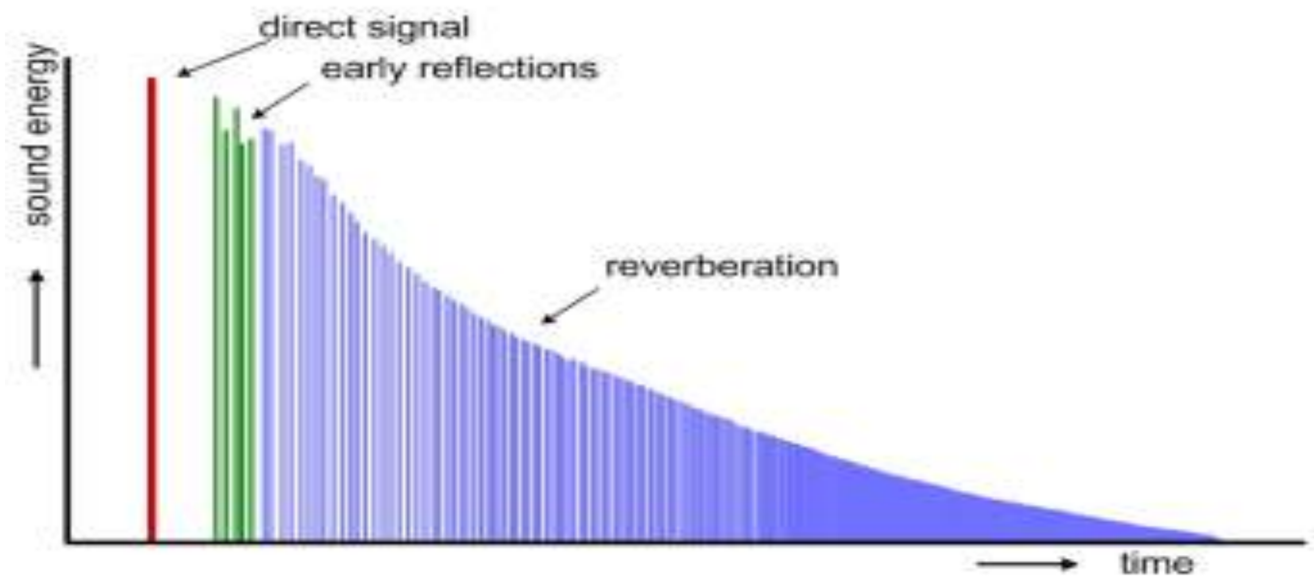
$$RT = \frac{\text{Volume} \times 0.161}{\text{Total Acoustic Absorption}}$$

DIRECT, EARLY AND REVEBERANT SOUND

Direct sound

We use the direct sound to localize the sound source, i.e. it enables us to position a source in space even with our eyes closed - and we are able to do this even though the energy of all reflections together is considerably greater than that of the direct sound alone. If there are obstructions between the listener and the sound source, the direct sound can be weakened to such an extent that our localization is impaired. Guaranteeing an unobstructed direct sound propagation is therefore always important when acoustic intelligibility and clarity are important.





DIRECT, EARLY AND REVERBERANT SOUND

Early reflections -Reflections that reach the listener within 50 ms of the direct sound increase the intelligibility of speech owing to the ability of the ear to integrate those sounds. An inter-aural time difference of 50ms corresponds to an approx. 17m difference in the lengths of the paths travelled by the direct sound and the reflection. The intelligibility of music is further enhanced by reflections with an inter-aural time difference of up to about 80 ms (= 27 m difference in the paths travelled). Intelligibility means the distinguishability of successive reflections in a musical performance in a closed room despite superimposed diffuse sound.

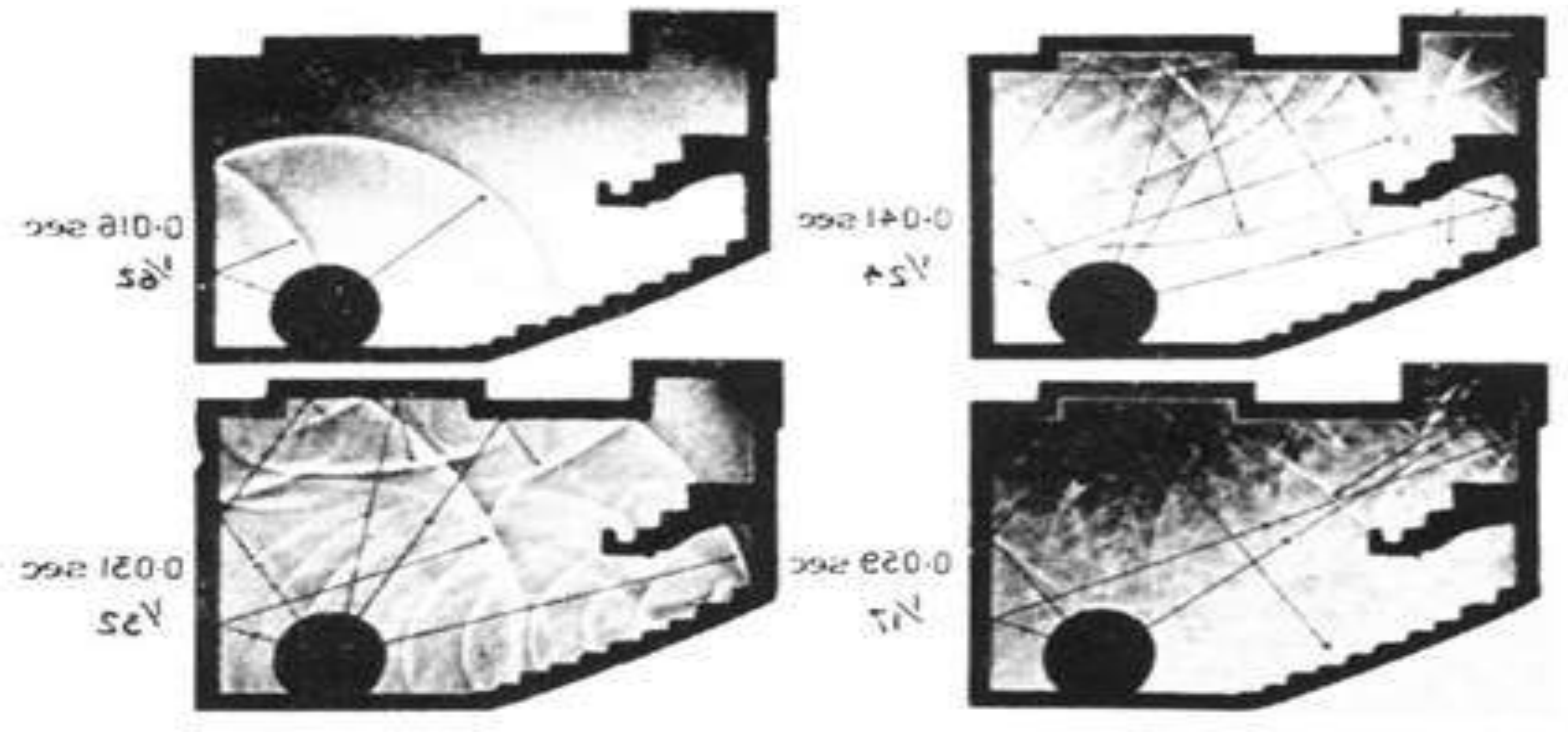
Based on these fundamental relationships, it is possible to derive direct consequences for the room geometry and, in particular, for the line of the ceiling in larger venues. Such rooms should be designed so that early reflections are directed towards the listeners. In addition, if the early reflections reach the ears of the listeners from the sides, this enhances the three-dimensional acoustic impression. This feeling of being "surrounded" by the music is these days an important quality criterion for concert halls in which symphony orchestras perform.

Reverberation

The early reflections are followed by the reverberant sound in which the density of the reflections increases and in many rooms the energy decreases at an approximately exponential rate. The reverberation of a room is the most important acoustic quality feature, especially since the reverberation, in contrast to the early reflections, is usually not, at best only marginally, dependent on position.

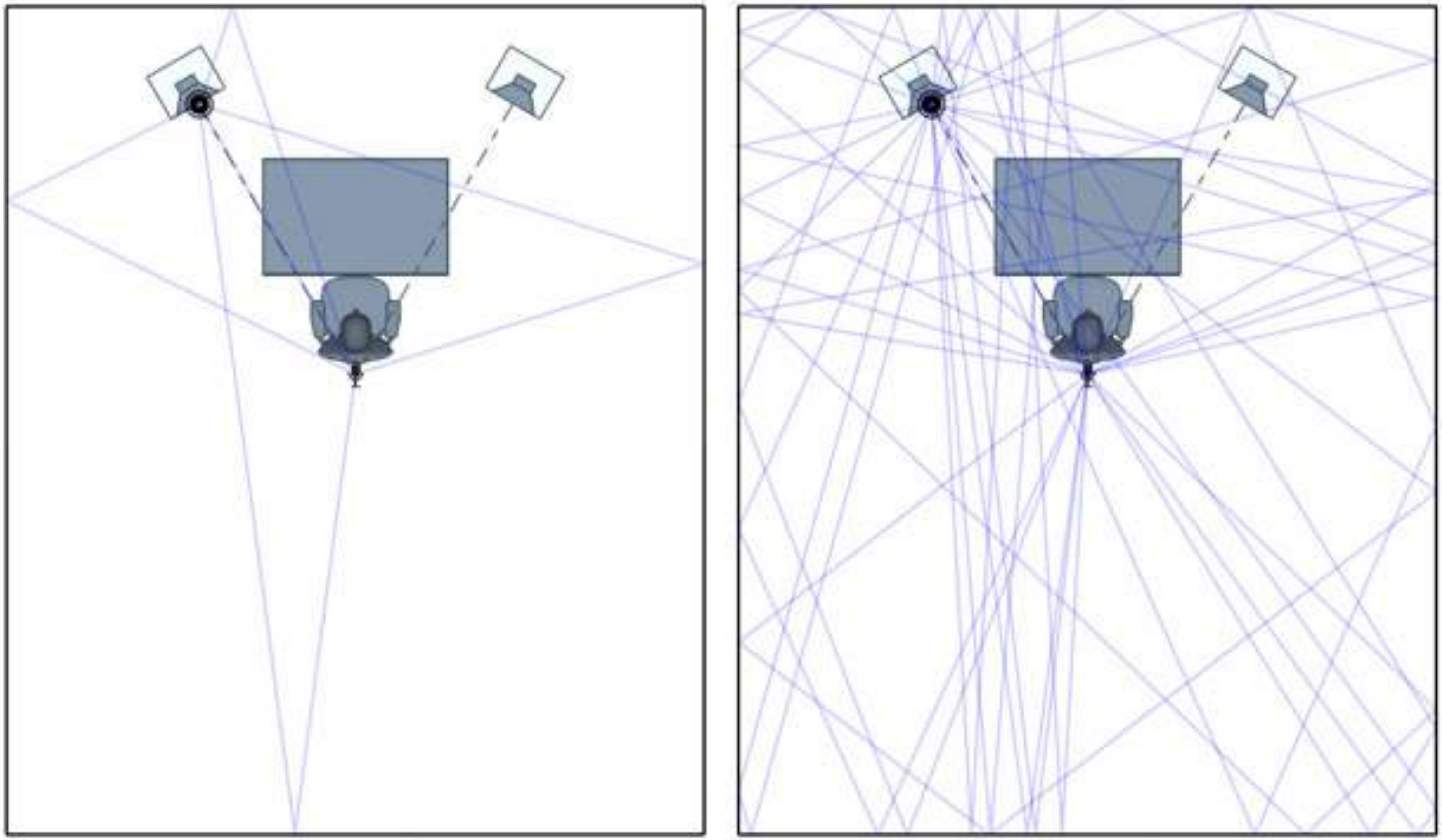
Which reverberation time is desirable for which room depends entirely on the function of that room. In cathedrals and churches, for example, a long reverberation time reinforces the sacred character and provides organ and choral works with the proper acoustic environment. In contrast to this, the reverberation time in lecture theatres should not be too long in order to avoid successive syllables being lost in the reverberations (although it is possible to adjust for this by speaking slowly)

DIRECT, EARLY AND REVERBERANT SOUND



DIRECT, EARLY AND REVERBERANT SOUND

DIRECT, EARLY AND REVERBERANT SOUND



PERFORMANCE STANDARDS – BB93, HTM AND BREEAM

Performance Requirements

The function of a space therefore 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.

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. 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.

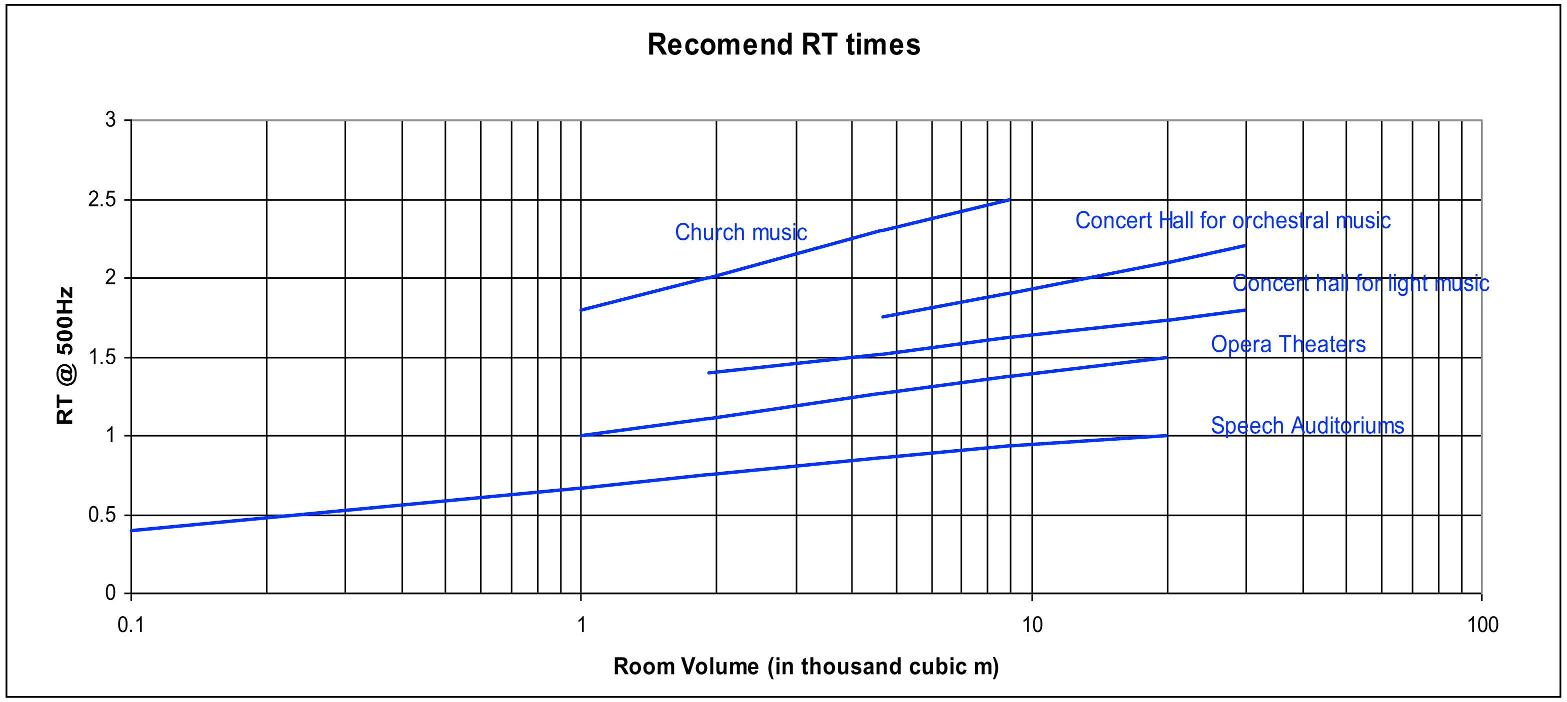
MACH Acoustics advises that an acoustic consultant should be appointed to undertake a detailed assessment if an alternative to ceiling tiles is to be used.

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	

REVEBERATION TIME IN LARGE SPACES

Rooms used for speech require a relatively short reverberation time such to maintain speech intelligibility levels within these spaces. For a small room, a value of 0.5 to 0.8 seconds is appropriate. However, for large auditoriums, a higher reverberation time is necessary, due to the audience being further away from the speaker; hence a greater degree of sound reinforcement is required from the reverberation tail.

The sound in hall used for music and other function are often enhanced by reverberation and therefore a range of different performance targets are used for these spaces.



ACOUSTIC PROPERTIES OF MATERIALS

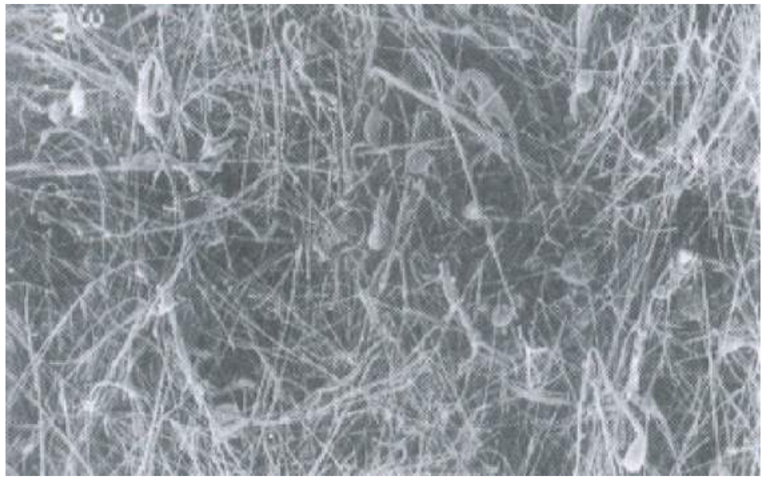
To control reverberation time, acoustic absorption is used. Absorbent materials conventionally take two forms; fibrous materials or open celled foam. Fibrous materials absorb sound, since sound waves force the fibres to bend and this bending of the fibres generates heat. The conversion of acoustic energy 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.

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.

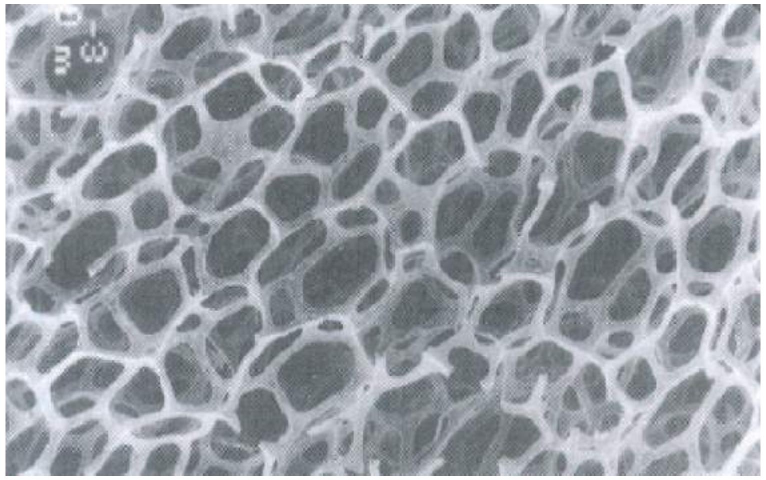
The thickness of a given material along with properties such as its fibrousity governs the acoustic performance of a product. Finishes within a space are therefore defined in terms of their absorption coefficient. This is a number between 0.0 (100% reflective) for example stone, tiles, concrete and 1.0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



Magnified Image of Fibrous Acoustics Absorption



Magnified Image Open Celled Foam, Acoustics

SOUND ABSORPTION

The product of the area of an absorber and its absorption coefficient is called the sound absorption of the material. Thus, if the surface area of a material is S, and its absorption coefficient a, then the sound absorption provided by the material (A) is:
A= Sa (4.2)

The unit of absorption (A) is called sabin, after the American acoustician Wallace Clement Sabine (1868-1919). Thus, if the surface area of a material is 10 m2 and its absorption coefficient 0.75, the amount of absorption provided by this material is 10(0.75) = 7.5 sabins.

