# Just the facts
## acoustics

A technical briefing document about carpet tiles and acoustical performance.

Acoustics are an important consideration when designing any space. Those responsible for designing indoor spaces – from offices and classrooms to cinemas – have the challenge of creating attractive, functional and comfortable rooms that enable clear communication and reduce unwanted noise.

The choice of materials for floor, ceiling and wall coverings are all important factors in the acoustics of a room. These can all help to achieve the desired acoustic qualities depending on the size, building type and, most importantly, how the space will be used.

Architects, interior designers, engineers and municipal authorities face a multitude of claims – often confusing or contradictory – about the acoustic credentials of different materials, making it difficult to find out 'Just the facts' about how they can create the desired acoustic environment.

Just the facts...

# Contents

# **Sound design** principles

An integrated design approach is essential to achieving good acoustics – whether for an auditorium or a private office.

The choice of material inside a building can make a significant difference to the acoustic environment, but designers must take into consideration other factors such as site selection, facade, glazing and planning of the room layout so that quiet spaces are oriented away from outside noise sources such as a busy road.

This booklet aims to provide a simple and clear guide to the science behind acoustics and what acoustics mean for the people using indoor spaces as well as offering a straightforward explanation of the tests and technical language used to describe acoustic qualities of building materials and carpet tile in particular.

## The basics of building Acoustics

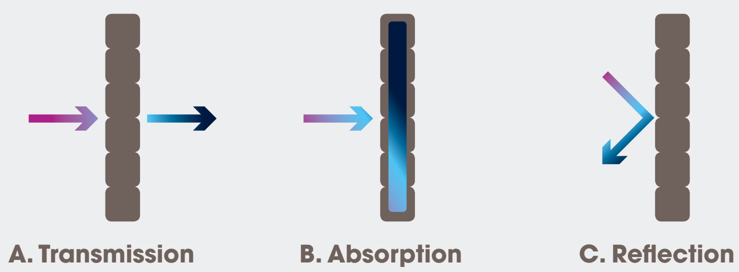
When sound reaches a surface, there are several possible outcomes that can occur individually or simultaneously.

A. The sound passes through the surface into the space beyond.

B. The surface absorbs the sound.

C. The sound strikes the surface and changes direction

## Sound / Surface Interaction

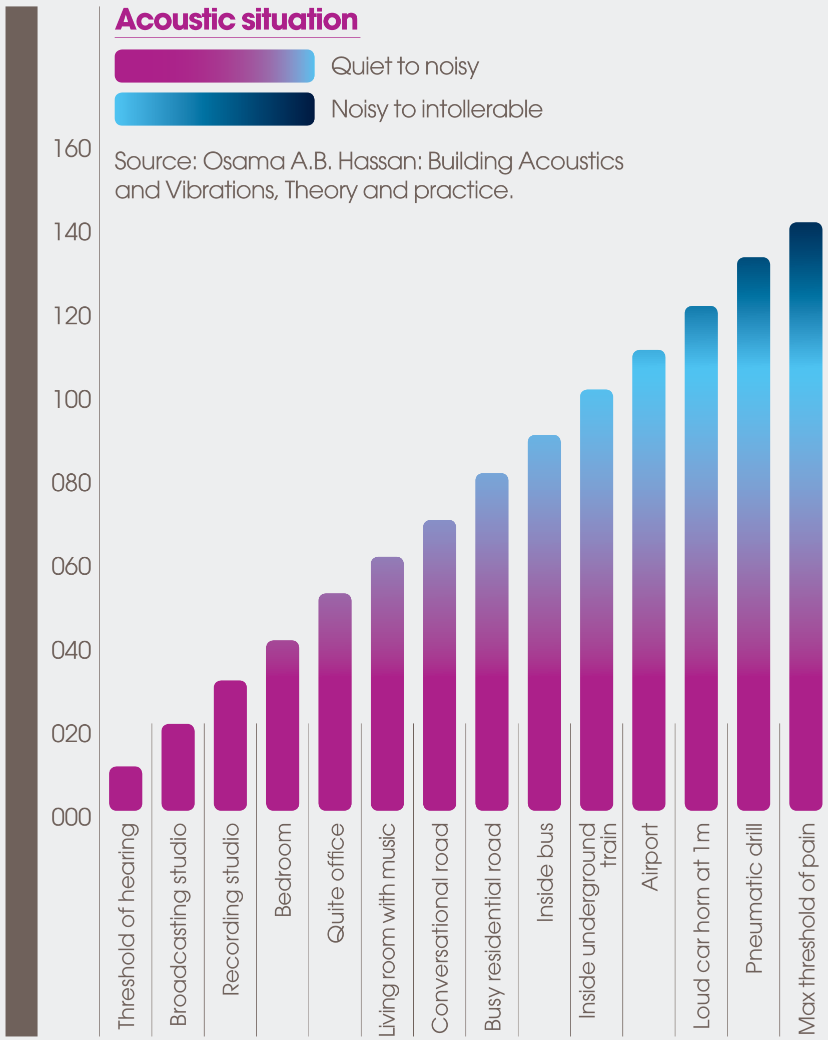



# **Why are buildings acoustics** important?

The word ‘acoustics’ is borrowed from the Greek “akouein” which means “to hear” and is now used to describe the scientific study of sound and vibration and its behaviour in various media and environments.

Unwanted sound that is annoying or interferes with listening is described as noise. Excessive noise levels can affect concentration and become an obstacle to normal activity. At extreme levels, it can cause pain and loss of hearing.