For a room with several surfaces, the total absorption provided by these surfaces is given by sum of the Sabine's provided by each of these surfaces i.e.

$$\sum(\text{Surface Area} * \text{Absorption Confident}) = \sum(S * \alpha)$$

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

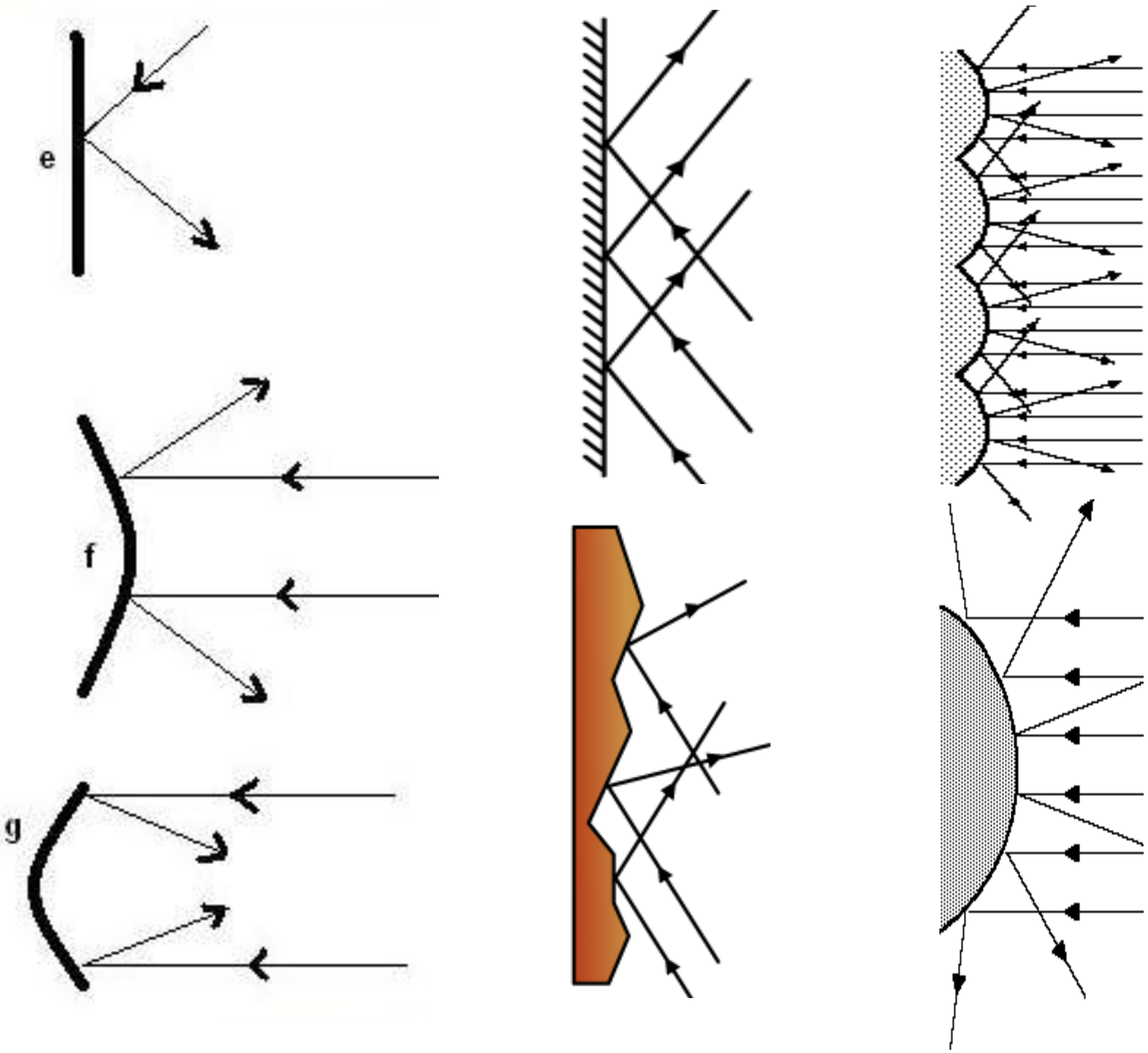
SOUND ABSORPTION - MATERIAL PROPERTIES

Floor materials	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz
Carpet	0.01	0.02	0.06	0.15	0.25	0.45
Concrete (unpainted, rough finish)	0.01	0.02	0.04	0.06	0.08	0.1
Concrete (sealed or painted)	0.01	0.01	0.02	0.02	0.02	0.02
Marble or glazed tile	0.01	0.01	0.01	0.01	0.02	0.02
Vinyl tile or linoleum on concrete	0.02	0.03	0.03	0.03	0.03	0.02
Wood parquet on concrete	0.04	0.04	0.07	0.06	0.06	0.07
Wood flooring on joists	0.15	0.11	0.1	0.07	0.06	0.07
Reflective wall materials	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz
Brick (natural)	0.03	0.03	0.03	0.04	0.05	0.07
Brick (painted)	0.01	0.01	0.02	0.02	0.02	0.03
Concrete block (coarse)	0.36	0.44	0.31	0.29	0.39	0.25
Concrete block (painted)	0.1	0.05	0.06	0.07	0.09	0.08
Concrete (poured, rough finish, unpainted)	0.01	0.02	0.04	0.06	0.08	0.1
Doors (solid wood panels)	0.1	0.07	0.05	0.04	0.04	0.04
Glass (1/4" plate, large pane)	0.18	0.06	0.04	0.03	0.02	0.02
Glass (small pane)	0.04	0.04	0.03	0.03	0.02	0.02
Plasterboard (12mm (1/2") paneling on studs)	0.29	0.1	0.06	0.05	0.04	0.04
Plaster (gypsum or lime, on masonry)	0.01	0.02	0.02	0.03	0.04	0.05
Plaster (gypsum or lime, on wood lath)	0.14	0.1	0.06	0.05	0.04	0.04
Absorptive wall materials	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz
Drapery (10 oz/yd2, 340 g/m2, flat against wall)	0.04	0.05	0.11	0.18	0.3	0.35
Drapery (14 oz/yd2, 476 g/m2, flat against wall)	0.05	0.07	0.13	0.22	0.32	0.35
Drapery (18 oz/yd2, 612 g/m2, flat against wall)	0.05	0.12	0.35	0.48	0.38	0.36
Drapery (14 oz/yd2, 476 g/m2, pleated 50%)	0.07	0.31	0.49	0.75	0.7	0.6
Drapery (18 oz/yd2, 612 g/m2, pleated 50%)	0.14	0.35	0.53	0.75	0.7	0.6
Performated metal (13% open, over 50mm(2") fiberglass)	0.25	0.64	0.99	0.97	0.88	0.92
Ceiling material	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz
Plasterboard (12mm(1/2") in suspended ceiling grid)	0.15	0.11	0.04	0.04	0.07	0.08
Underlay in perforated metal panels (25mm(1") batts)	0.51	0.78	0.57	0.77	0.9	0.79
Metal deck (perforated channels,25mm(1") batts)	0.19	0.69	0.99	0.88	0.52	0.27
Metal deck (perforated channels, 75mm(3") batts)	0.73	0.99	0.99	0.89	0.52	0.31
Plaster (gypsum or lime, on masonary)	0.01	0.02	0.02	0.03	0.04	0.05
Plaster (gypsum or lime, rough finish or timber lath)	0.14	0.1	0.06	0.05	0.04	0.04
Wood tongue-and-groove roof decking	0.24	0.19	0.14	0.08	0.13	0.1
Miscellaneous surface material	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz
People-adults (per person)	2.5	3.5	4.2	4.6	5	5
Ventilating grilles	0.3	0.4	0.5	0.5	0.5	0.4
Water or ice surface	0.008	0.008	0.013	0.015	0.02	0.025

SOUND SCATTERING

When sound is reflected from a surface it is partly reflected in a specular direction (ie the angle of incidence equals the angle of reflection) and partly scattered into other directions. The amount of reflected sound energy that will be scattered is given by the surface's scattering coefficient, s.

Where a perfectly smooth surface giving pure specular reflection has a scattering coefficient of 0 and a very irregular surface scattering all sound away from the specular direction has a scattering coefficient of 1. Scattering coefficients are a relatively new measure in room acoustics so there is little data currently available but they are important in room acoustics computer modeling



CALCULATING REVEBERATION TIME

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

SUSTAINABLE ACOUSTIC TREATMENTS

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.

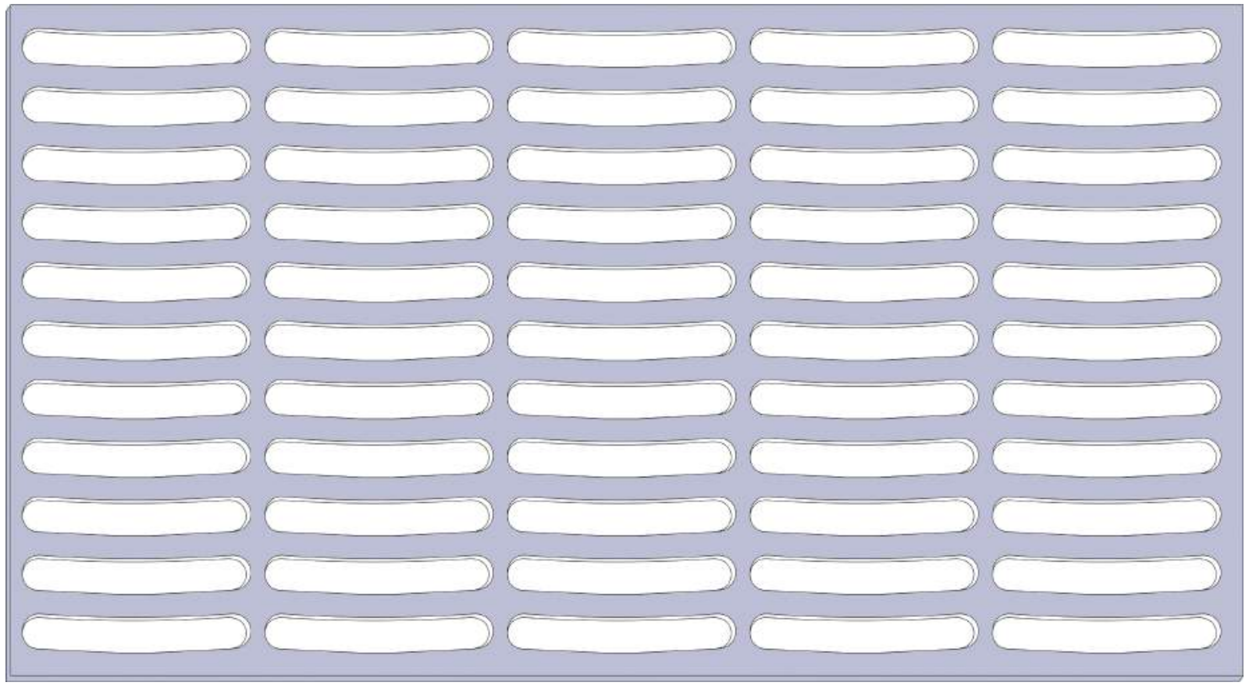
Illustration 7 shows the use of Bamboo for providing an architectural acoustically transparent finish.

SUSTAINABLE ACOUSTIC TREATMENTS

3	4
5	6

SUSTAINABLE ACOUSTIC TREATMENTS

7	
8	9



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.

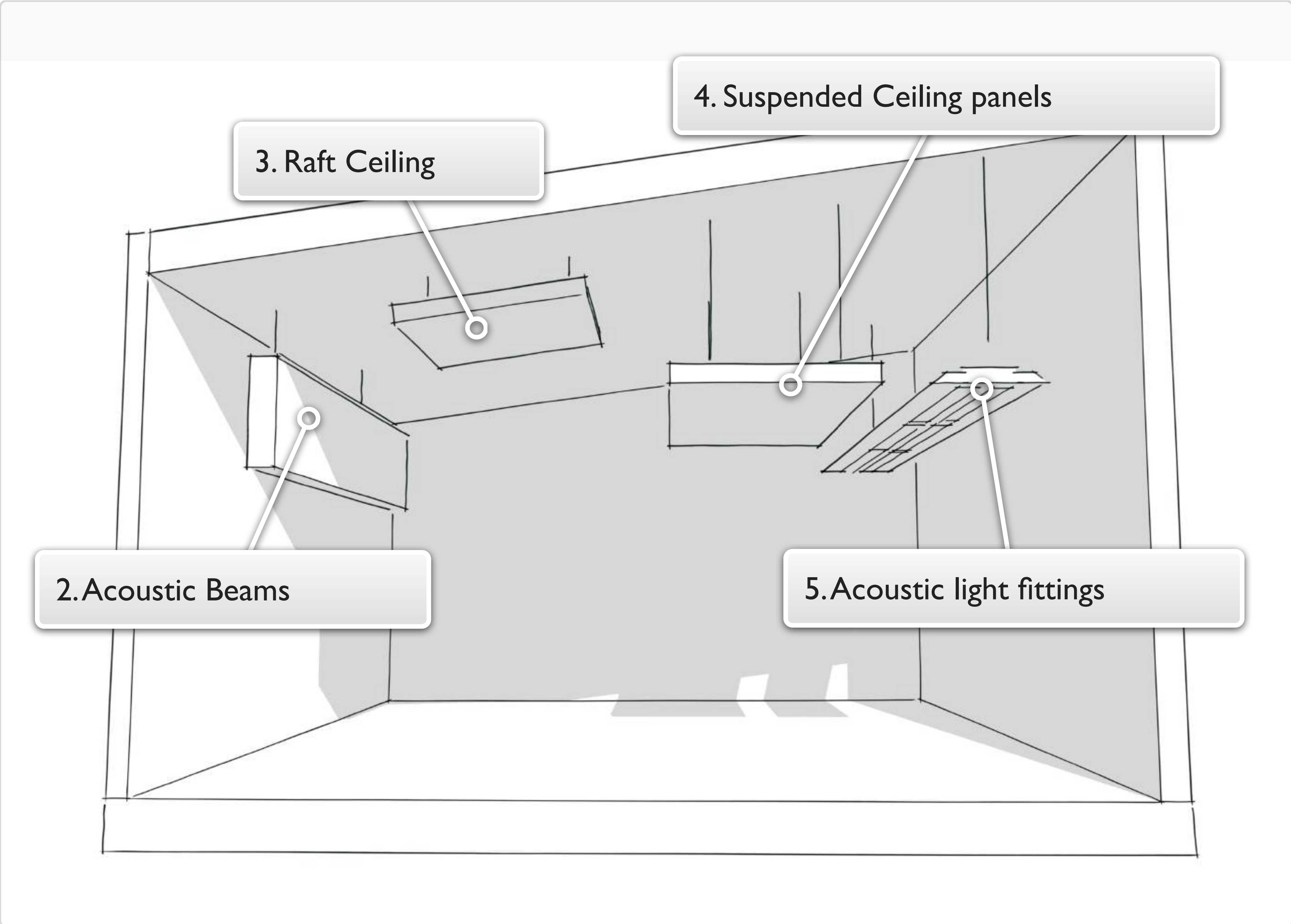
2 - Acoustic beams can be extremely effective since all sides of the beams will provide acoustic absorption.

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.

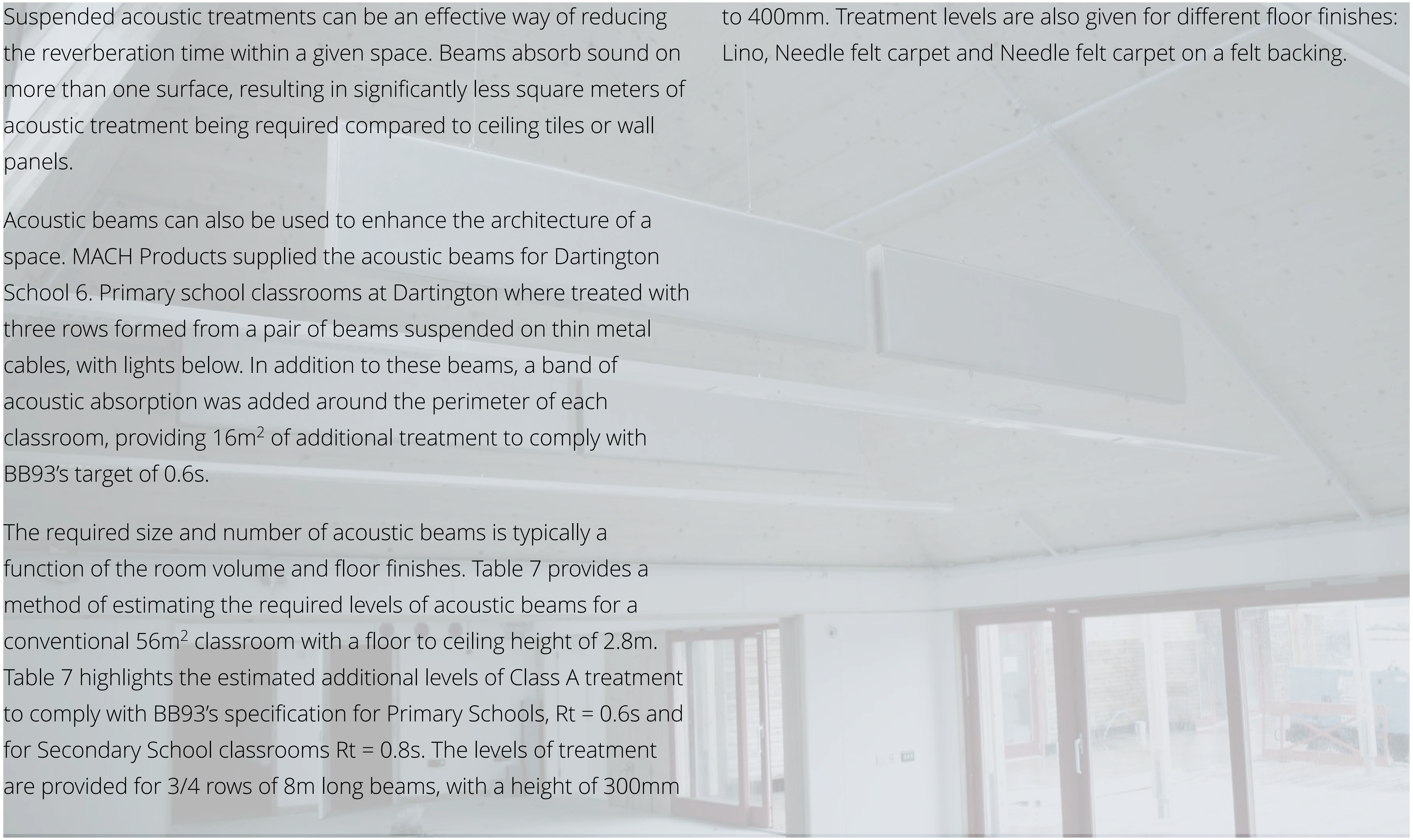
4 - Suspended acoustic panels - A similar design to that of 2, but in this case, the acoustic panels are suspended on wires.

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.

THERMAL MASS AND ACOUSTIC ABSORPTION



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 16m^2 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 56m^2 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.

ACOUSTIC BEAMS

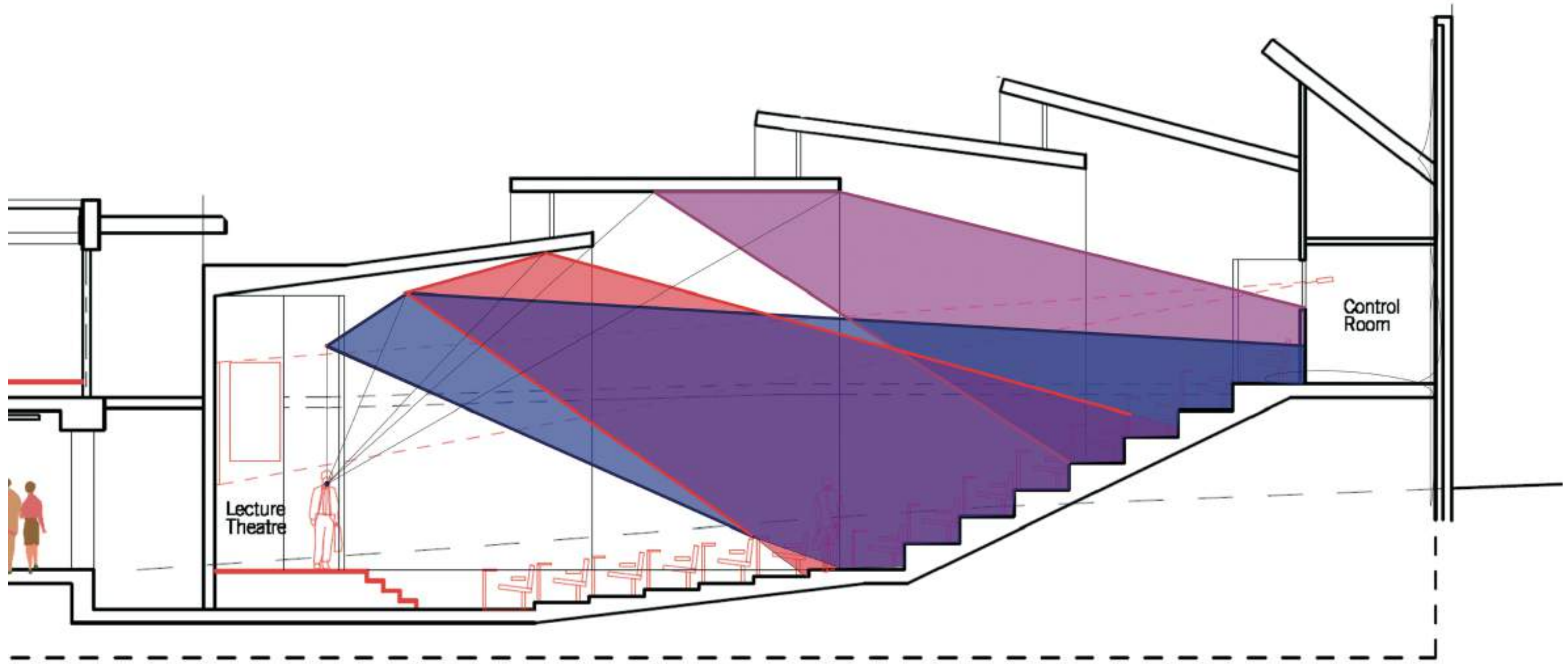
No- Rows of Acoustic Beams, 8m in length	Floor Finish	Additional level of treatment to comply with BB93			
		Rt= 0.6s 300mm beam	Rt= 0.8s 300mm beam	Rt= 0.6s 400mm beam	Rt= 0.8s 400mm beam
3	Lino floor	$31m^2$	$19m^2$	$27m^2$	$14m^2$
4	Lino floor	$27m^2$	$14m^2$	$21m^2$	$8m^2$
3	Needle felt carpet	$20m^2$	$8m^2$	$16m^2$	$4m^2$
4	Needle felt carpet	$16m^2$	$4m^2$	$10m^2$	$0m^2$
3	Felt backing carpet	$12m^2$	$0m^2$	$7m^2$	$0m^2$
4	Felt backing carpet	7	0	0	0

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



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FACADE ATTENUATION INSTALLATION

Facade Lecture Notes

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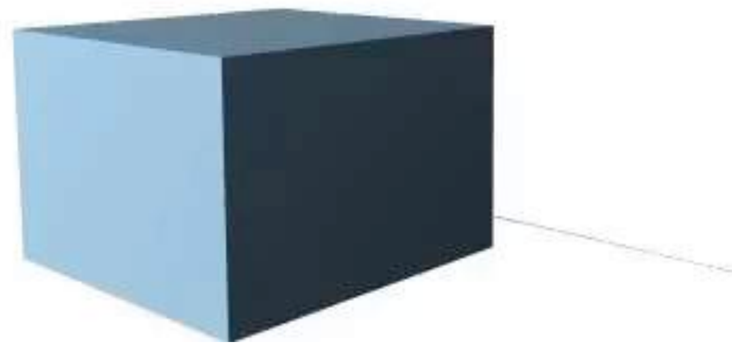
NAT VENT - FACADES, CROSS VENTILATION AND HEAT RECOVERY

When naturally ventilating a building on a noisy, or moderately noisy site, the acoustic design of the facade is 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 and the performance of the acoustic foam, the NAT Vent Attenuator is an exceptionally slim product with an outstanding acoustic performance. The size and depth of the NAT Vent Attenuator is dependent upon 2 main factors.

The free/open area specified by the M&E consultant or 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.

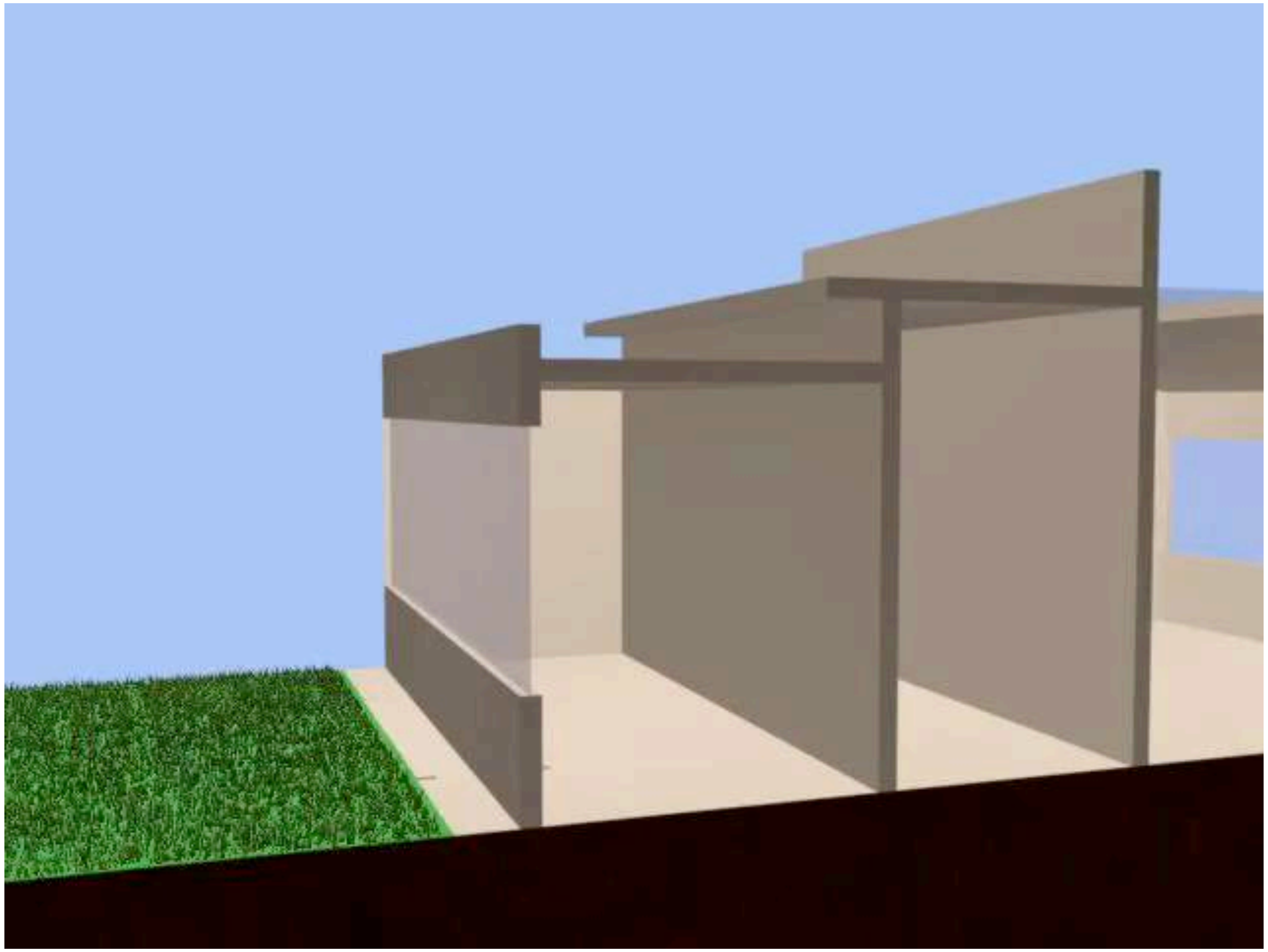
The second factor affecting the depth of the attenuator is the required level difference between the environmental noise and the internal noise limit. The greater the difference, the longer the attenuator.

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 building's ventilation and acoustic requirements.



SUMMARY - FACADES, CROSS VENT & OTHERS

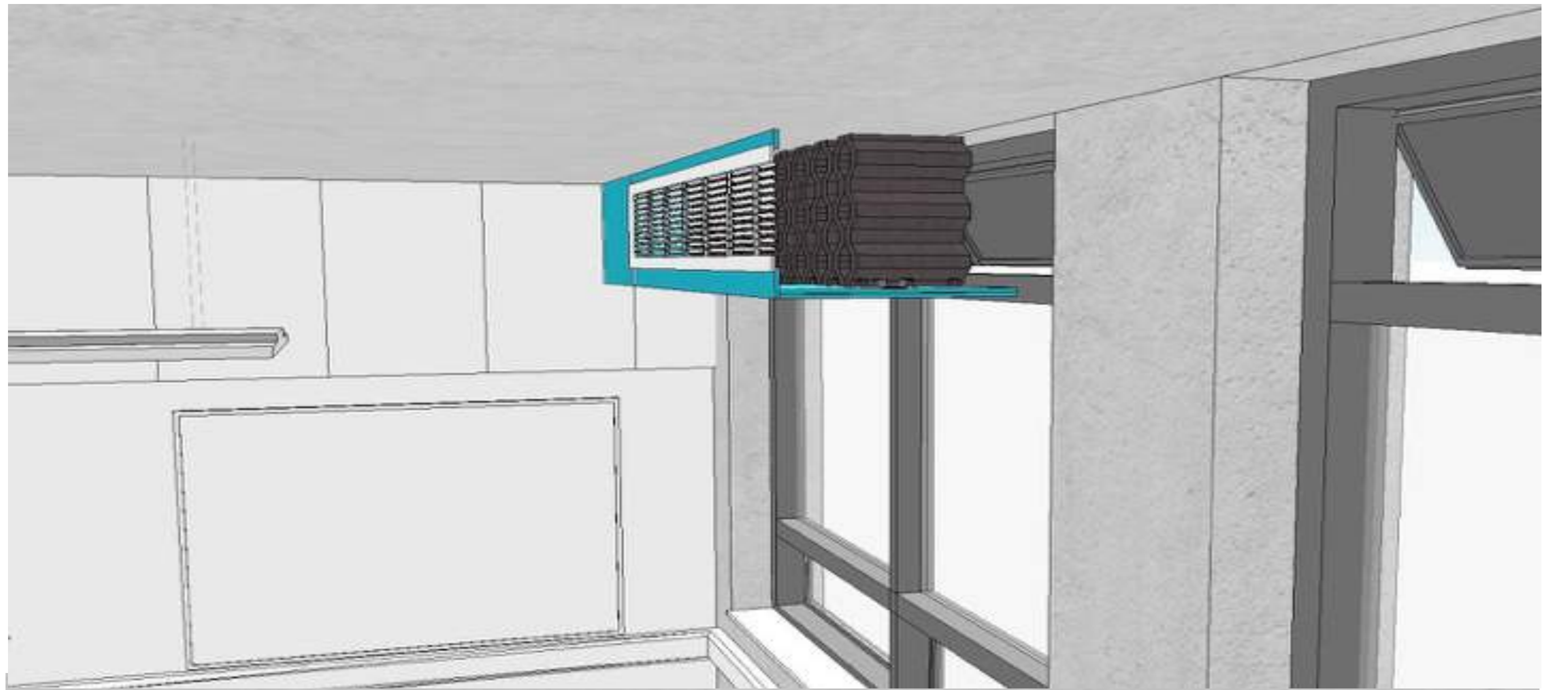
The core advantage of the Honeycomb Attenuator is its cost and flexibility, derived from its simplicity. The intelligent tessellate wedges forming a honeycomb structure, allowing the flow of air whilst restricting the passage of sound. Forming the project for laser cut foam means it is possible to cut the wedges to meet unique feature or any building. Hence it is possible to design the Honeycomb Attenuator to fit into almost any space, irrespective of its shape, the foam wedges also meeting to fit into convectional square and rectangular openings.

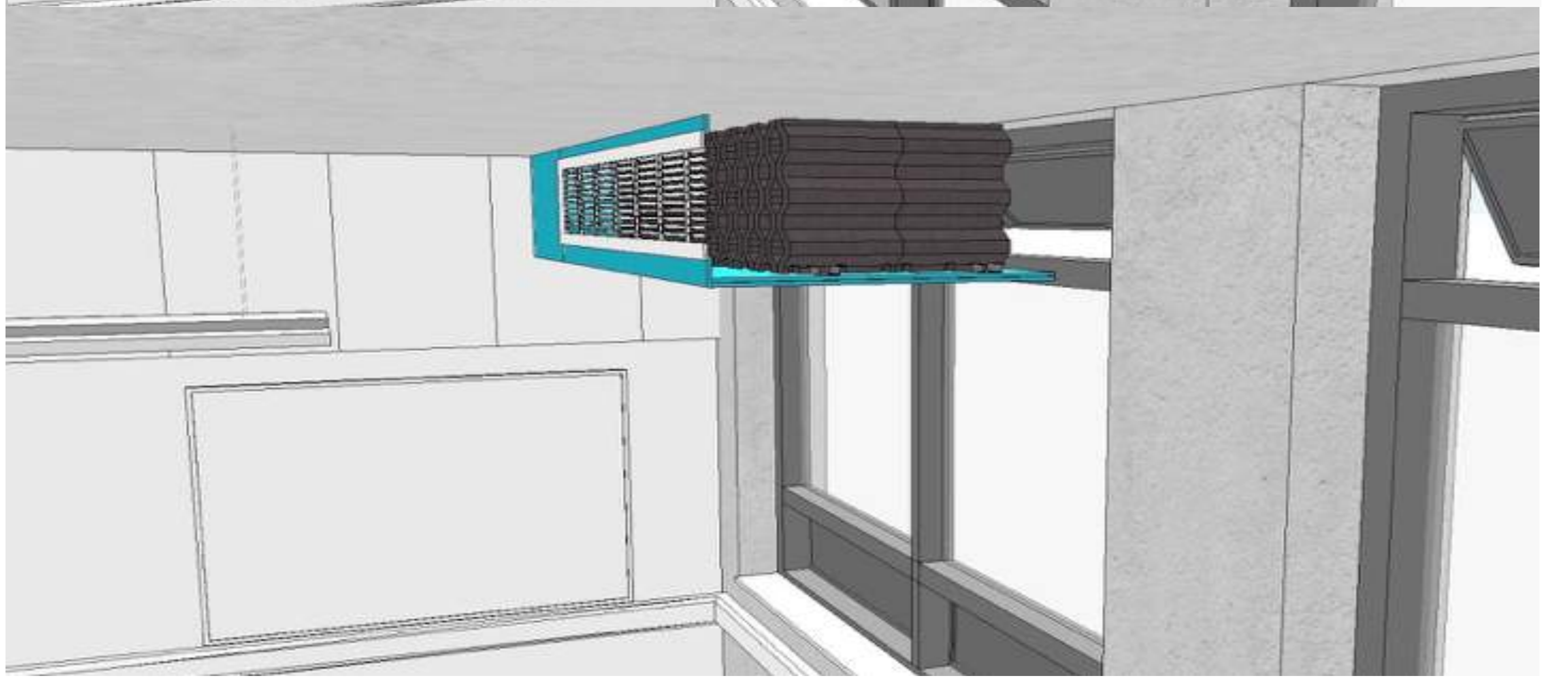


SIZE AND PERFORMANCE

The Honeycomb Attenuator is typically design for every project individually, since due to it flexibility in term of it position, performance and size.

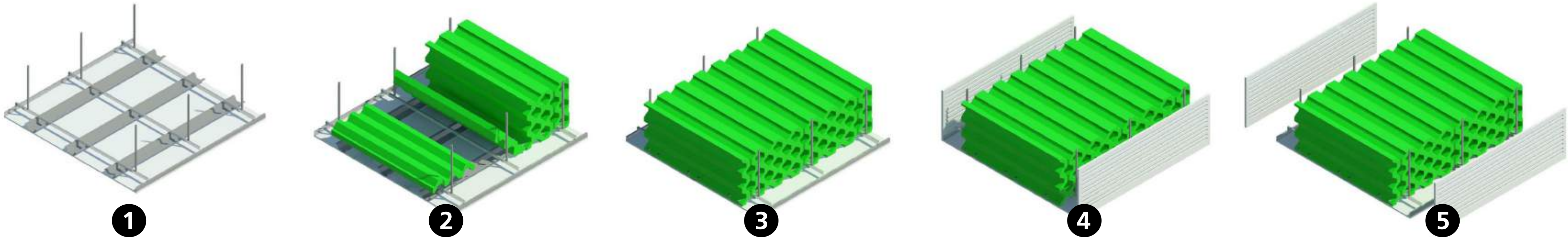
However it flexibility installation option are end less as shown in the images below.

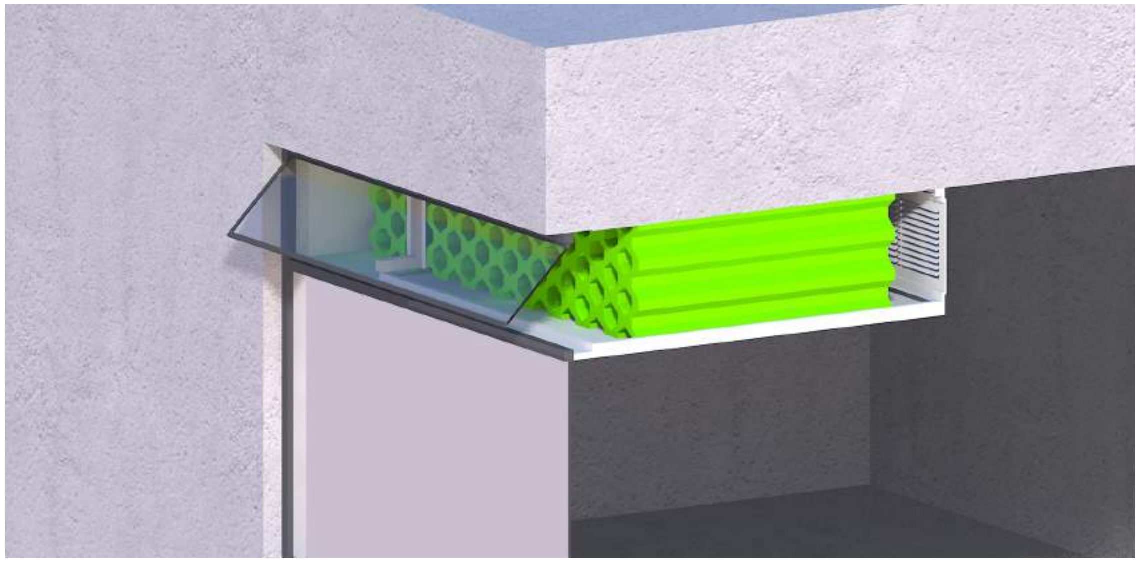




MF INSTALATION

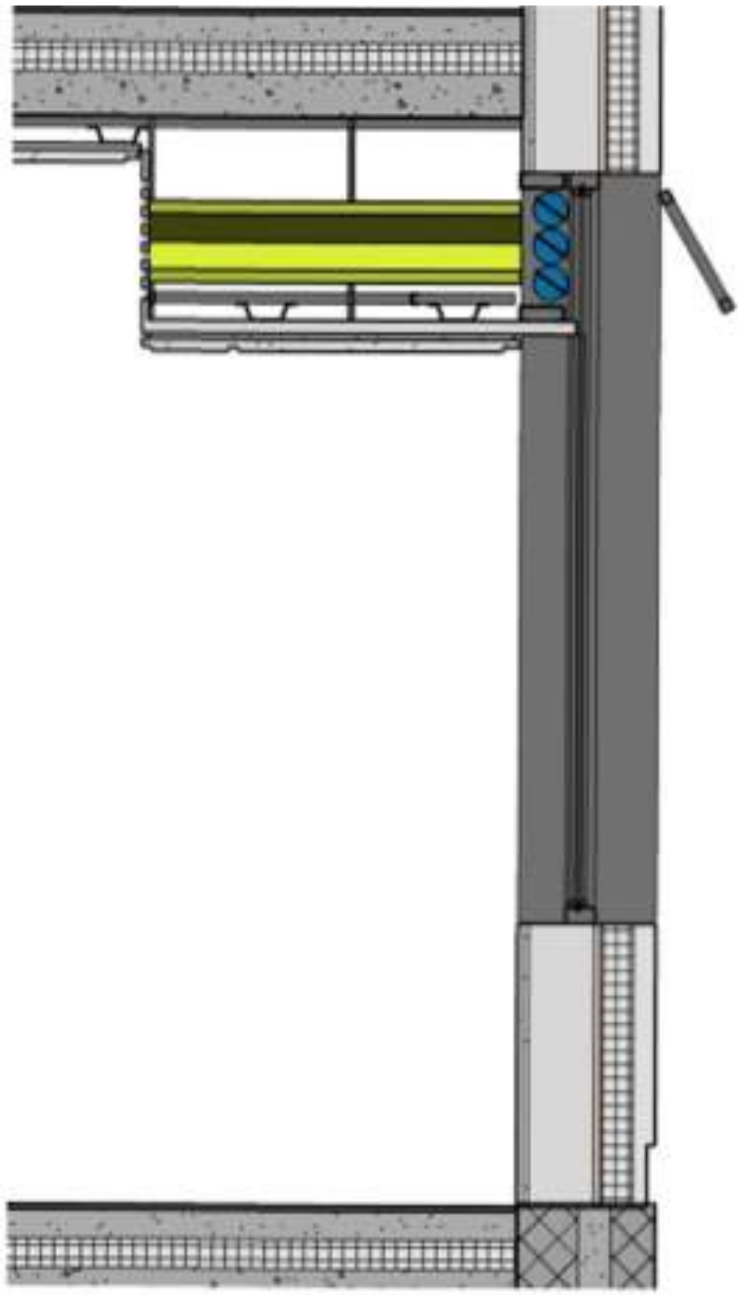
Build Process For the Nat Vent into an MF bulkhead adjacent to a facade or corridor wall