Noise pollution is often connected with industrial environments, vehicles or construction sites, but noise does not need to be excessively loud to cause problems in the workplace. It can also be subjective and depend on the reactions of the individual.



# Why are building acoustics important?

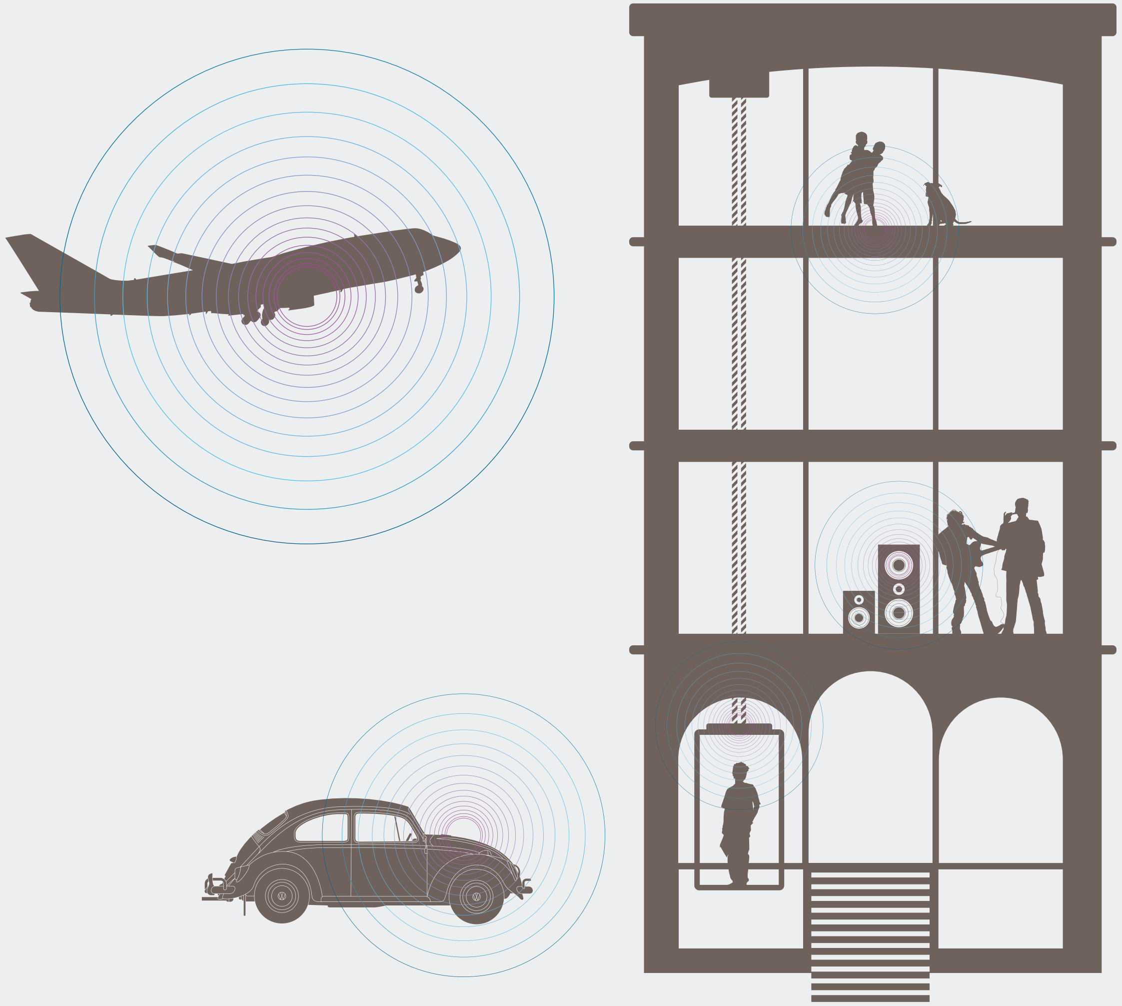
In office and learning environments noise can cause distractions and discomfort. Other factors such as lack of privacy and ability to control the noise can increase the problem.

A poor acoustic environment and unwanted noise in offices and schools can:

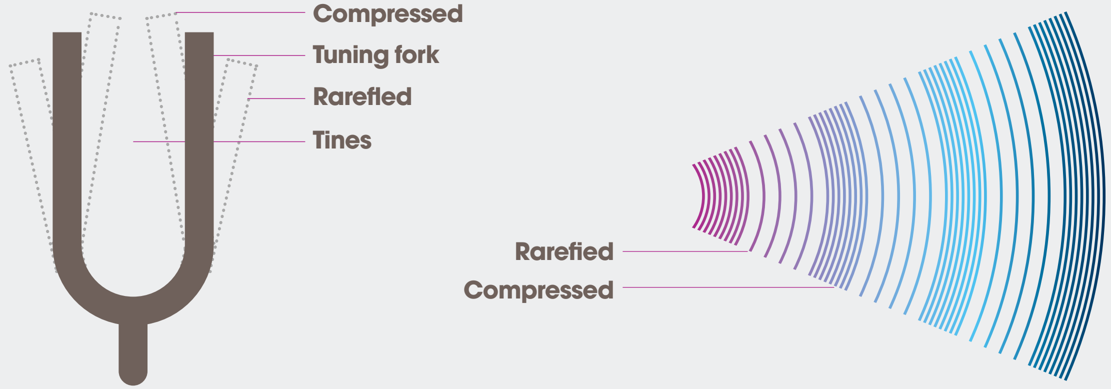
- Limit communication
- Reduce work performance and productivity
- Cause stress, frustration and potential physiological problems
- Affect attention, concentration and behaviour of students, impeding learning and academic achievement.