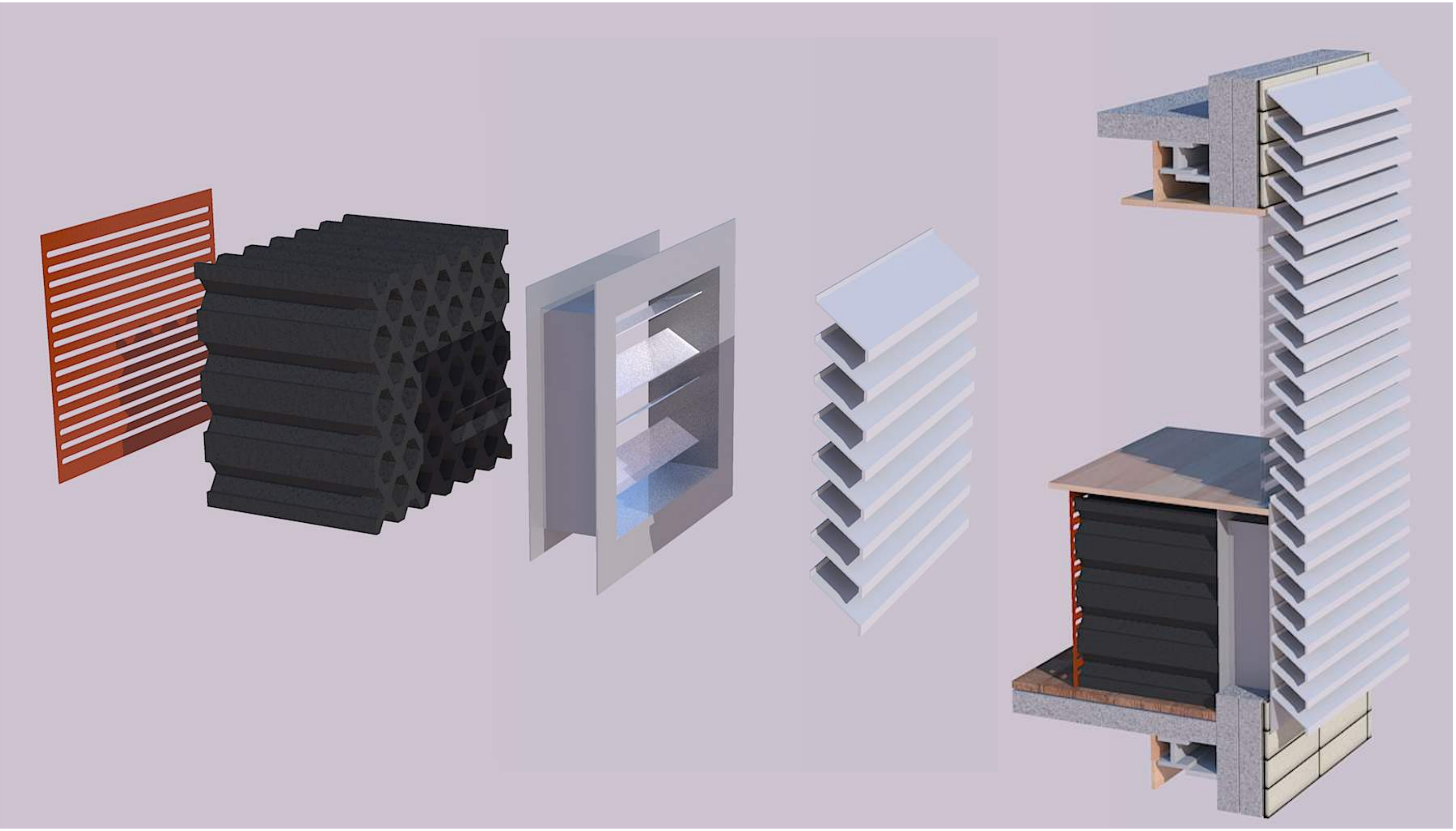


Nat Vent used to prevent noise ingress left, NAT Vent as a Cross Talk Right

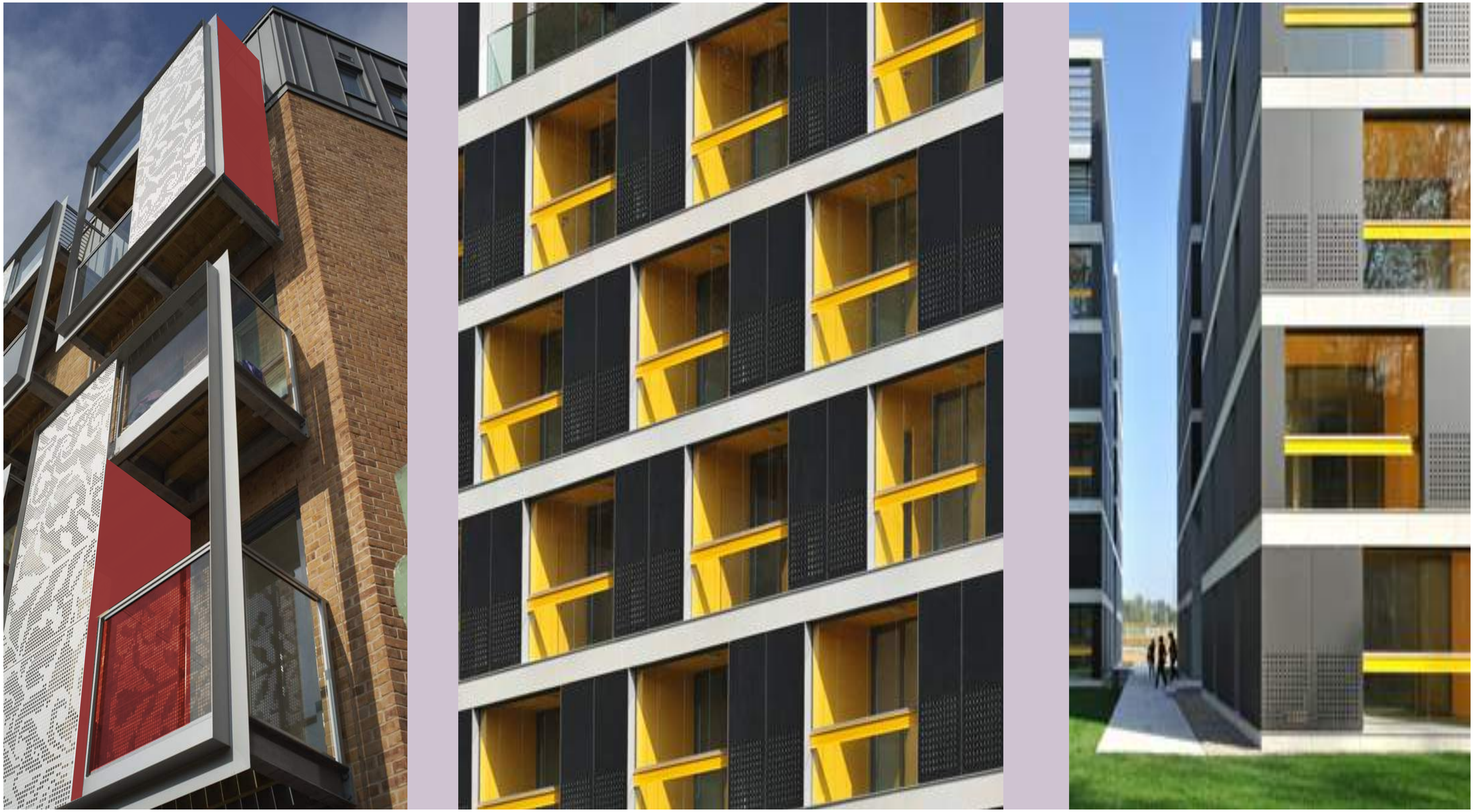
WINDOW INSTALATION



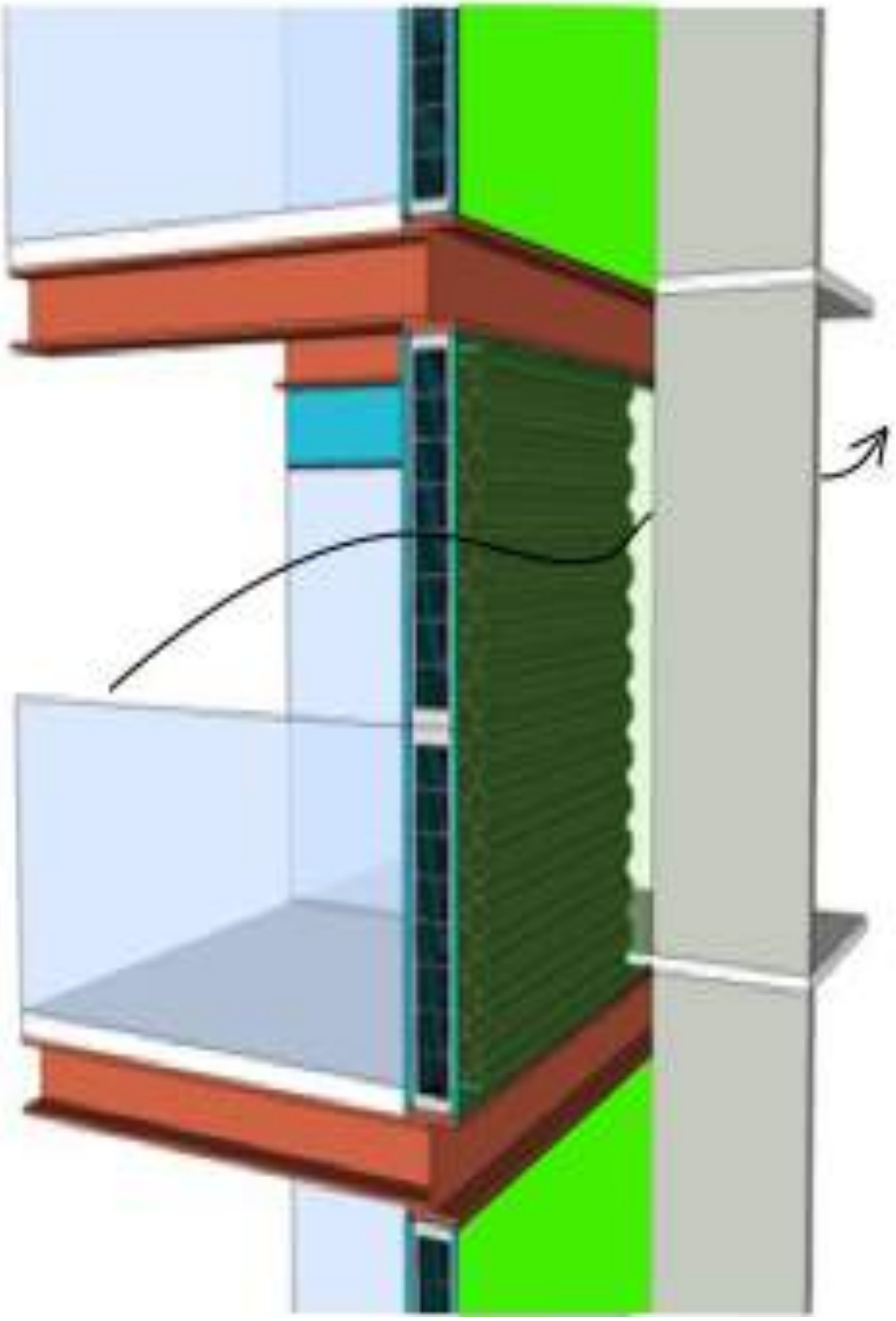
FACADE ATTENUATOR



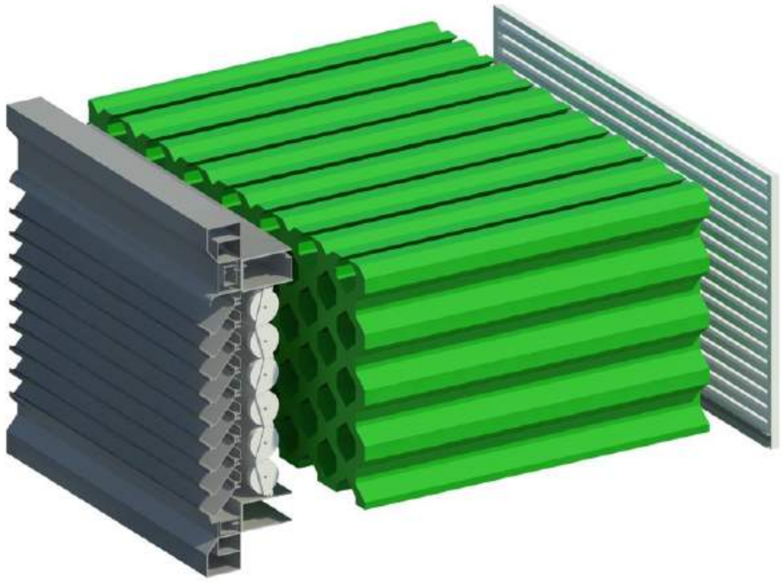
POSSIBLE INSTALATION LOCATIONS

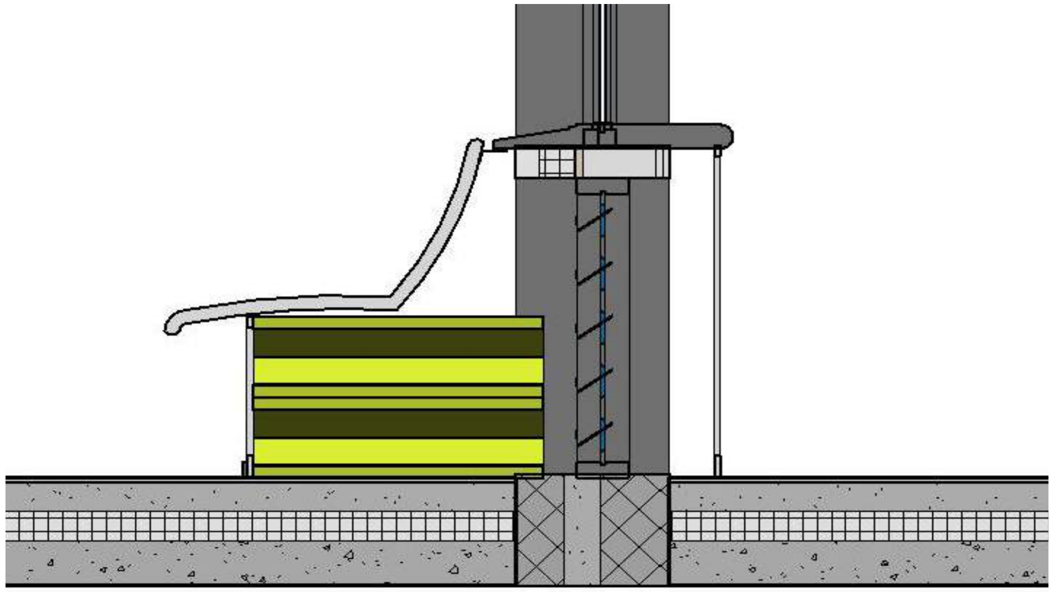


NAT VENT - VERTICAL FINS

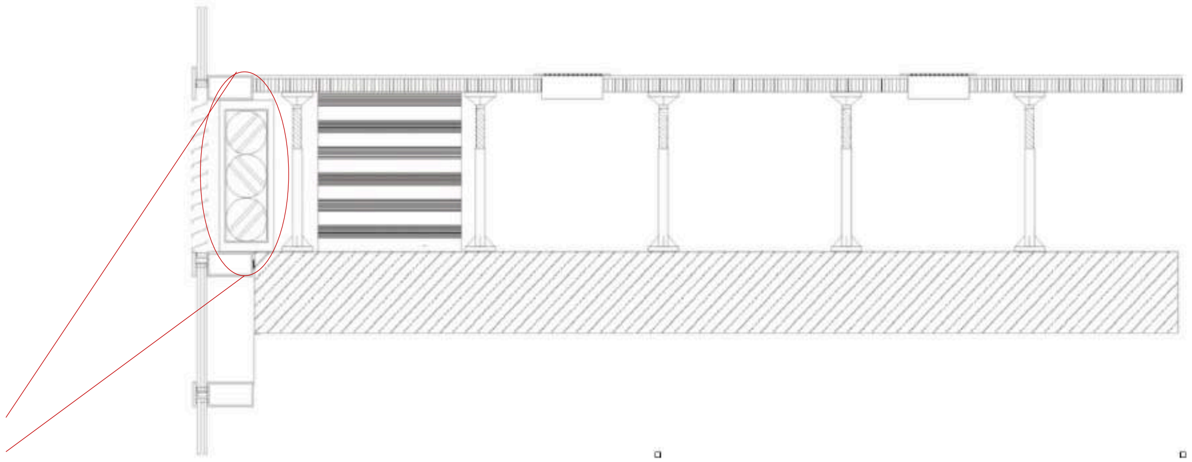


BISPOKE INSTALATIONS





UNDERFLOOR INSTALATION



NAT Vent Attenuator Located under the raised floor used to control noise ingress

NAT Vent Attenuator cleverly cut in the factory such to fit around pedestals

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Founder of MACH Acoustics
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NATURAL VENTILATION - CROSS VENTILATION

Facade Lecture Notes

www.machacoustics.com

NAT VENT - AS A CROSS TALK

Natural ventilation works best when undertaken in combination with cross ventilation, this not only improves the air flow through a space, but also reduces the size of the openings required within the façade. As such, improved ventilation is provided with reduced levels of noise ingress.

The drawback of cross ventilation is that a new sound path is provided, where sound can pass from a corridor space into a sensitive area. As such, a cross talk attenuator is required such to prevent the passage of sound whilst still maintaining the air flow to the corridor spaces.

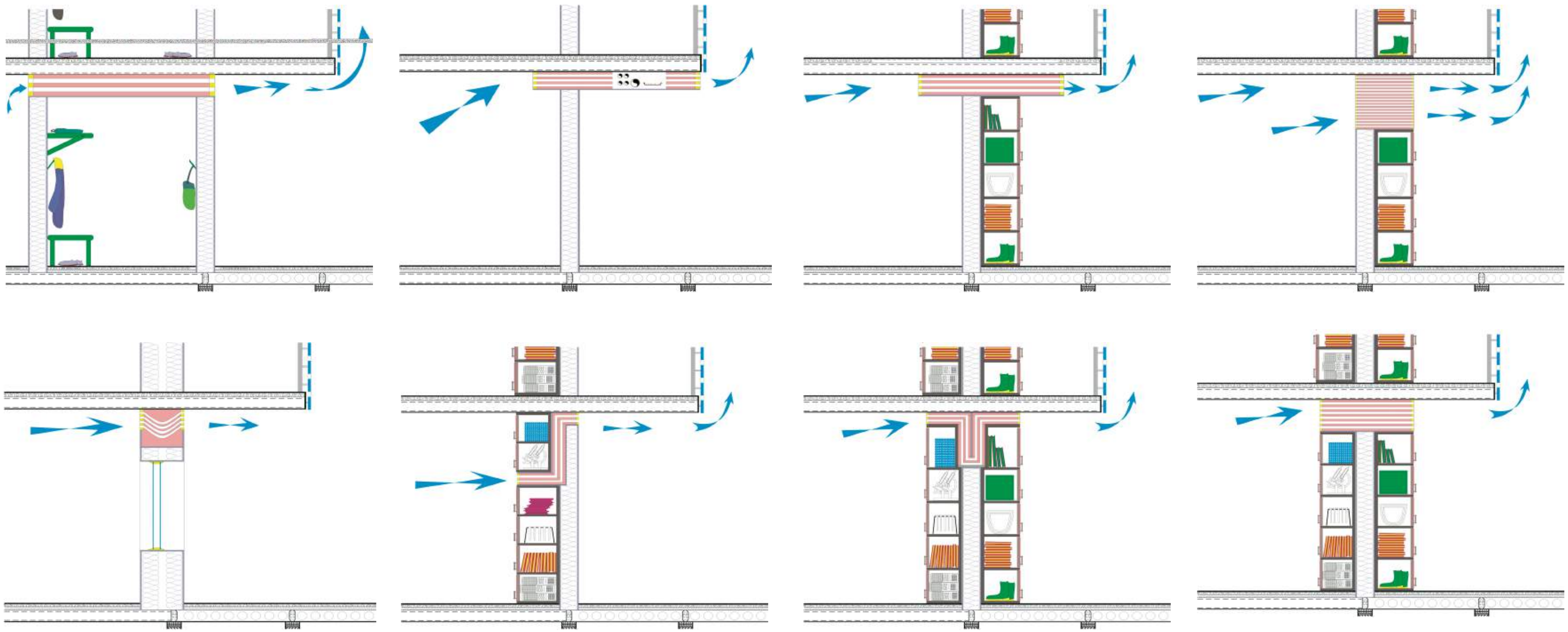
The NAT Vent Attenuator, as noted above, is highly flexible, meaning that it can be adapted to work both as a façade attenuator (preventing noise ingress into flats) and as a cross talk attenuator (preventing noise ingress from corridors into flats). The NAT Vent Attenuator can be incorporated into partitions such to allow for cross-ventilation, in order to meet a spaces ventilation needs whilst maintaining its acoustic privacy.

The core specifications of the NAT Vent are provided below.

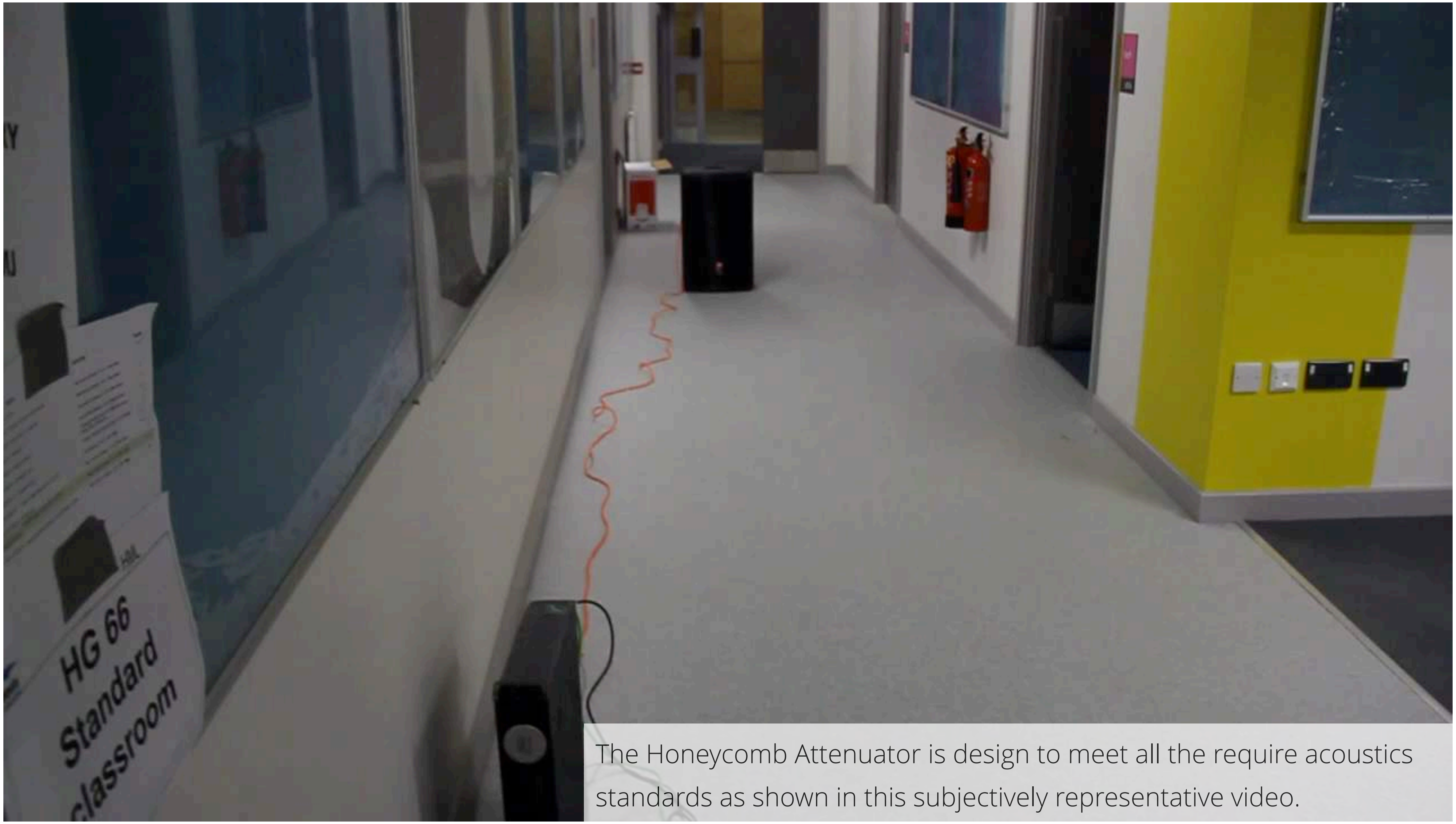
- Low resistance to flow of air: Pressure loss < 1 Pa at operating velocities and coefficient of discharge (Cd) typically 0.4.
- Lightweight high performance acoustic foam (~26kgm-3) requires minimal supporting structure.
- Can coexist with building services within an existing bulkhead.
- Able to meet the current regulation 39 dB Dne,w standard for cross ventilators.
- Installation to a duct typically takes less than 1 hour. The acoustic foam blocks are simply stacked to create the honeycomb formation in the duct, orientated for air flow through the gaps.
- Unlike conventional attenuators, the NAT Vent Attenuator is made to order; we design the NAT Vent Attenuator around the proposed architecture or existing building fabric.
- Cost comparisons have identified the NAT Vent Attenuator to be 35% to 85% cheaper (depending upon design) than its competitors, thanks to reduced materials, simpler detailing and coordination on site.