There are some differences in the acoustic requirements of offices, classrooms and conference rooms, but several common noise problems affecting all of these include:

- Too much noise entering the space from outside the building
- Too much noise coming from adjacent spaces
- Too much noise in the space itself.

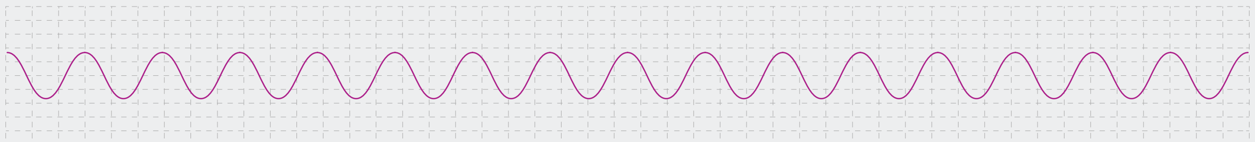


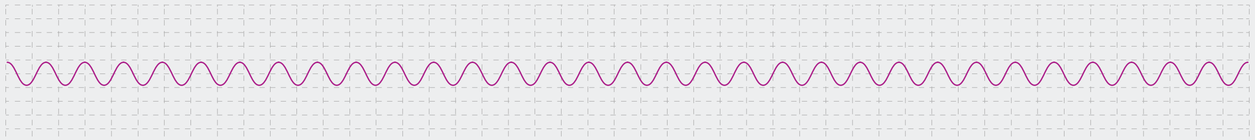
# The science of sound





**High frequency**


**Medium frequency**


**Low frequency**

**The desired acoustic environment varies according to the type of room and how people will use it. Here we outline a few fundamentals to understand human perception of sound and how building acoustics can affect this.**

**Sound travels in waves in all directions until it encounters an obstacle like walls or ceilings. For building acoustics two characteristics are of particular interest:**

### 1) Amplitude: How loud a sound is perceived to be

This is described by its amplitude in decibels (dB). Decibels follow a logarithmic scale so an increase of 10 dB corresponds to a perceived doubling of the sound's level and 20 dB to four times of the sound pressure level.

### 2) Frequency: The pitch of the sound

This is determined by the number of oscillations or cycles in a given time. Frequency is usually expressed in units of Hertz (Hz) where one Hz is equal to one cycle per second. This is split into octave bands covering a range of low, medium or high noise.

# Human perception of sound: frequency, reverberation and intelligibility of speech

Most everyday sounds are complex and a mix of different frequencies. The human ear is more sensitive to medium and high frequency noise (see illustration on next page). This sensitivity means that human beings are more aware of higher pitch sounds (within normal hearing range).

As a result, when two different sounds are equally loud (with the same dB intensity), the lower frequencies are less intelligible than the higher ones. The frequency of sounds must be taken into consideration to design an indoor space appropriate to its use. The acoustic requirements for an open office or a classroom are very different to those for a concert hall. This is particularly important when consideringcovering materials for floors, walls and ceilings, as the reaction of different materials will depend on a sound's frequency.

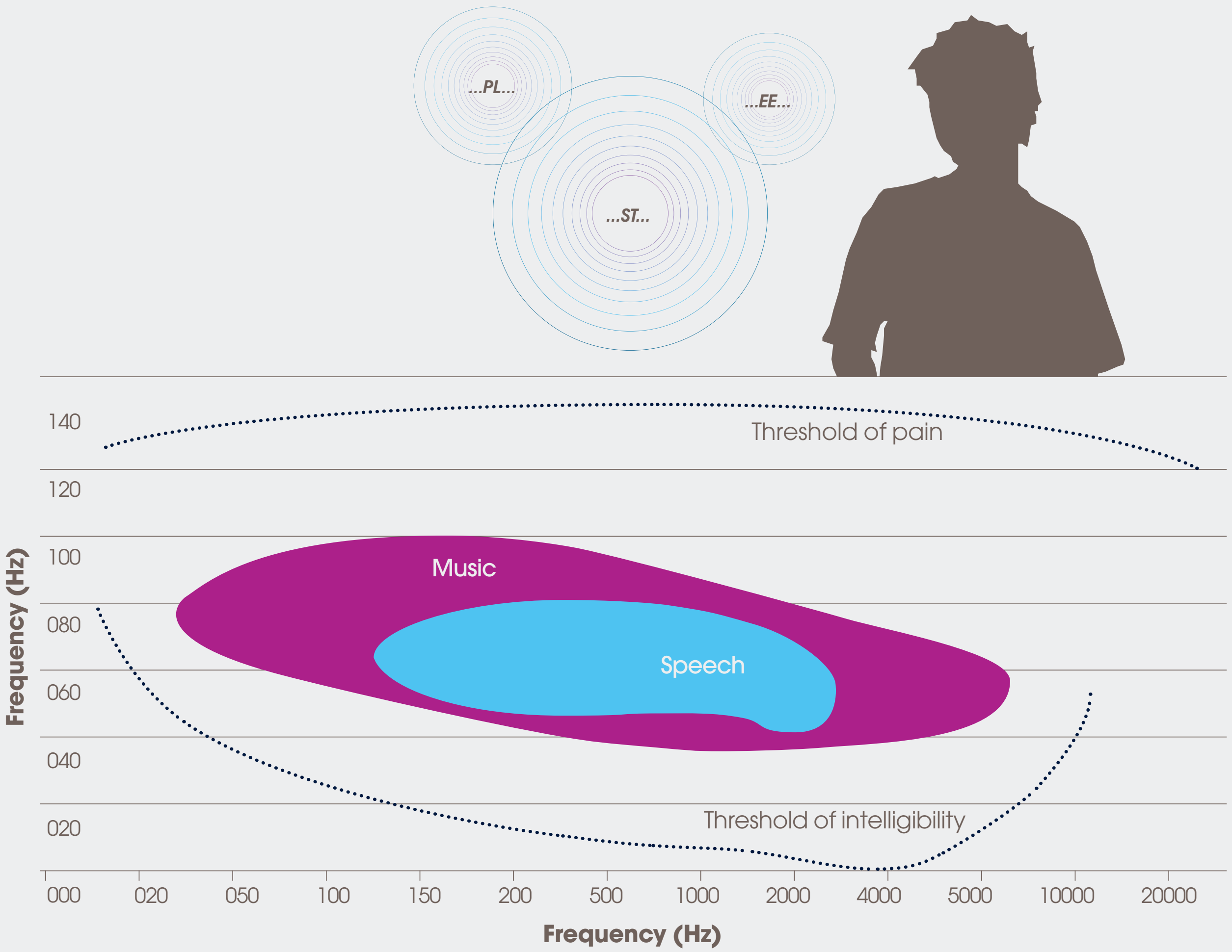
Reverberation – the persistence of a sound after its source has stopped – is another important consideration in acoustics due to its significant impact on speech intelligibility. This refers to the accuracy with which a person with normal hearing can understand a spoken word or phrase, and the ability of the listener to hear and correctly interpret verbal messages.

For example, in a classroom with high ceilings and hard parallel surfaces such as glass and tile, speech intelligibility is a particular problem. Sound bounces off walls, ceilings and floors, distorting the teacher's instructions and interfering with students' ability to understand what they are saying.

However, some indoor spaces demand other requirements to be taken into consideration. For example, in a restaurant, customers do not want to have to shout over each other to be heard by their fellow diners and in a call centre or open plan office, staff do not want to be distracted by hearing the details of other conversations going on in the room.

Choice of building materials, soft furnishings and coverings can help people hear speech that they need to hear and cut out what they do not.

# Human perception of sound: frequency, reverberation and intelligibility of speech




Source: www.trikustik.at

The diagram on this page provides a visual illustration of human interpretation of sound, showing the scope of what humans are able to hear. Understanding which sounds humans can hear – and which of these sounds they want to hear – enables designers to select the best materials to reduce unwanted noise.

Most vowel sounds are between 200 and 600 Hz. Only a few are high frequency between 2,000 and 5,000 Hz. Consonants, such as hissing sounds and explosives (p, t, k/b, d, g), are mainly located in the high frequency range. For instance, a “sh” sound is between 1,600 and 8,000 Hz and a “tz” sound is around 5,000. Think of a microphone check: “One, two, three” which covers the full range of frequencies.

People with normal hearing will recognize hissing sounds and explosives even if they are said relatively quietly (at a low dB level). This means designers must use materials that will absorb these higher frequency sounds to reduce unwanted speech background noise while taking into consideration the requirements of the building.

At 500 Hz, human speech is at its loudest (around 75 dB). However, this frequency is less important for noise reduction in an open office space if the challenge is to reduce speech intelligibility to avoid disturbance between individual workplaces.

If the same dB level is applied across the full frequency range (see diagram y), the lower frequencies are already less understandable than the higher ones and focus should be on the frequency ranges between 1000 and 4000 Hz which would have to be absorbed more intensively.

This also means that a reduction of noise in this lower frequency range (below 1,000 Hz) maybe counter-productive because the intelligibility of speech in the higher frequencies increases if low frequency background noise is reduced.

Additional sound masking may therefore be considered to prevent lower frequencies being absorbed too much by carpets, for example, which absorb most sound in this 500 Hz frequency range.

# **Key issues when choosing materials:** Absorption and impact noise

In deciding which flooring, wall or ceiling materials will help fulfil your acoustic needs there are two main considerations. These are sound absorption which relates to the transmission of airborne sound within a room; and impact noise which is related to the control of sound from one space to another. Of the two, sound absorption is the most important to facilitating a good acoustic environment in most modern buildings as it is a measure to assess the acoustic environment within a room.

Impact noise is mostly relevant when you want to assess the sound that is transmitted from an adjacent room. Generally the structure of a building and the insulation of walls including partitions, play a very critical role to reduce disturbance and prevent sound from being overheard outside the room in the case of privacy. This could be important for example when assessing unwanted noise of footsteps from a corridor, e.g. in a hotel or in a school, which shouldn't disturb guests in a bedroom or students in a classroom.