NAT VENT

As in the case for façade the Honeycomb Attenuator can be arrange and design to suet a wide range of installation option and design requirements

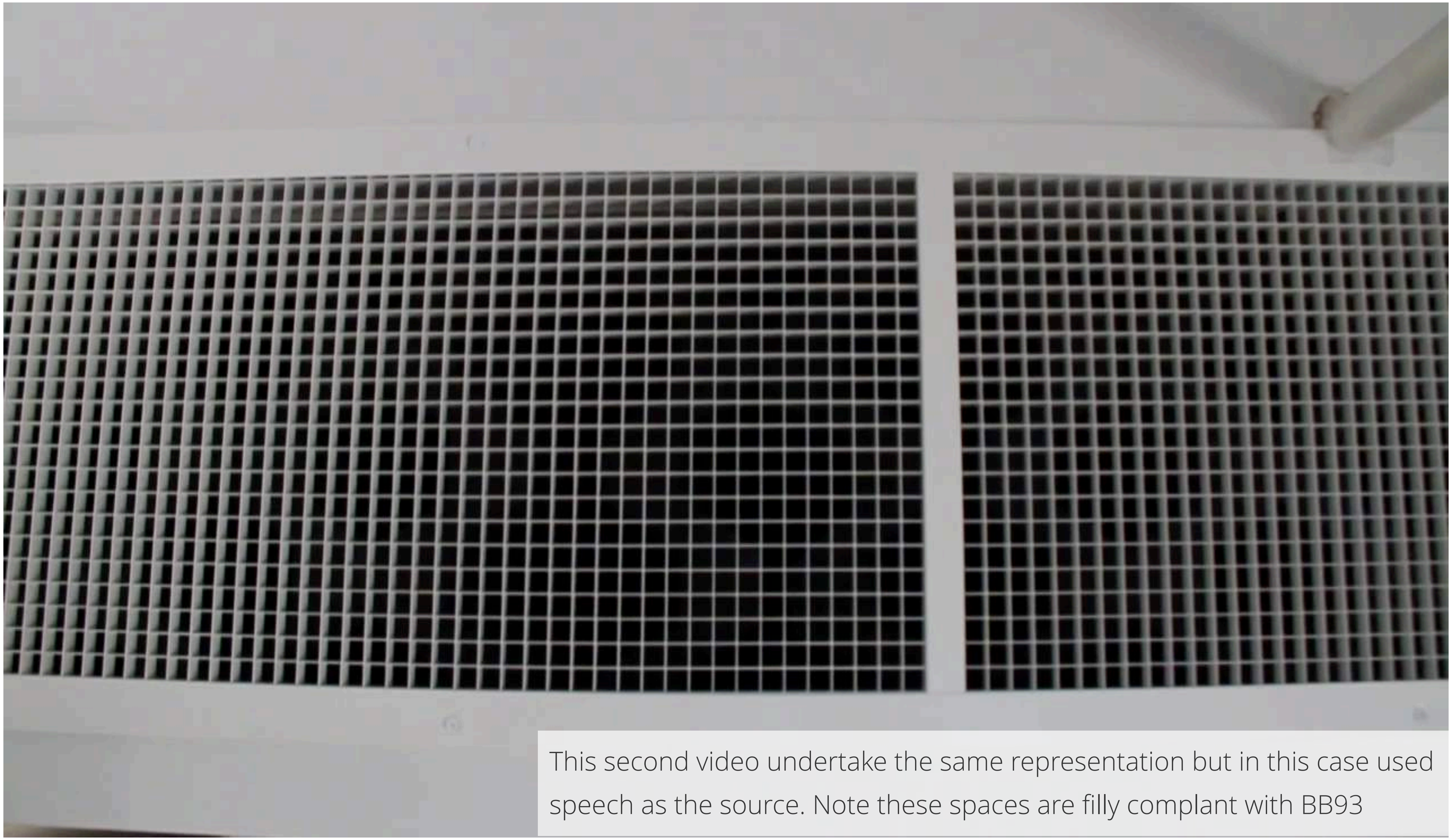


SUBJECTIVE PERFORMANCE



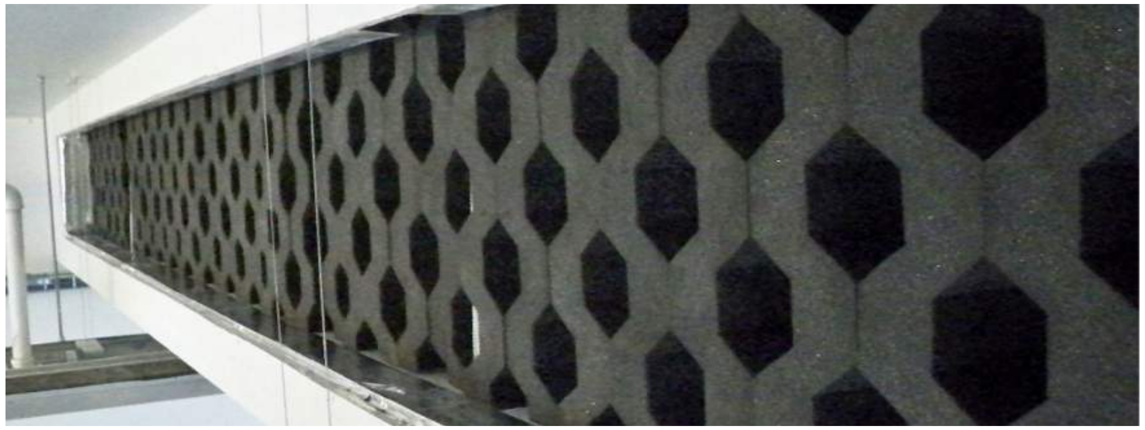
The Honeycomb Attenuator is design to meet all the require acoustics standards as shown in this subjectively representative video.

SIMPLE NAT VENT INSTALLATION

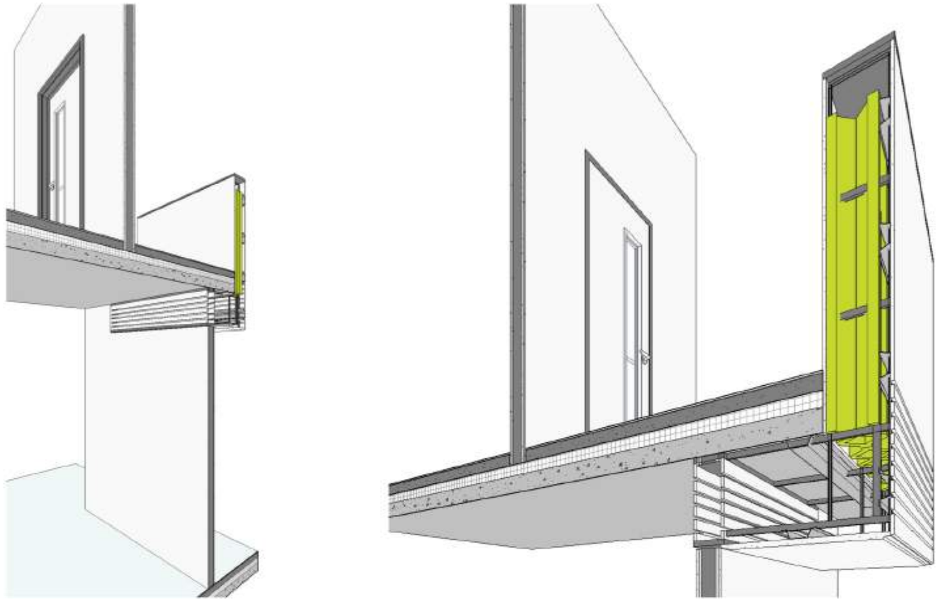


This second video undertake the same representation but in this case used speech as the source. Note these spaces are filly complant with BB93

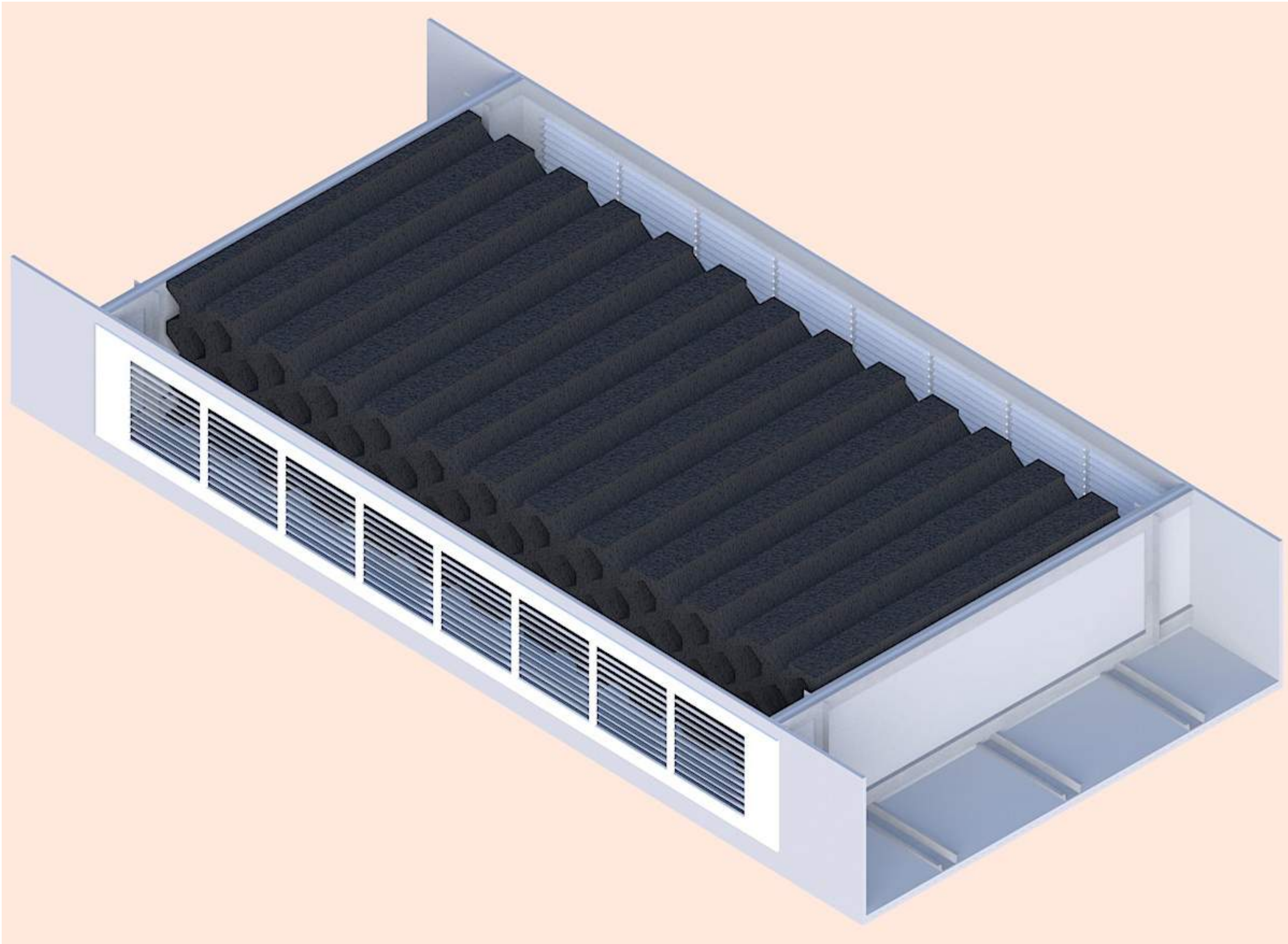
NAT VENT - AS A CROSS TALK



OPTION 1 BUILDINGS



NAT VENT - AS A CROSS TALK



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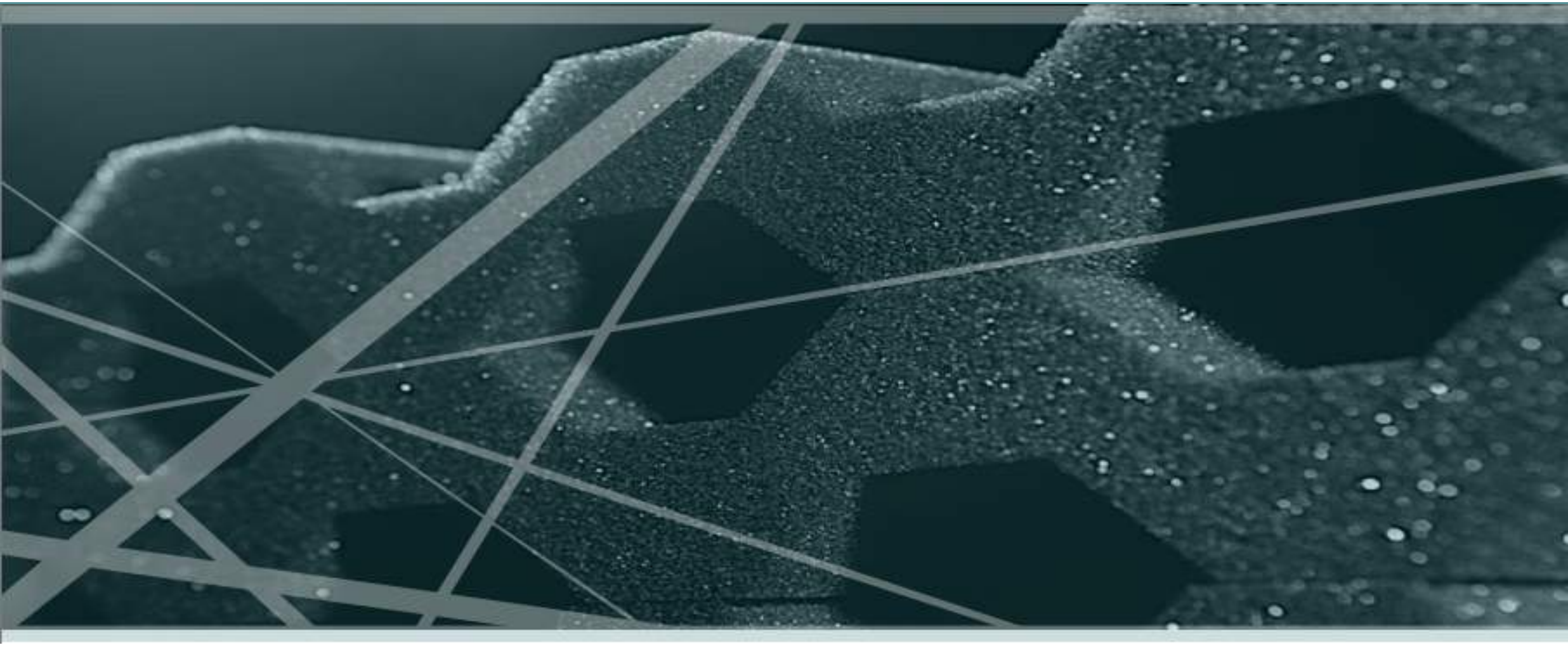


THE NAT VENT ATTENUATOR

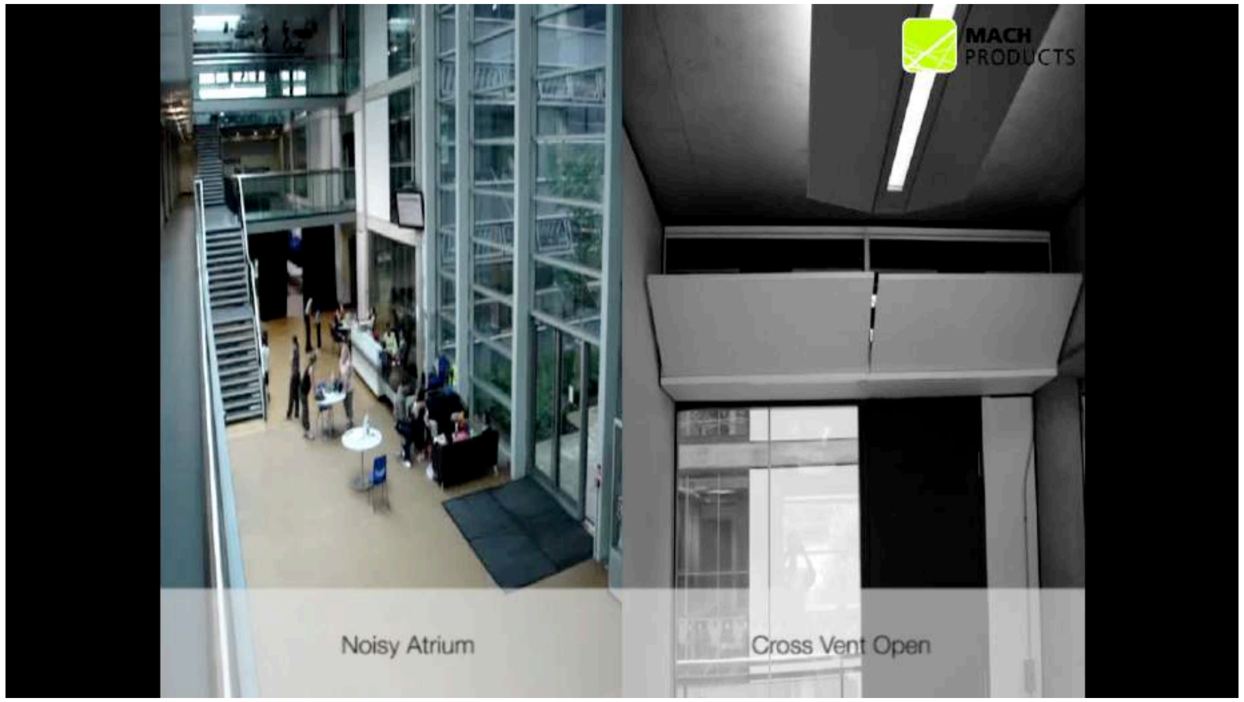
Facade Lecture Notes

FACADE & CROSSTALK ATTENUATION

The NAT Vent Attenuator therefore allows the flow of air into and through a building. The NAT Vent can be used to prevent environmental noise break in, as well as maintaining the acoustic privacy of partitions containing ventilation openings.

In the case where a building uses heat recovery, the NAT Vent maintains privacy across partitions, while allowing air to be recirculated around a building.

The NAT Vent Attenuator is designed and supplied by MACH Acoustics, to overcome the acoustic challenges in the design of low carbon buildings.



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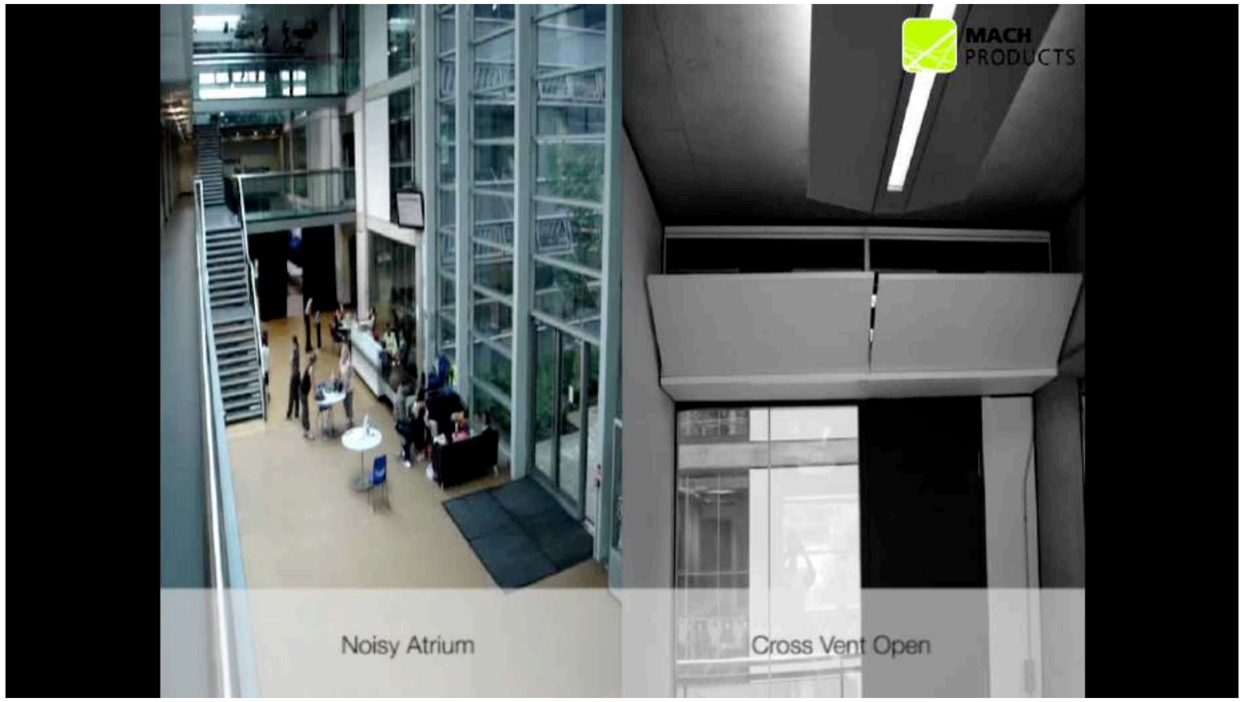
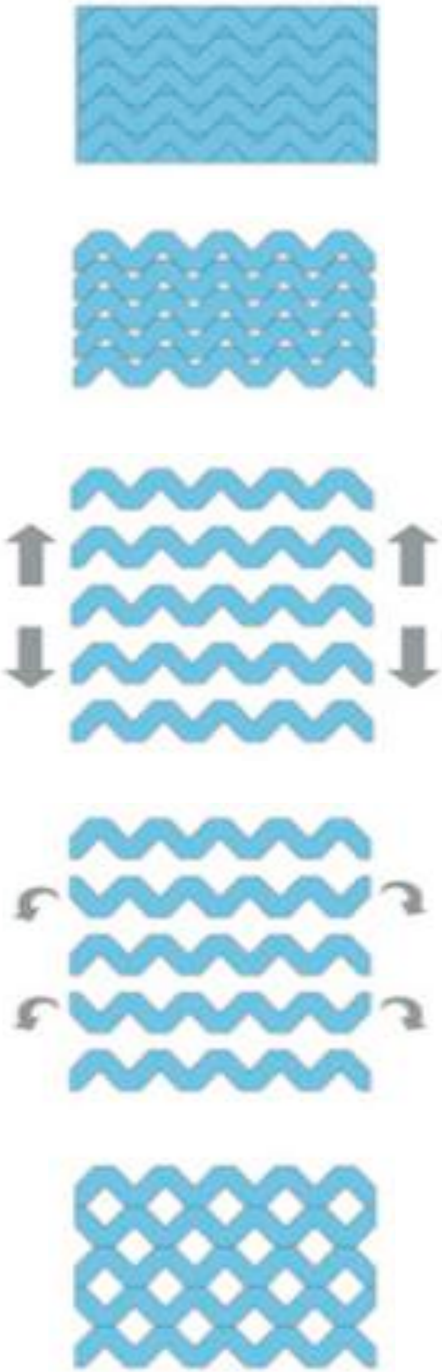
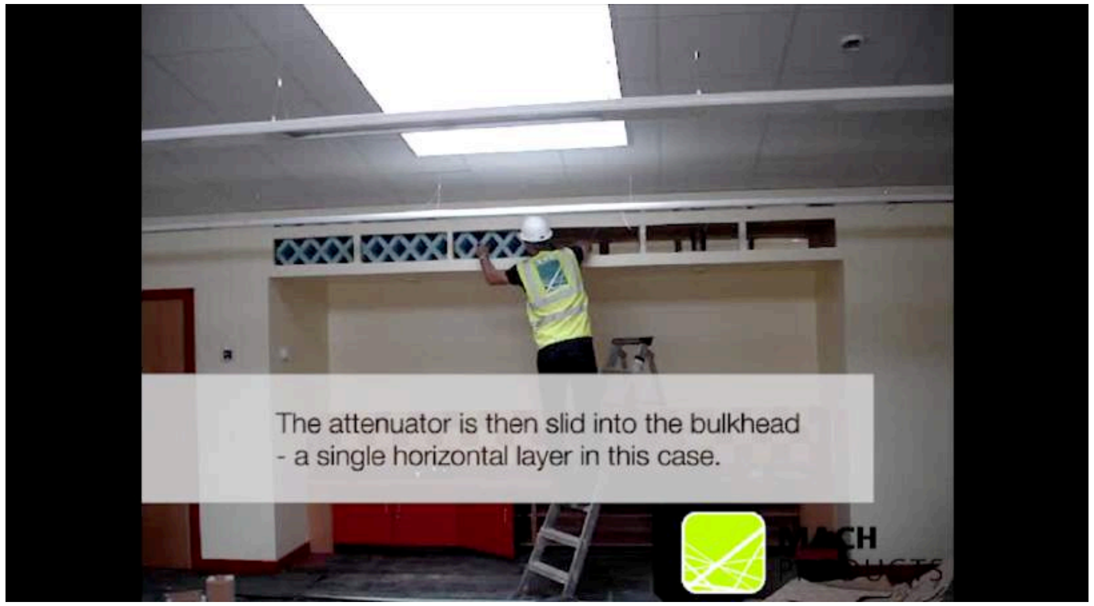


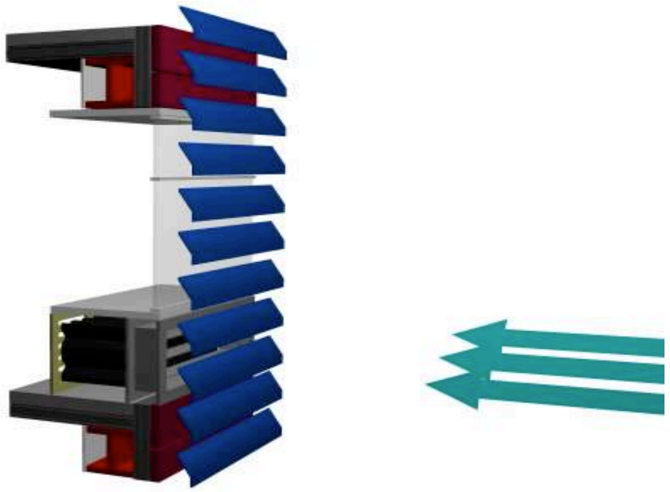
WHAT IS THE NAT VENT ?