## Absorption:

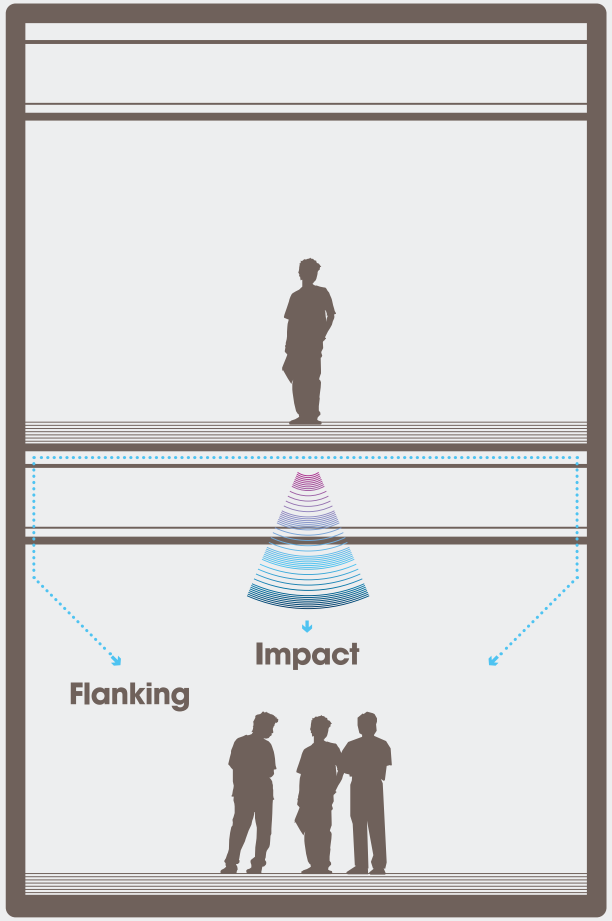
A sound remains present in a room after it is made because it is reflected off of surfaces such as desks or chairs. The reverberation time of a room is the time it takes for sound to decay by 60dB once the source of sound has stopped. If sound is effectively absorbed, reverberation time is reduced.

## Impact noise:

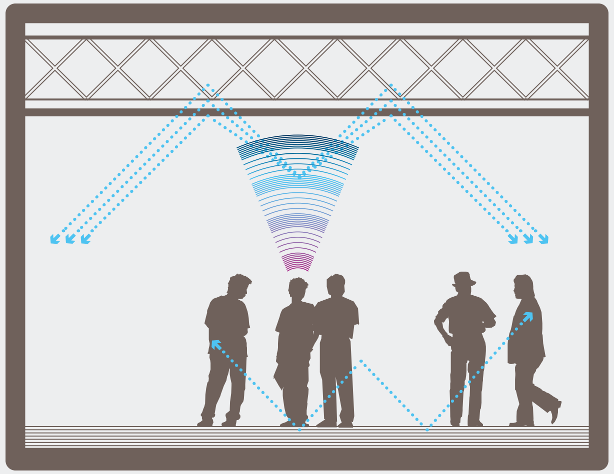
Impacts on a surface from, for example, footsteps, chairs being moved or objects being dropped create vibrations within the surface which become sound waves when transmitted to the air. Impact noise is mainly transmitted through the floor but it can also reverberate through the walls.

Placing sound impact reducing materials in the room can dramatically reduce the intensity of sound from both impact noise and background noise from office equipment, telephones or conversation.

## Impact sound transmission




## Airborne sound transmission



# Open plan offices: The challenge

**Open plan offices have become widely popular because they are cost effective and flexible. Many organisations also find they can improve cooperation and communication within and between different teams. However, noise levels and lack of privacy can create concerns for people working in open plan offices.**

In an open plan office, sound is transmitted directly and reflected off the ceiling. Factors that contribute to unacceptable noise levels include heating, ventilation and air-conditioning systems, low partition heights, ringing phones, noisy copy machines and office chatter.

The use of absorbing ceiling and floor covering materials is essential to reduce unwanted noise. Carpet plays an important role in reducing sound reverberation, because it absorbs up to 10 times more airborne noise than any other flooring material. This can considerably enhance the feeling of wellbeing.

# **Classrooms:** The challenge

A student's ability to hear and understand what is being said in the classroom is vital for learning. If sound lingers in a room, there is more interference with speech. A long reverberation time creates poor acoustics that affect understanding and learning. This makes it important to reduce reverberation of sound in a classroom. Recognition of numbers, letters and simple words significantly improves with better acoustics.

**A study has shown that in a "relatively good classroom listening environment", children with normal hearing correctly recognized 71% of the spoken message. This dropped to less than 30% in a "poor, but commonly reported classroom environment".**

C. Crandell and J. Smaldino. 2000

Carpet is the most efficient and effective floor covering for acoustic modification for absorbing excessive reverberation of high-frequency consonant sounds and dampening noise from students and movement of classroom furniture. It can contribute to an overall reduction in the amount of noise and reverberation.

# Choosing **sound absorbing materials**

The efficiency of a sound absorbing material can be expressed by its sound absorption coefficient at different frequencies or as a 'Weighted Sound Absorption Coefficient' ($\alpha_w$). Values range from 0 where all sound is reflected to 1 expressing full absorption.

Carpet is a very efficient sound absorber compared to all other flooring materials. Other materials such as furniture with sound absorbing surfaces, partitions, upholstery, curtains and drapes also contribute to acoustics as the coefficients of all the different materials in a room combine to increase the overall sound absorption.

**To achieve the best overall result the sound absorbing materials should be used on all surfaces; walls, ceilings and floors.**

## Absorption Coefficient data for common materials in buildings

| Material | Sound absorption coefficient, a in octave frequency bands (Hz) | | | | |
|---|---|---|---|---|---|
| | 250 | 500 | 1000 | 2000 | 4000 |
| Fair-faced concrete or plastered masony | 0.01 | 0.01 | 0.02 | 0.02 | 0.03 |
| Fair-faced brick | 0.02 | 0.03 | 0.04 | 0.05 | 0.07 |
| Painted concrete block | 0.05 | 0.06 | 0.07 | 0.09 | 0.08 |
| Windows, glass fascade | 0.08 | 0.05 | 0.04 | 0.03 | 0.02 |
| Doors (timber) | 0.10 | 0.08 | 0.08 | 0.08 | 0.08 |
| Glazed tile / marble | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 |
| Hard floor coverings (e.g lino, parquet) on concrete floor | 0.03 | 0.04 | 0.05 | 0.05 | 0.06 |
| Soft floor coverings (e.g. carpet) on concrete floor | 0.03 | 0.06 | 0.15 | 0.30 | 0.40 |
| Suspended plaster or plasterboard ceiling (with large airspace behind) | 0.15 | 0.10 | 0.05 | 0.05 | 0.05 |

Source: UK Building Regulations Approved Document E Resistance to the passage of sound, 2002 version

# **Measuring the sound** absorption **of materials**

The sound absorption properties of objects such as a carpeted floor, chairs or padded screens are quantified by the equivalent sound absorption area (EAA). This is the area of a perfectly absorbing surface which would absorb the same amount of incident sound as the real object. The EEA of an absorbent covering is given by the Sabine formula:

$$EAA = S \times \alpha_w$$

where S is the surface area of the absorbent covering, and aw is its absorption coefficient.