The core advantages of the Honeycomb Attenuator are its cost and flexibility, derived from its simplicity. The NVA is formed from 3D cut acoustic foam wedges. These intelligent wedges tessellate together to form a honeycomb structure, which allows the flow of air whilst restricting the passage of sound, making the Honeycomb Attenuator a perfect tool for dealing with the acoustic challenges in naturally ventilated, low carbon buildings.

Since the product is formed from foam, it is possible to cut the wedges to meet the unique feature or any building. Hence it is possible to design the Honeycomb Attenuator to fit into almost any space, irrespective of its shape.



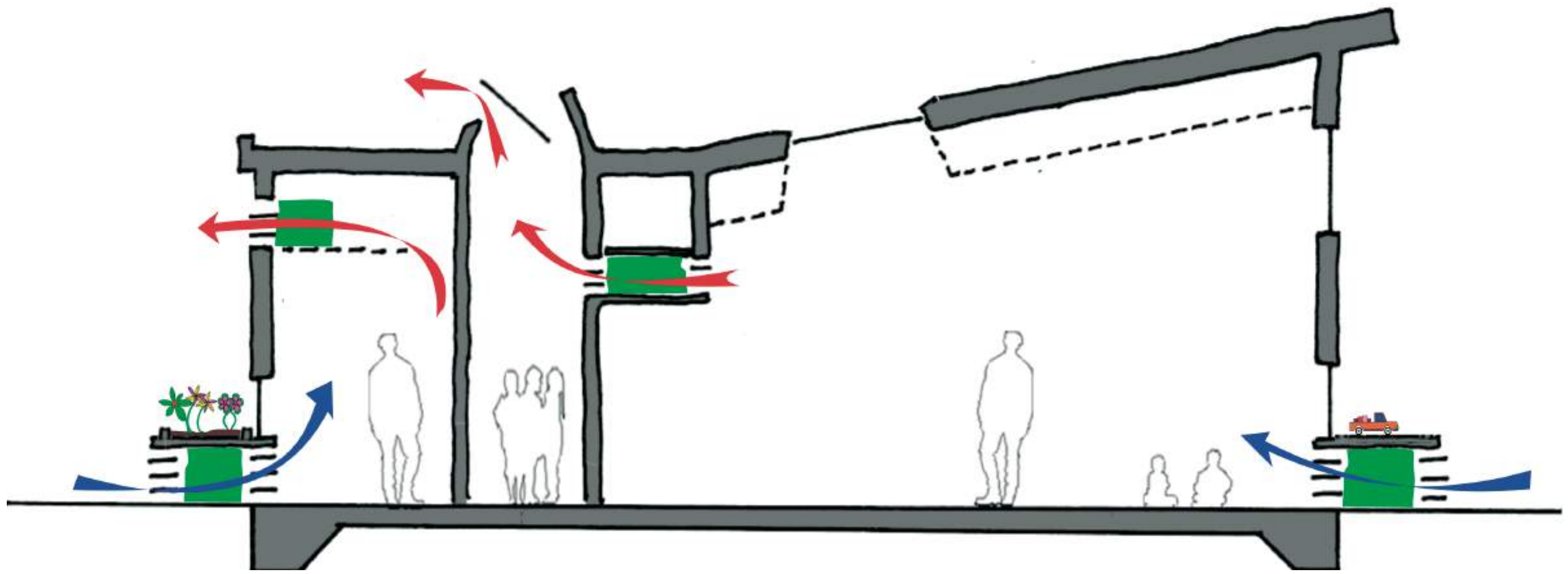


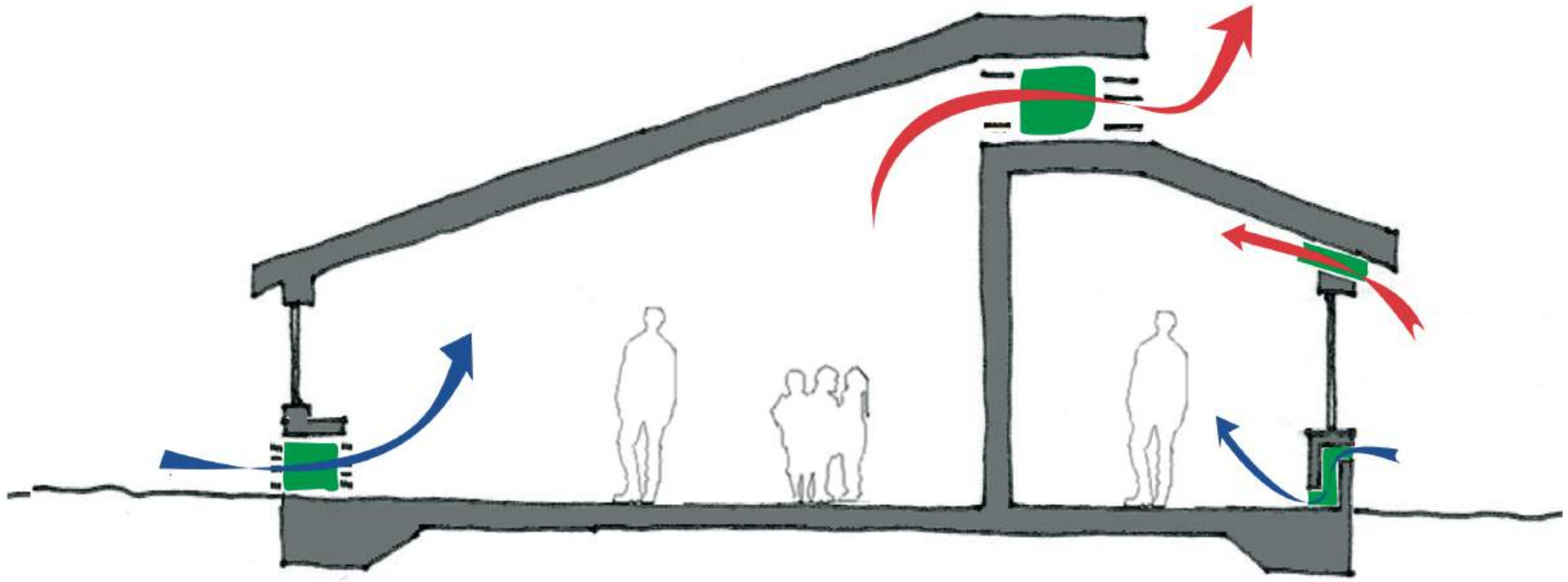


THE NAT VENT ATTENUATOR

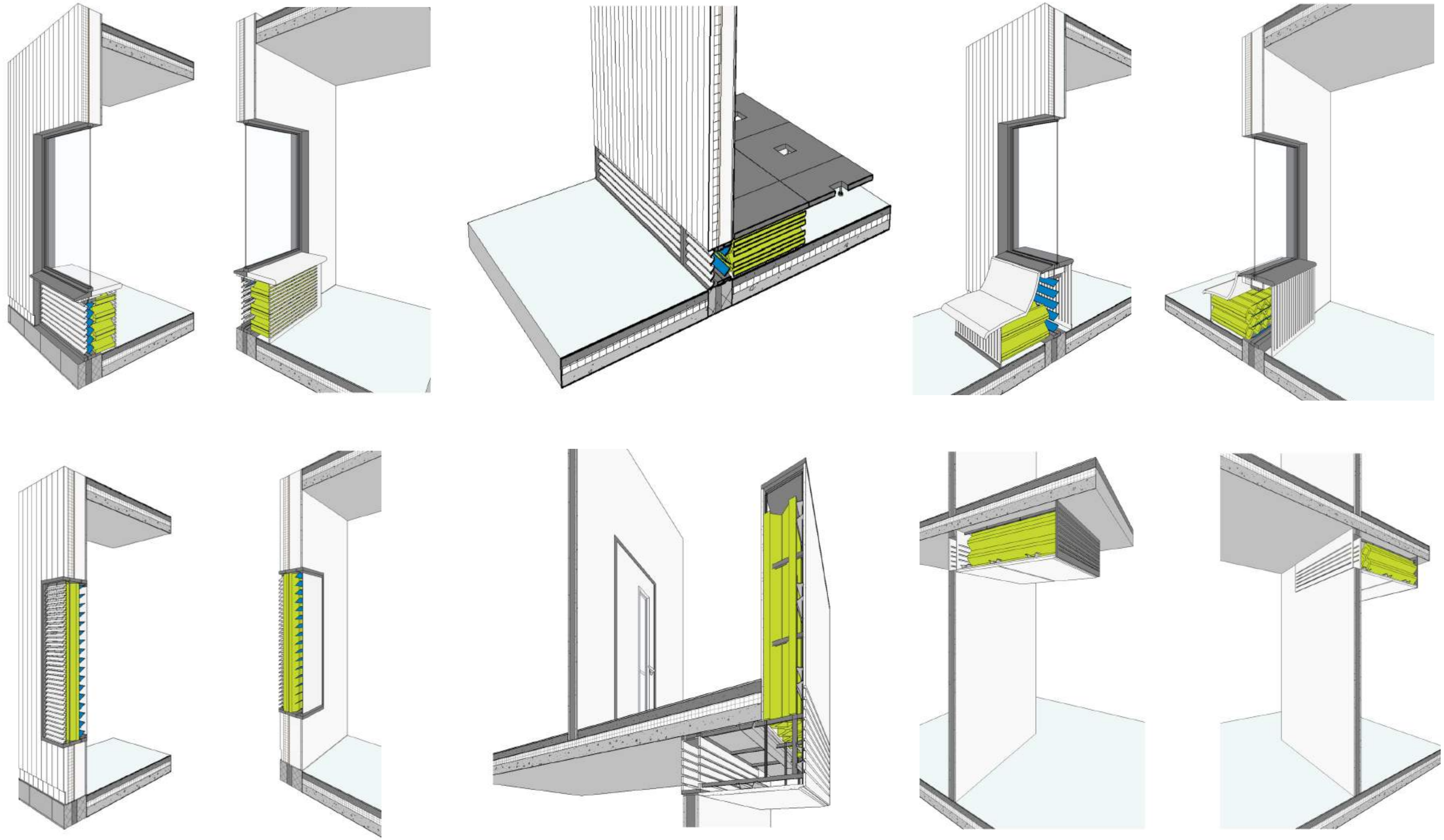
One of the main difficulties in designing low energy buildings is the prevention of noise break-in from the many noisy sources affecting modern buildings, including motorways, dual carriageways, trains, airplanes and inner city noise. Secondly, whilst cross ventilation is one of the most effective forms of natural ventilation, maintaining privacy and standards across partitions presents an acoustic challenge.

The NVA was designed to form a unison between natural ventilation and acoustics, without having to design your building around large bulkheads accommodating big heavy attenuators.





CROSS VENT, FACADE & OTHER EXAMPLE INSTALLATIONS

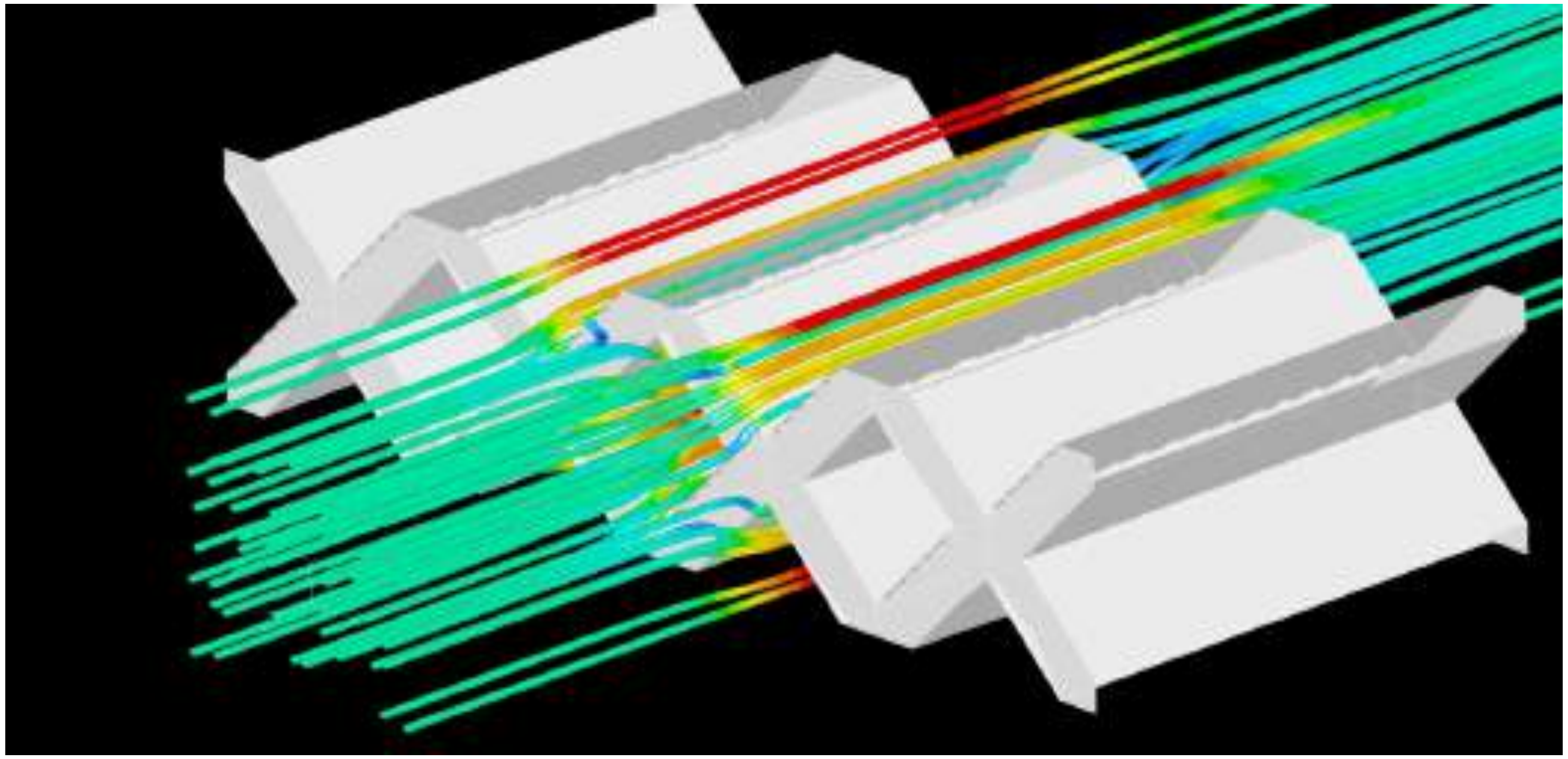


PERFORMANCE ACOUSTICS

Once placement method has been decided, the performance requirement is achieved by simply extending the length of the attenuator (the manufacturing process does not restrict the size of the product). This means the NAT Vent Attenuator can achieve performance levels from 20 dB Dne,w to 40+ dB Dne,w.

Designed purposely for low energy buildings, the Honeycomb Attenuator offers extremely low airflow resistance, with exceptional acoustic performance. Our attenuators are conventionally designed for a given specific project, however the table below provide a range of typical sound reduction levels. It acoustical performs is better than conventional attenuators, thus allowing for smaller attenuators, resulting in an easier installation proses, simpler coordination with services and greater flexibility in reduce bulkhead dimensions an so on.

Such to mitigate again airflow resistance MACH used CFD to model the pressure drop of the Honeycomb Attenuator, with a typical natural ventilation complling with BB101 offering less than a few pascals of pressure loss.



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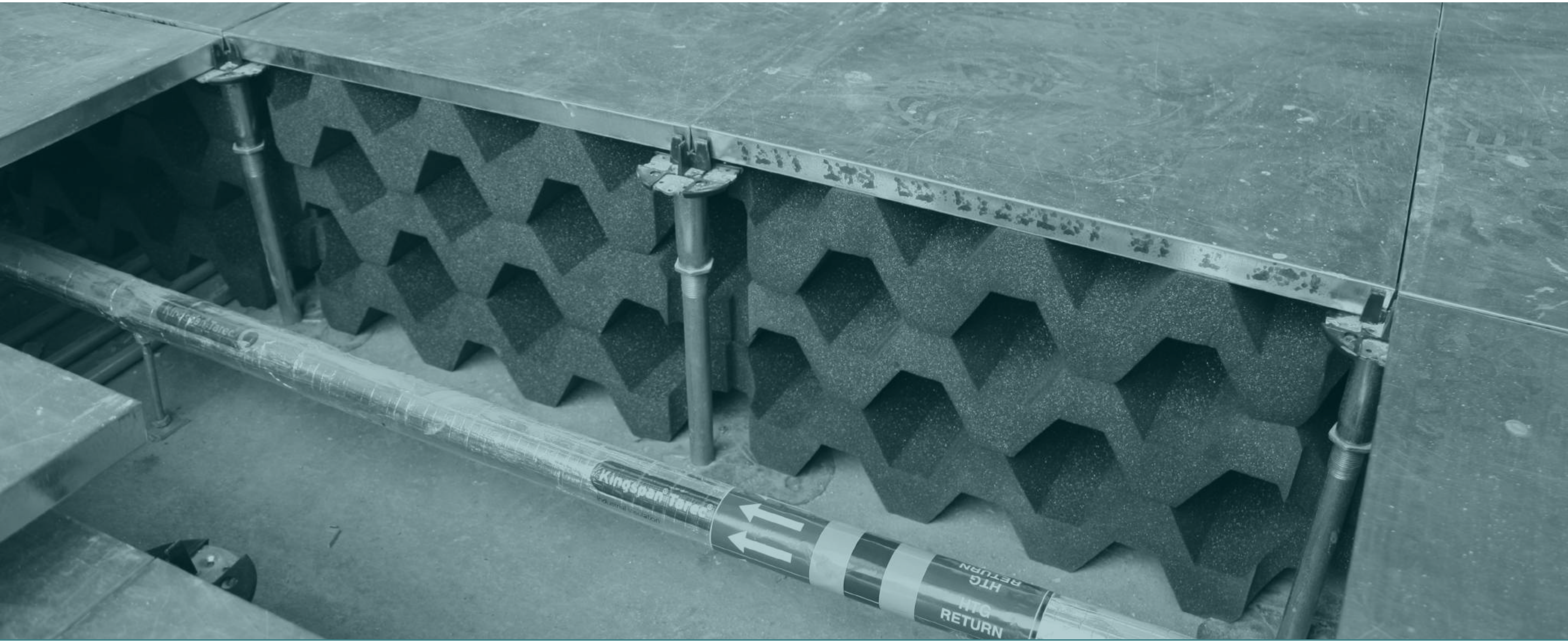