There are no firm rules for open offices but according to various Green Building Schemes it is recommended to have an EEA ≥ 0.6 in open offices.

### Calculation example

**What are the EAA calculation parameters?**

$$A = S_{treated} \times \alpha_w$$

Carpeted floor; no other absorbent treatment.

**What is the necessary absorption coefficient $\alpha$?**

**Answer: $\alpha_w \geq 0.60$αα**

No existing carpet can achieve this performance.

**Conclusion**

A carpet alone is not sufficient to reach the target. A carpet with $\alpha_w = 0.20$ provides one third of the required absorbent surface.

# **Measuring the sound** absorption **of floor coverings**

Two tests are commonly used within the flooring industry to measure sound absorption of floor coverings – the EN ISO 354 and the Noise Reduction Coefficient (NRC). At InterfaceFLOR, we use EN ISO 354 to measure the sound absorption levels of our floor covering because it follows internationally recognised standards

### EN ISO 354: Acoustics – measurement of sound absorption in a reverberation room

When sound hits a soft surface, such as a carpet, some of its energy is lost to the surface, absorbing the sound. In our tests, sound absorption is measured in a large reverberation room (see picture). Sound absorption coefficients are used to calculate the amount of sound energy lost to the surface.

A coefficient of 0.00 means no sound has been absorbed whereas a coefficient of 1.00 means all sound has been absorbed. This is a linear scale, so a value of 0.25 means that 25% of the sound is absorbed. Sound absorbing characteristics ofmaterials vary significantly with frequency. Low to mid frequency sounds are difficult to absorb because they have a long wavelength. However, humans are less sensitive to these frequencies (see page 7) making the absorption of mid to high frequency sounds more important in acoustics.

A single-number rating (a weighted sound absorption coefficient calculated in accordance with EN ISO 11654) is often quoted and denotes the sound absorber class. For carpets, the weighted sound absorption coefficient is generally less than 0.30 which makes them a Class E sound absorber. Typical values for cork, wood and concrete floors are between 0.00 to 0.10.

InterfaceFLOR products are typically 0.15 to 0.25, so they absorb more sound than a hard floor. Combined with ceiling and wall coverings and other soft furnishings, our carpet tiles can help to significantly reduce discomfort from airborne sound.

### Other non- EN/ISO standards – noise reduction coefficient, NRC

The NRC is an arithmetic average of sound absorption coefficients at frequencies of 250, 500, 1,000 and 2,000 Hz indicating a material's ability to absorb sound. The sound absorption coefficients at 125Hz and 4,000Hz are not used to calculate the NRC and so this is a single-number rating of sound absorption at mid-frequencies. Because NRC is an average of just four values, it is possible that two materials with the same NRC could actually have very different sound absorption performance characteristics. A broader frequency range should be considered to evaluate materials for rooms where music or speech perception is important.

### Absorption classes and ratings after EN ISO 11654

| Sound absorption class | Weighted sound absorption $\alpha_w$ | | | | | |
|---|---|---|---|---|---|---|
| A | 0,90 | 0,95 | 1,00 | | | |
| B | 0,80 | 0,85 | | | | |
| C | 0,60 | 0,65 | 0,70 | 0,75 | | |
| D | 0,30 | 0,35 | 0,40 | 0,45 | 0,50 | 0,55 |
| E | 0,15 | 0,20 | 0,25 | | | |
| Unclassified | 0,00 | 0,05 | 0,10 | | | |

# Measuring reductions in impact noise

### ISO 10140-3:2010 – Acoustics – Laboratory measurement of sound insulation of building elements – Part 3: Measurement of impact sound insulation