HEAT RECOVERY, STACKS & RAISED ACCESS

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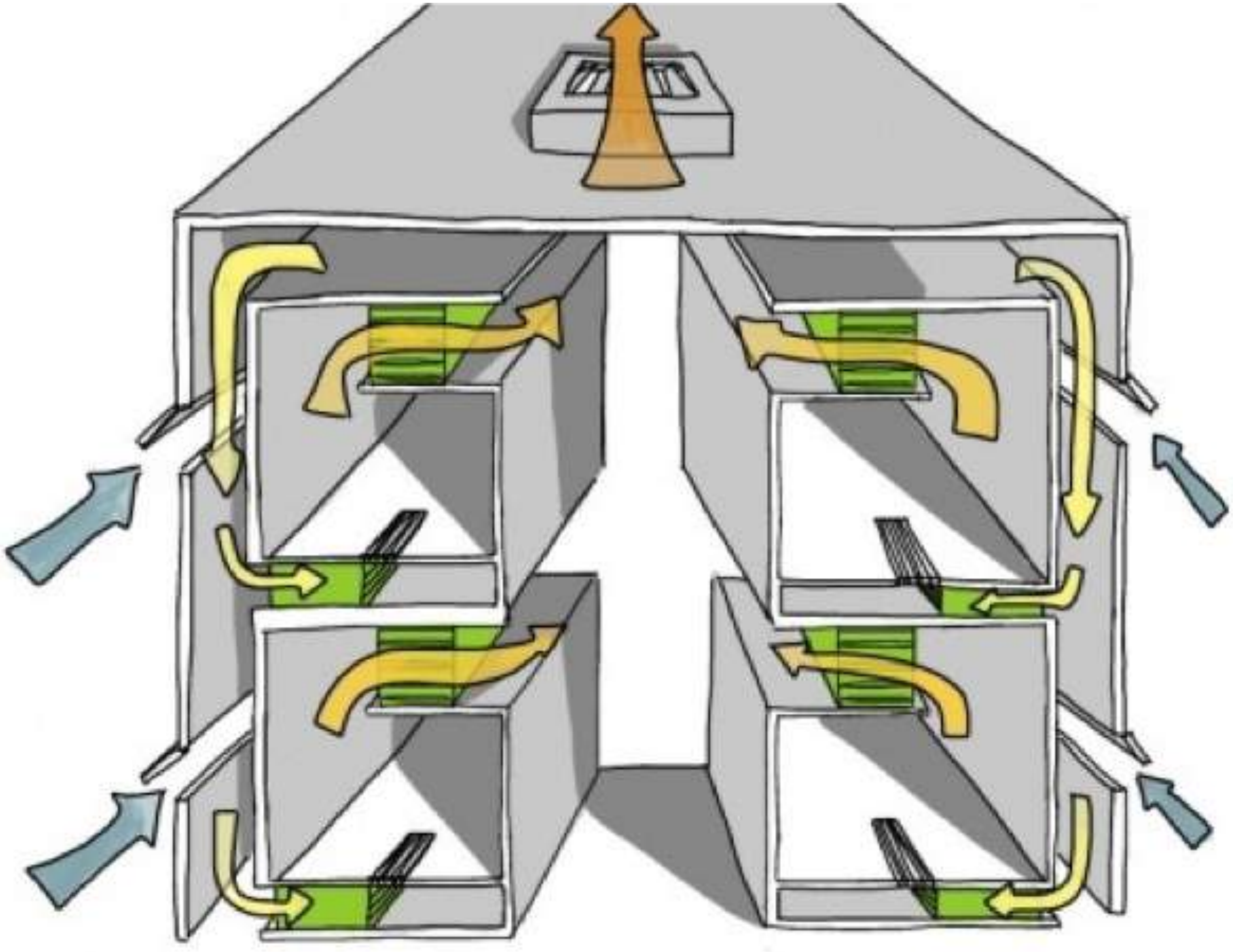

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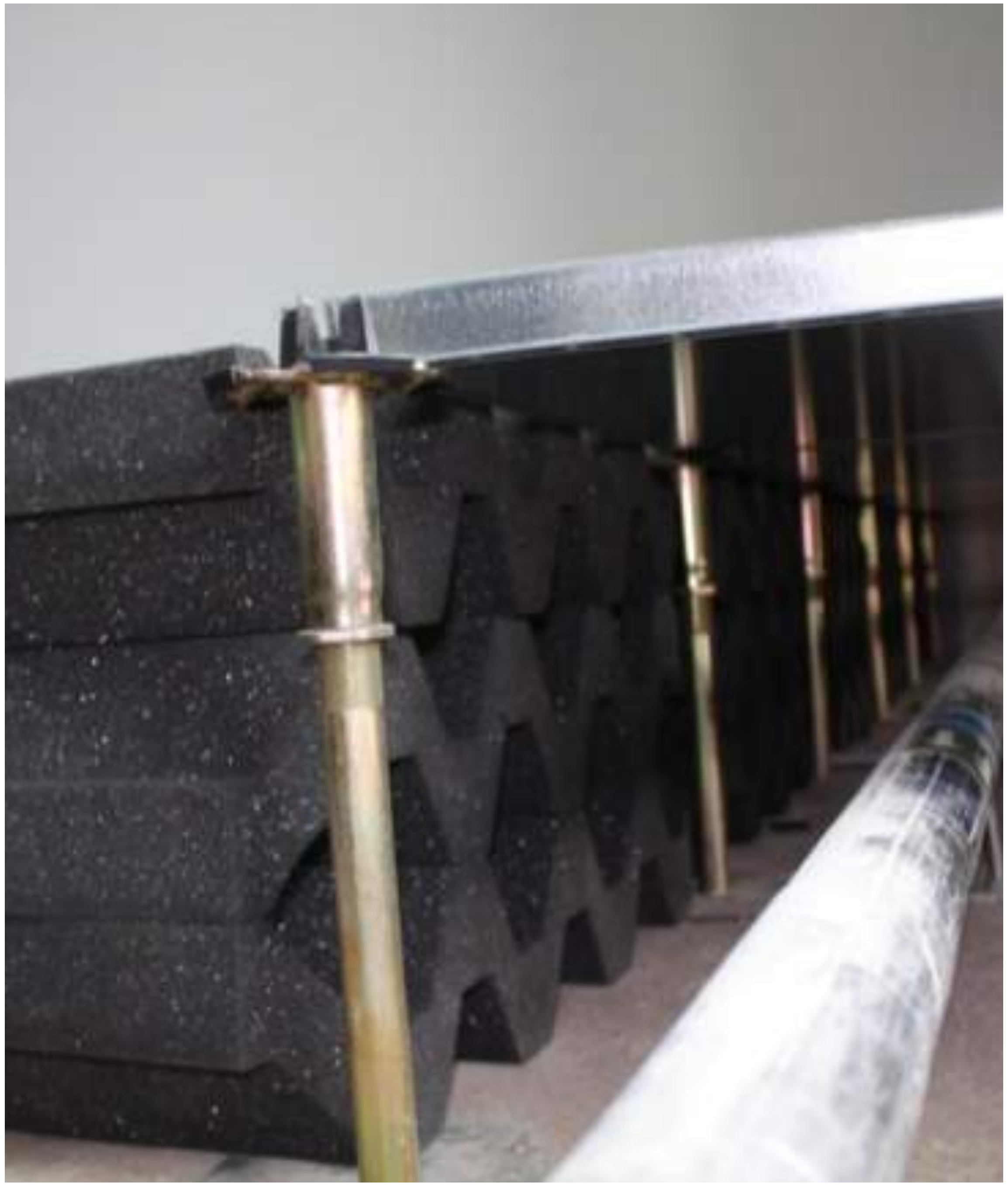

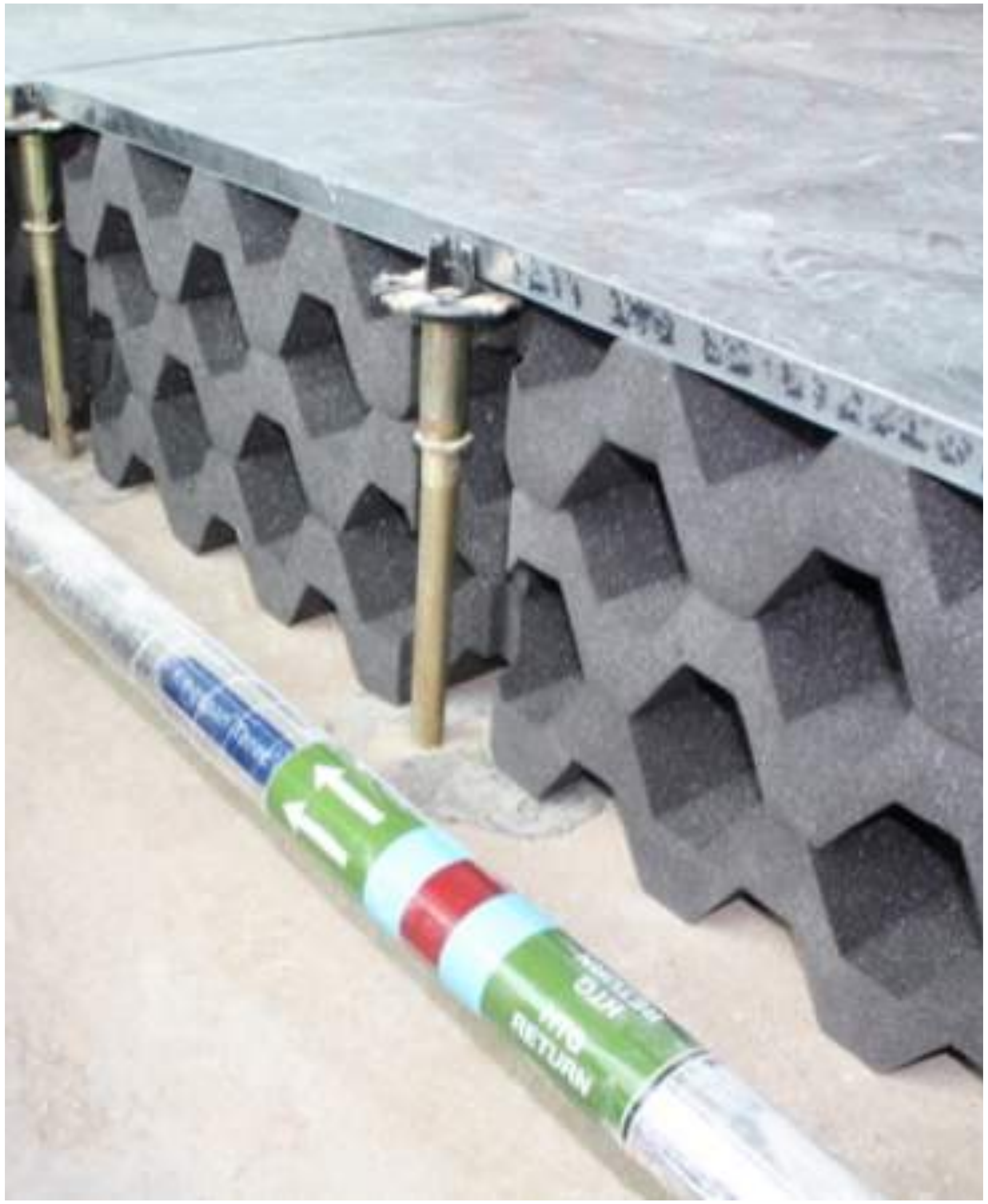

IMAGES

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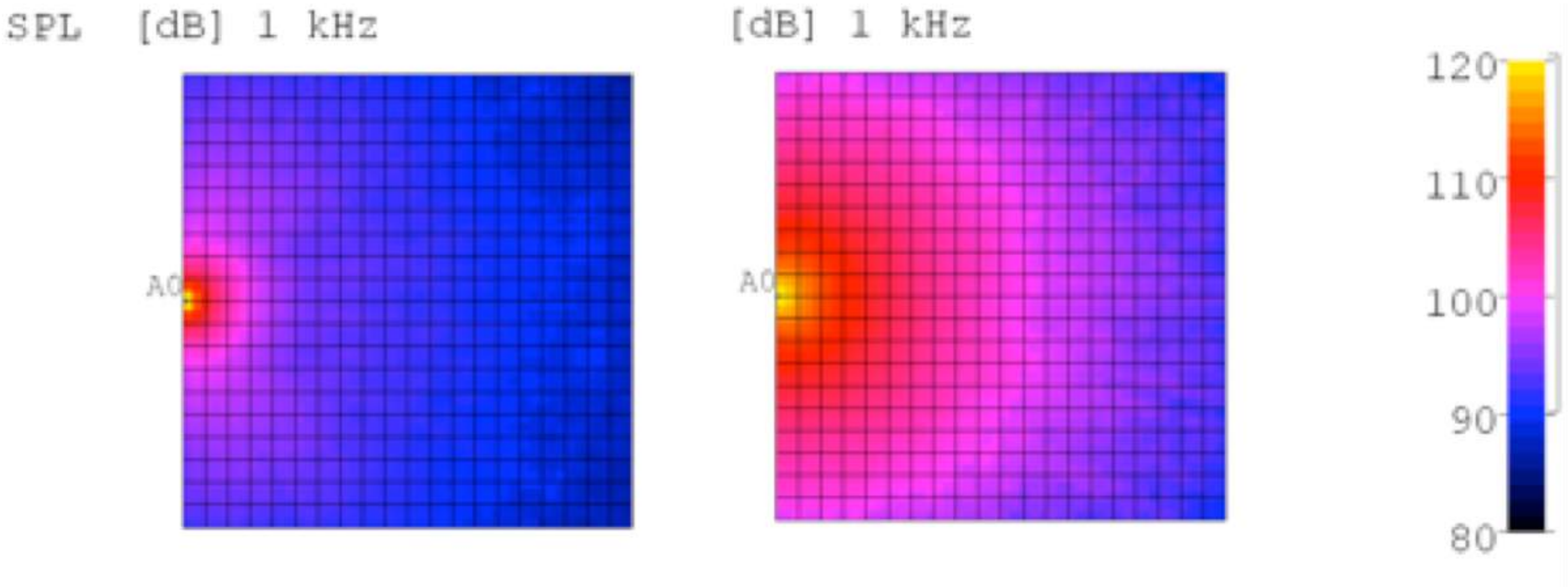

MACH ACOUSTICS

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MACH
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Presented By Ze Nunes
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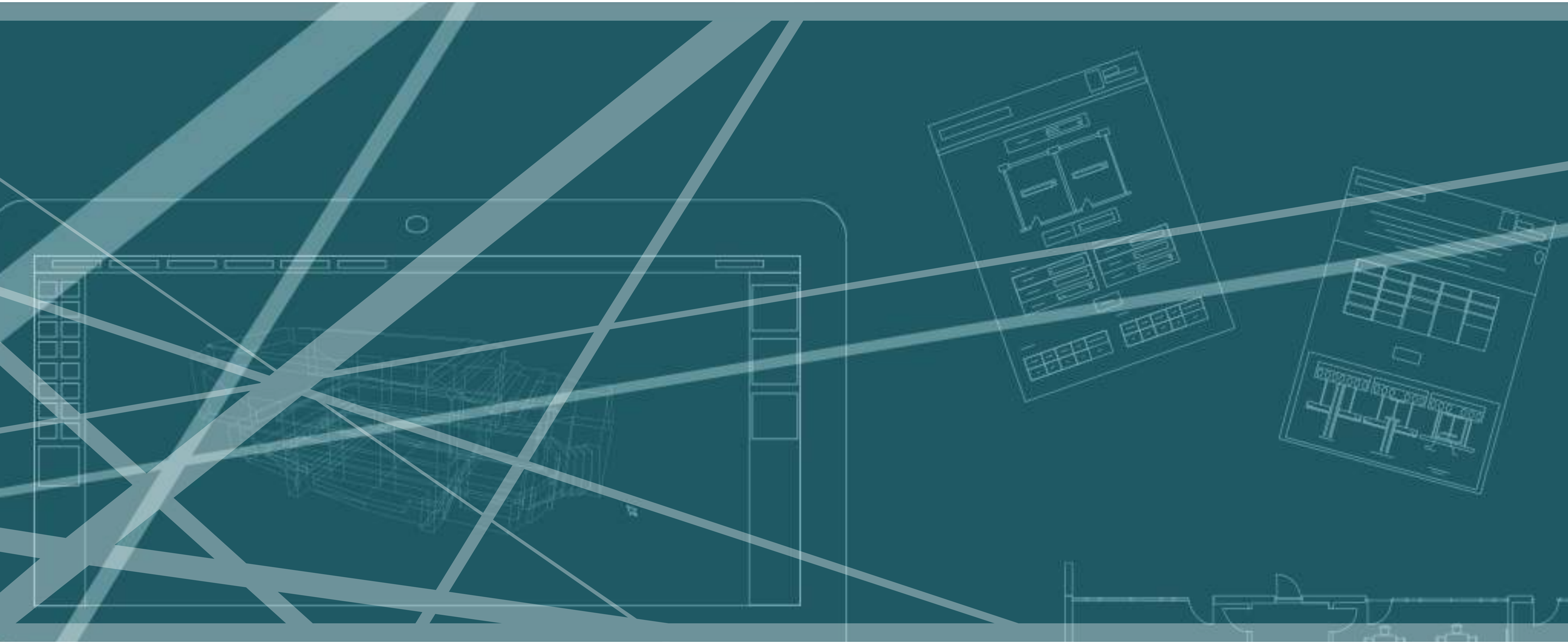
Lecturer At the University Of Bath



WEB BASED DESIGN TOOLS

Our expertise at your fingerprints

www.machacoustics.com

WEB BASED DESIGN TOOLS - INTRODUCTION

At MACH we believe that by sharing information and lessons learned from our extensive research and development programme, more buildings will be built around informed design strategies, resulting in less resilience and lower costs.

Our standalone Web Based Design Tools place our expertise at your fingertips and offer an excellent way of investigating ideas and concepts at the early stages of building design.

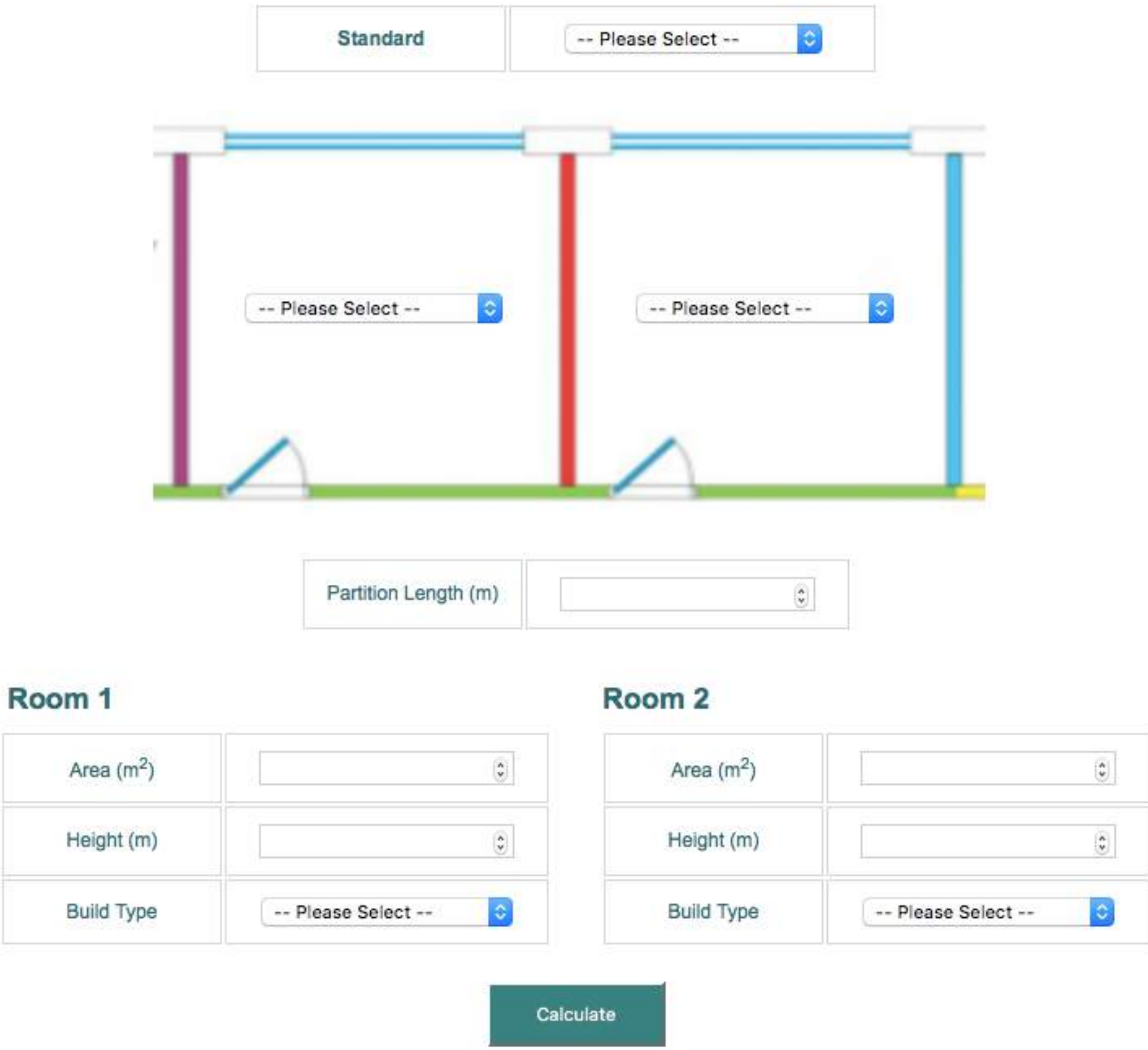
Our innovative range of tools are aimed at architects, contractors and designers

PERFORMANCE SPECIFIER

As a starting point this tool specifies the background noise levels, required sound insulation levels (both on site and laboratory levels) and the reverberation times for all spaces held in the standards below.

- BB93 - Schools
- BREEAM - Offices, Schools etc.
- HTM - Healthcare
- Part E
- BS 8233

Having established appropriate performance standards for a space, this tool can be used to pass the selected standards to a second tier Web Based Design Tool, where these tools can be used to determine construction methods to meet the specified standards.

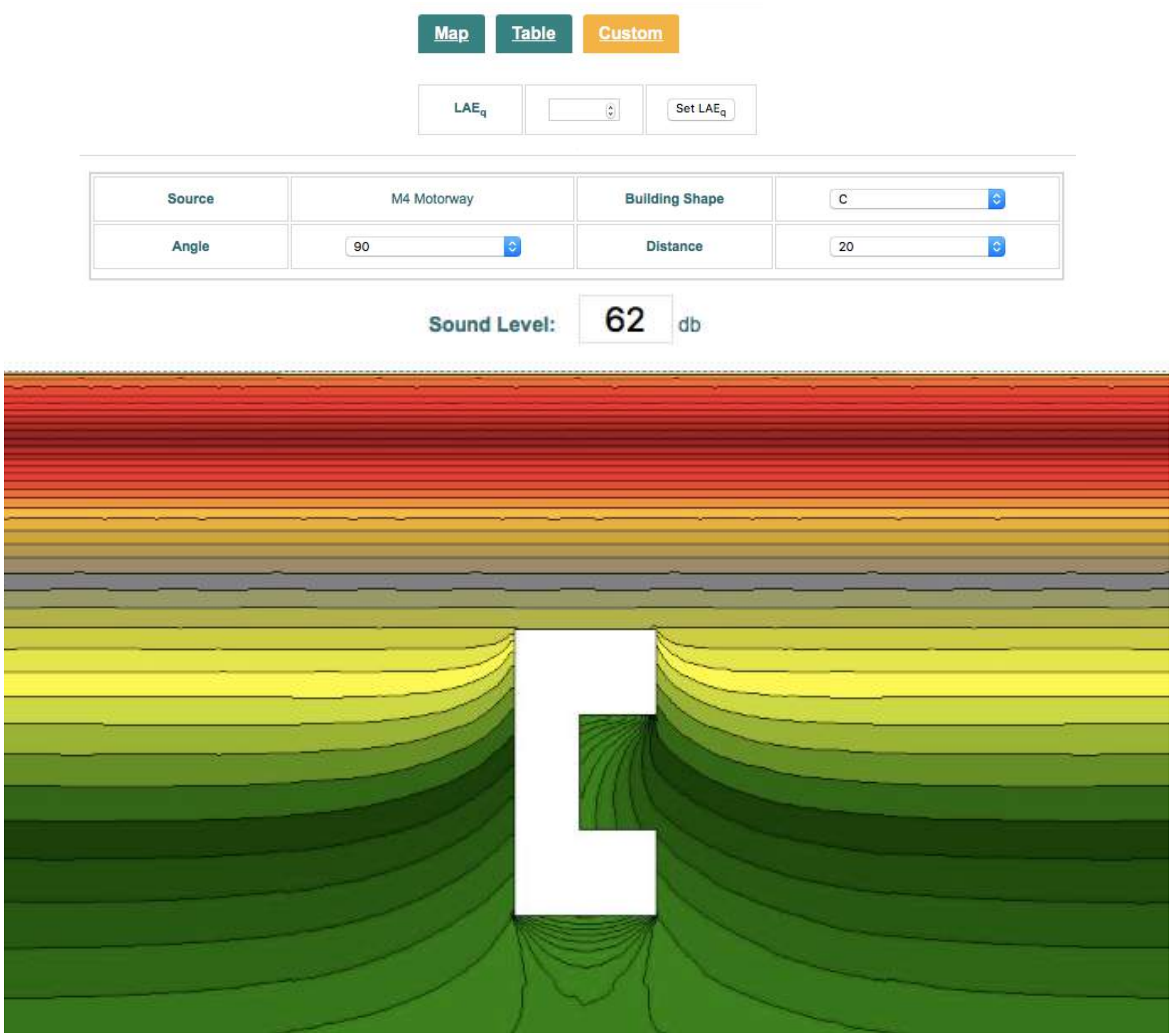


NOISE MAPPING TOOL

Having established the background noise requirement for a given space, it is useful to determine noise levels at the façade of a building, such to determine the required sound reduction.