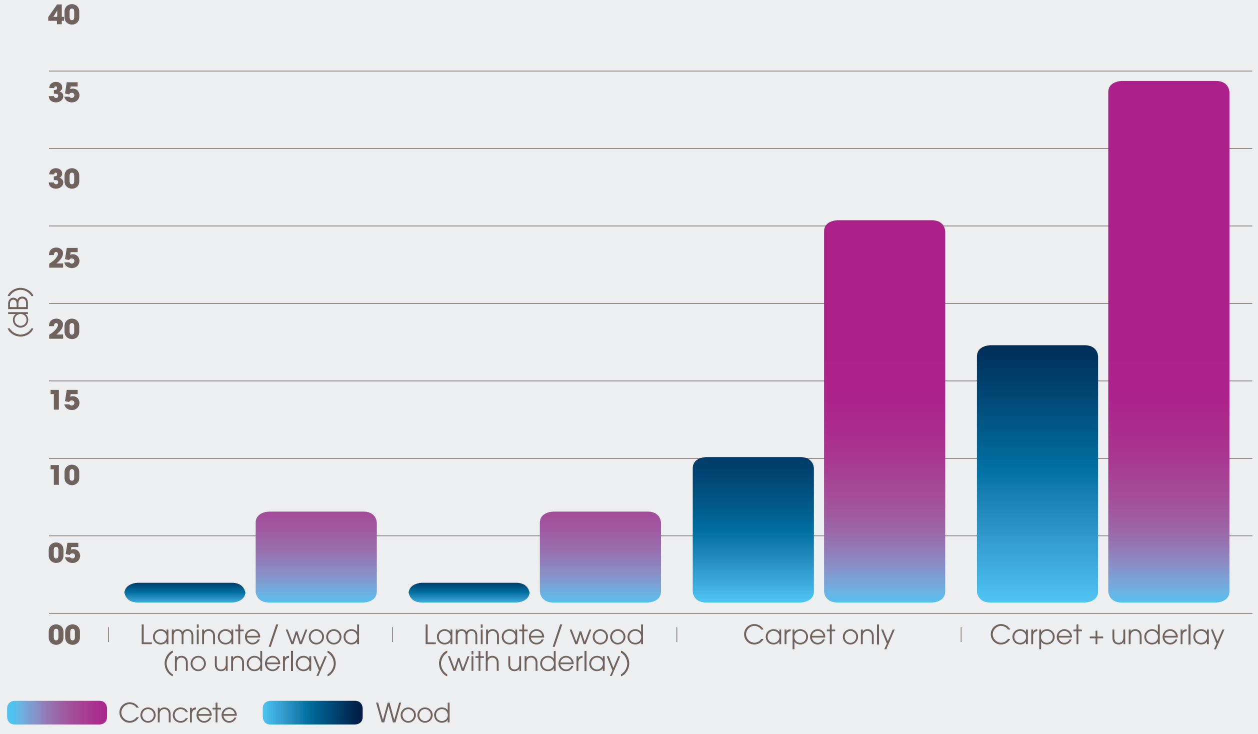
Impacts on a surface create vibrations within that surface which become sound waves when transmitted to the air. Measuring the effect of a surface such as carpet on reducing impact sound indicates how much less sound is transmitted into an adjoining room or the room below by, for example, footsteps or objects being dropped.

Reduction of transmitted impact noise is measured in a large reverberation room where a concrete floor slab is inserted into the roof and a tapping machine (see picture below) is used as the impact sound source. The values are given in decibels (dB) and show how much less sound is transmitted with the use of different flooring materials.

Soft flooring reduces impact noise much better than hard flooring. InterfaceFLOR carpet tiles reduce impact noise by between 12dB and 34dB compared with 1dB and 6dB for a hard floor.

**A good acoustic environment is always the result of many factors, but to effectively control noise from footsteps and other impacts, no flooring alternative is more effective than carpet.**

**level of impact noise improvement (dB) comparing laminate/wood and carpet on different base floors**



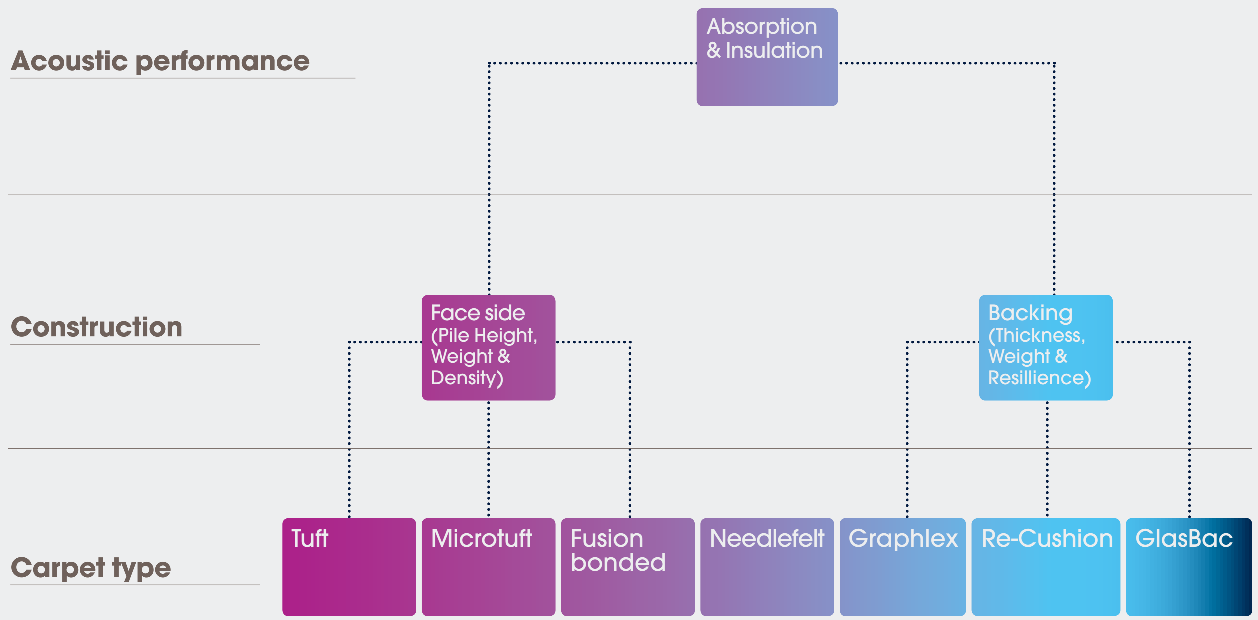
# Acoustic results **and InterfaceFLOR carpet tiles**

Choosing carpet is always a matter of several factors such as design, functionality, sustainability, price and service. At InterfaceFLOR we aim to not make any compromises on requirements that are important to our customers, and we know acoustics is one of the factors that will contribute to an overall good choice.