It is often the case that simple openable windows can be used to ventilate spaces on the far side of a building, since the building itself can be used to provide a good acoustic buffer. Noise levels at the façade of a building are dependent upon the building position and orientation - so, an essential consideration at early design stages.

This tool presents the benefits of building shape, location and orientation to a wide range of noise sources.

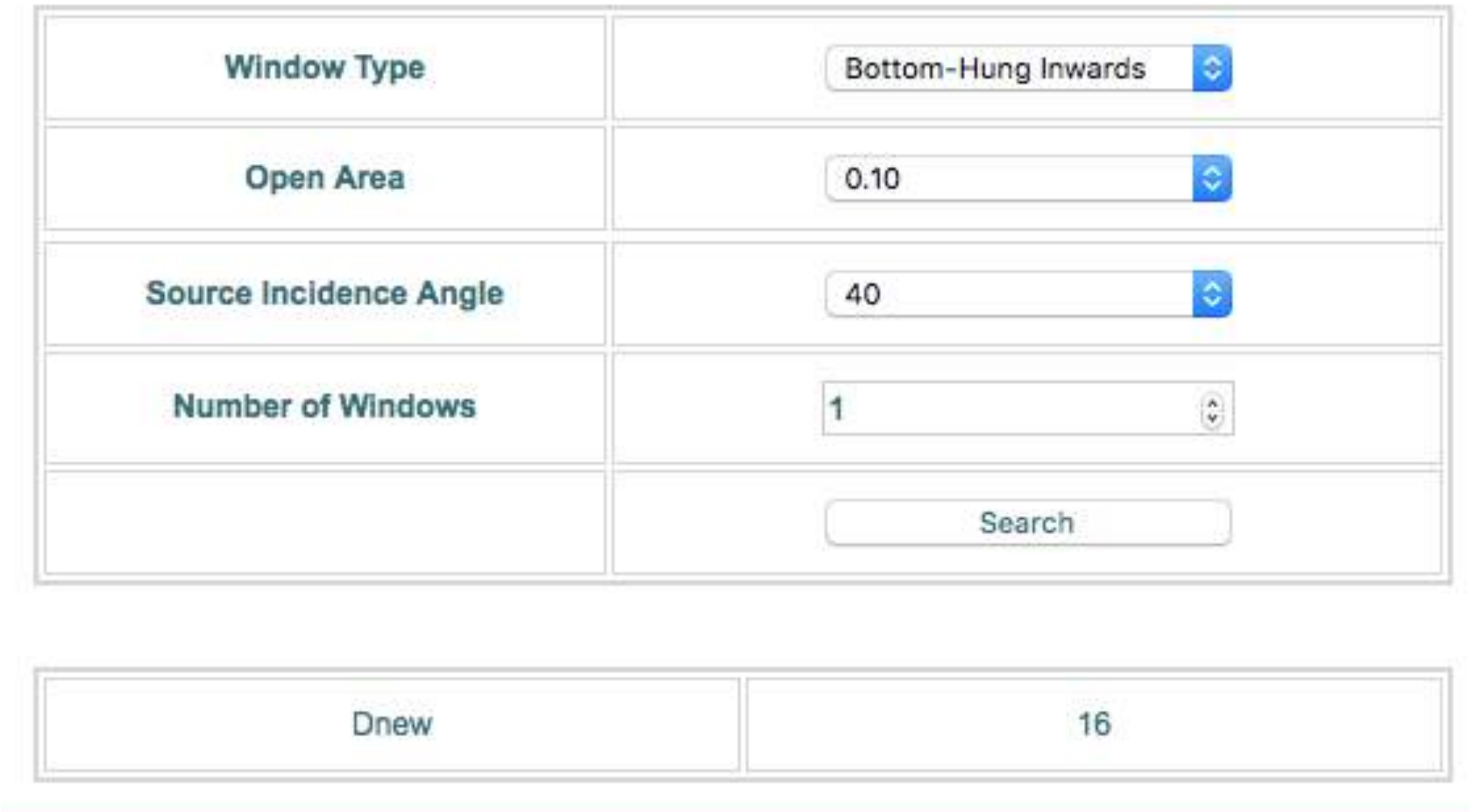


OPEN WINDOWS

MACH Acoustics Noise Mapping Tool & Performance Specifier allow the sound reduction of a façade to be established. When naturally ventilating a building, the key factor affecting the performance of the façade, is the open window.

This tool therefore aims to help select window types to maximize the chances of using natural ventilation.

Since the 1970's, the acoustic performance of windows has been stated to be 10 - 15 dB, however Napier University has shown that the tested sound reduction of conventional windows lies between 13 - 26 dB, depending upon opening area, the angle of sound to the window and the window type. This tool has therefore been provided such to offer designers easy access to this test data.



WINDOW/ATTENUATED FACADE SELECTOR

One of the main difficulties in designing low energy buildings can be the prevention of noise break-in via vented facades.

Thus tool should be used in conjunction with our Noise Mapping Tool - allowing users to estimate noise levels at the building envelope, based upon it's shape, position and orientation to a noise source.

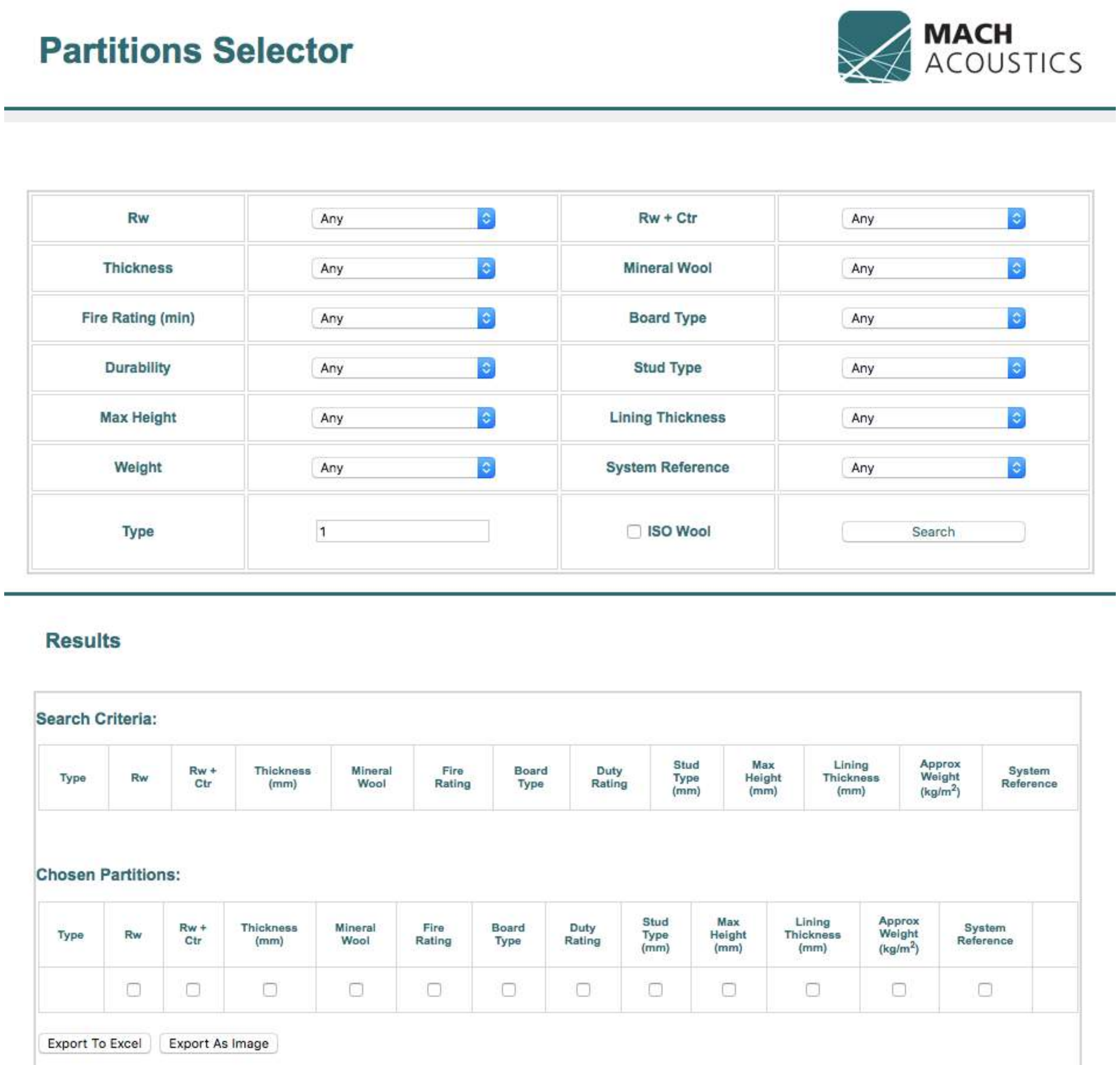
This tool takes Napier's work one step further, allowing users to investigate the outcome of MACH's research into vented facades.

Please read our book - The Future Of Windows for further information, available free to download from iTunes.

SEPARATING WALL - PARTITION SELECTOR

Whilst MACH's Performance Specifier Tool determines the on-site DnTw and laboratory Rw sound insulation requirements for walls and floors in a range of different building types, the Partition Selector holds a full specification for almost all British Gypsum, Siniat and Knauf partitions.

It also considers the purpose, appropriate and cost effective acoustic detail between the wall and other separating elements.



SOUND INSULATION OF COMPOSITE STRUCTURES

Having access to a sound insulation database provides clients with useful insight into the sound insulation of complex and composite structures.

This tool allows users to determine the sound reduction of over 250 materials and composite structures including glazing, block lined with plasterboard, stud walls incorporating plywood, floor build ups and so on.

MACH is constantly updating this database. We are happy to receive email requests for specific construction projects. This information will be added to the database as well as sent back to you by return.

Please email chris@machacoustics.com for this consultancy service. There is typically no charge for this.

Marshall Day Acoustics, INSUL (v7.0) [Computer Software]. www.insul.co.nz

RESIDENTIAL DESIGN TOOL

The fundamental construction type chosen for a project has a huge impact on the acoustic performance and the ease with which the acoustic performance can be increased.

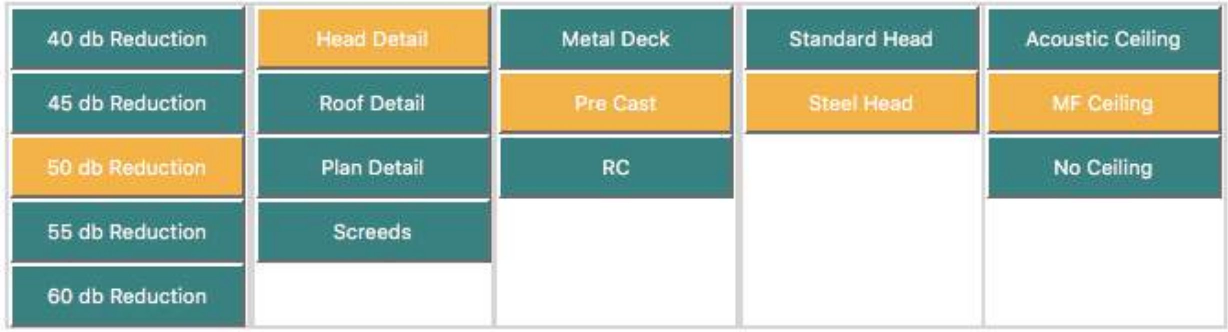
This residential design tool has been created to provide our clients with key pieces of acoustic design information to aid the decision making process when reviewing various construction options. By making better choices at an early design stage, or at tender stage, significant re-design can be avoided which not only saves money but also reduces risk. Once a construction type is selected, this tool allows you to switch between the various on-site performance targets and even provides a simple graphical animation of the changes to the construction detail as you move through the options.

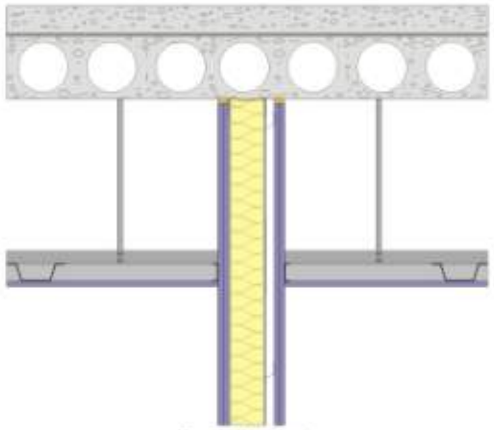
CONSTRUCTION DETAILS

The construction detail finder is an innovative online building design tool for architects and building contractors to eliminate unwanted noise and structural sound between classrooms, office spaces and residential dwellings.

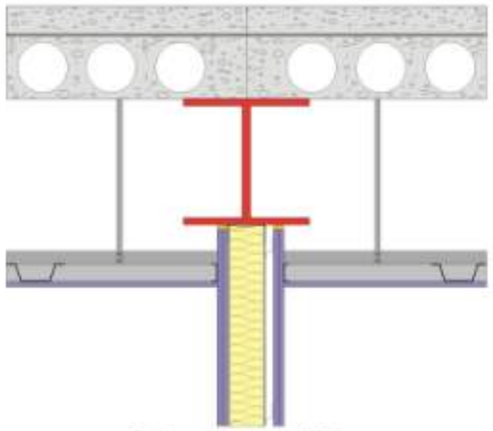
The simple to use navigation system allows the user to select the approximate level of sound reduction required, and then the type of detail needed - head detail, base detail, plan details etc...

The buildings frame, soffit, and/or ceiling type are then selected to find the most appropriated and cost-effective acoustics detail between wall and other separating elements.

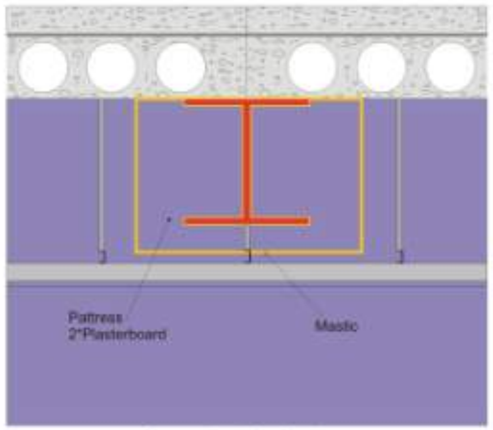




Standard Head Detail



Partition to the Underside of Steel

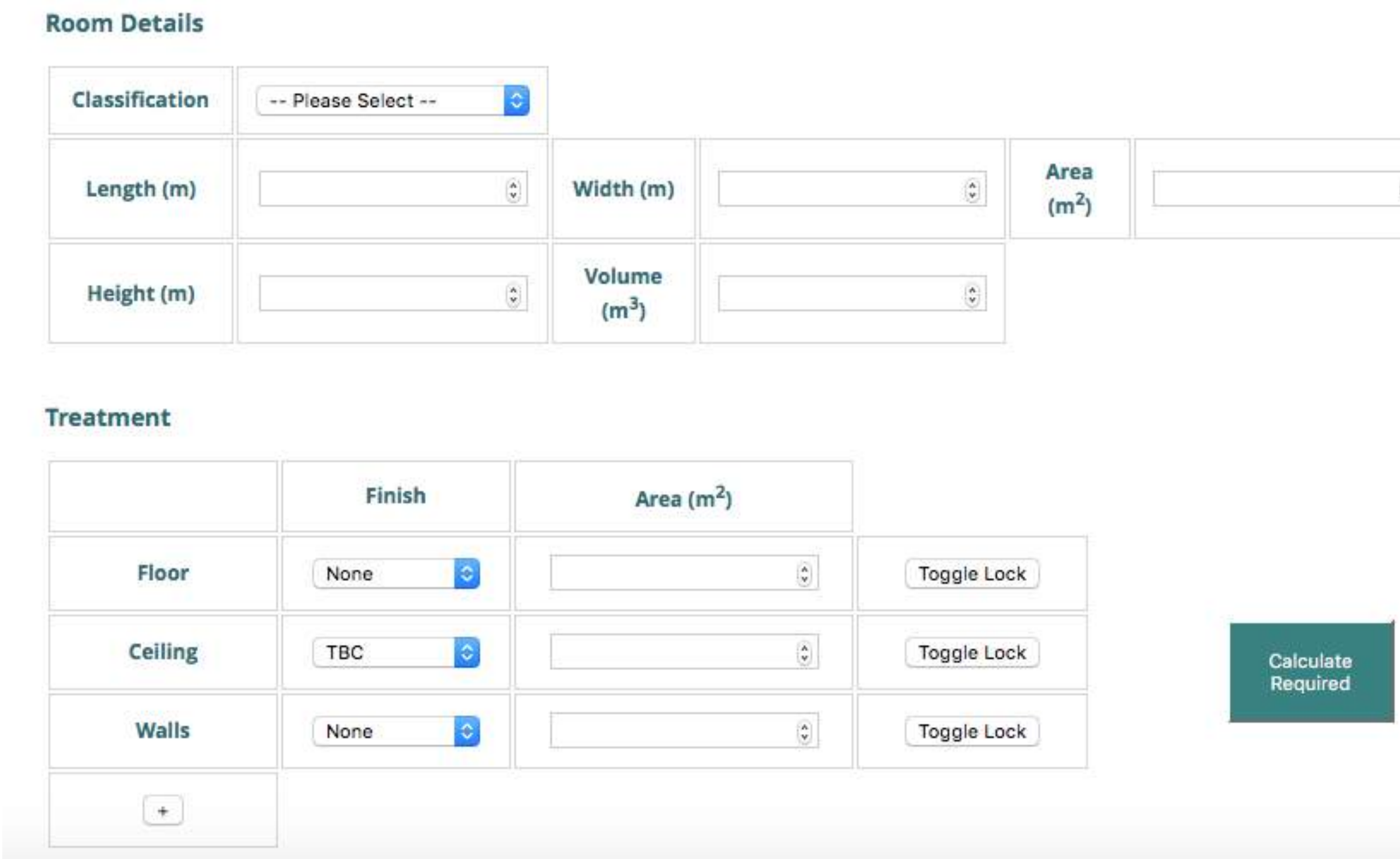


Pattress Around Steel Passing
Through partition

ROOM ACOUSTIC CALCULATOR

Room acoustics affect the way a space sounds. A high reverberation time can make a room sound loud and noisy, with speech sounding muddy and unintelligible. Hence rooms designed for speech typically have a low reverberation time: ≤1 second, whilst music halls tend to have a higher reverberation time such that the room adds depth and warmth to the music.

This Web Based Design Tool calculates the required levels of acoustic treatment needed to achieve a specific reverberation time, where this specific reverberation time can be obtained from the Performance Specifier tool. The logical, intuitive calculation process allows users to identify quantities of ceiling tiles, wall panels and other acoustics treatment such as rafts and acoustic lights etc...



ROOM ACOUSTIC - TREATMENT FINDER

Room acoustic treatments can have a major impact upon the appearance and cost of a building.

This database tool works in a similar way to the Partition Selector, but here, a filtering process allows different room acoustic treatments to be identified, along with their specifications, manufacturers and indicative costs.

The key advantage of this tool, is that once materials have been selected, they can then be transferred across into the Room Acoustic Calculator to identify the effects of these treatments on the reverberation time of a given space.

Performance	Class A	Class B	Class C	Class D		
Location	Suspended	Wall	Ceiling	Furniture		
Type	Surface Finish	Panel/Tile	Rafts	Baffles	Furniture	Lights
Material	Timber	Glasswool	Plaster(board)	Fabric	Metal	Sustainable

Spectral
http://www.spectral-lighting.co.uk/blade/inde

Add to Calc

Custom Audio Design
http://www.customaudiodesigns.co.uk/prosonic-nimbus-frame

Add to Calc

MACH ACOUSTICS - WEB BASED DESIGN TOOLS

Whole Building Design - Revit Tools

Providing our clients with information at their fingertips, and being able to respond quickly to design questions, is a long term goal here at MACH Acoustics.

Our Web Based Design Tools enable architects and contractors to change design proposals as a project progresses, and have become invaluable to many of our clients.

By bringing all of our tools under one umbrella, we hope to allow designers to assess the implications of change to the whole building, or just one part of it, whatever the requirements may be. We can now combine the Web Based Design Tools with our unique database, allowing each and every part of the project to be reviewed and investigated together.

The approach we are taking is similar to a cloud based Revit model, with the data manipulated in a tabulated format, where different elements and design tools can be called upon to allow for key parts of the building to be revised and assessed by different members of the design team in real time.

There is however the obvious question as to who takes responsibility for design changes. MACH does. We prepare the unique project spreadsheet based upon our understanding of the building performance requirements and design intent. All the acoustic elements are designed within this spreadsheet, providing a live interactive tool, allowing users to assess their own concepts.

We would value the opportunity to come in and talk to you about our consultancy services.

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