The overview opposite gives an indication of what influences the acoustic results of InterfaceFLOR carpet tiles. The acoustical performance will be a result of the desired carpet type and construction parameters. The performance will be influenced by the mass, thickness, resilience and density of the chosen materials.

In general with comparable constructions, an increase of these parameters will increase the acoustical performance.

Specific results for individual products can be found in our technical specifications.




**Floor covering standard symbols used (values given as examples):**

$\alpha_w 0.20$

Sound absorption according ISO 354: Weighted sound absorption aw is a single figure rating used to describe the performance of a material.

26dB

Sound insulation according ISO 10140-3 calculation according ISO 717-2: Impact sound improvement index $\Delta L_w$ expressed in dB.

# Choosing acoustic floor covering – summary and top 6 tips

### 1. Understanding the real nature of the problem

The acoustic situation for the end user will always vary from project to project. It is critical to know what are the problems that need solving to know how a floor covering can contribute. Does the user need to improve the intelligibility of speech – for instance in a meeting room or in class room? Or is there a need to suppress the intelligibility of speech to increase the feeling of privacy in an open office space?

### 2. Knowing the relevant measures

Impact sound transmission (measured in dB) relates to the sound insulation from an adjacent space, while sound absorption is most relevant to assessing the acoustic situation within a room.

### 3. Knowing what to listen for

High alpha values e.g. above aw 0,25 do not necessarily mean better sound absorption for end users. Define the typical sounds and the frequencies that need to be absorbed, in cooperation with the end user. Then check the values in the relevant octave bands for the floor covering offered.

### 4. Taking into consideration other factors

The acoustical performance of the floor covering is one of many factors that will contribute to an overall good choice. Don't forget other relevant aspects. For example carpet in offices needs to be worked on with castor chairs, so choosing a soft carpet with very high absorption might make moving across this rather hard work. Also wear performance might not be as good as a denser construction.

### 5. Avoid taking counter productive actions

The human ear is more sensitive to medium and high frequency noise. Be careful not to absorb too much background noise in the lower frequencies, since the higher frequencies will thereby be more intensively recognisable.

### 6. Achieving the best overall result

Textile floor covering generally has much better sound absorption and impact sound values than hard flooring. However, a carpet alone will never achieve total sound absorption on its own. Ceilings and walls also need to be controlled and often deliver the decisive critical contribution to a good acoustical environment.

# Glossary of **terms**

**Ambient Noise:**

Ambient noise encompasses all sound present in a given environment, being usually a composite of sounds from many sources near and far.

**Architectural Acoustics:**

The control of noise in a building space to adequately support the communications function within the space and its effect on the occupants. The qualities of the building materials used to determine its character with respect to distinct hearing.

**Decibel (dB):**

A unit used to measure the intensity of a sound or the power level of any signal by comparing it with a given level on a logarithmic scale. (in general use) A degree of loudness.

**Deflection:**

(In physics) deflection is the event where an object collides and bounces against a plane surface.

**Diffusion:**

The scattering or random reflection of a sound wave from a surface. The directions of reflected sound is changed so that listeners may have sensation of sound coming from all directions at equal levels.

**Echo:**

Reflected sound producing a distinct repetition of the original sound. Echo in mountains is distinct by reason of travel after original signal has ceased.

**Flanking:**

The transmission of sound around the perimeter or through holes within partitions (or barriers) that reduces the otherwise obtainable sound transmission loss of a partition.

**Frequency:**

The number of oscillations or cycles per unit of time. Acoustical frequency is usually expressed in units of Hertz (Hz) where one Hz is equal to one cycle per second.

**Hearing Range:**

20-20000 Hz
(Audible by humans)
250-4000 Hz
(Speech Intelligibility)
250-2500 Hz
(Typical small table radio)

**Hertz (Hz):**

Frequency of sound expressed by cycles per second.

**Loudness:**

A listener's auditory impression of the strength of a sound. The average deviation above and below the static value due to a sound wave is called sound pressure. The energy expended during the sound wave vibration is called intensity and is measured in intensity units. Loudness is the physical resonance to sound pressure and intensity.

# Glossary of **terms**

### Noise:

Unwanted sound that is annoying or interferes with listening. Not all noise needs to be excessively loud to represent an annoyance or interference.

### Noise Reduction (NR):

The amount of noise that is reduced through the introduction of sound absorbing materials. The level (in decibels) of sound reduced on a logarithmic basis.

### Noise Reduction Coefficient (NRC):

The NRC of an acoustical material is the arithmetic average to the nearest multiple of 0.05 of its absorption coefficients at 4 octave bands with centre frequencies of 250, 500, 1000, 2000 Hertz. The NRC rating can be viewed as a percentage (example: .80 = 80%) of what sound waves that come in contact with the acoustical material are absorbed by the material and NOT reflected back within the room.

### Reflection:

The amount of sound wave energy (sound) that is reflected off a surface. Hard non-porous surfaces reflect more sound that soft porous surfaces. Some sound reflection can enhance the quality of the signal of speech and music.

### Reverberation Time:

The reverberation time of a room is the time it takes for sound to decay by 60 dB once the source of sound has stopped. Reverberation time is the basic acoustical property of a room which depends only on its dimensions and the absorptive properties of its surfaces and contents. Reverberation has an important impact on speech intelligibility.

### Sabin:

A unit of sound absorption based on one square foot of material. Baffles are frequently described as providing X number of sabins of absorption based on the size of the panel tested through the standard range of 125 – 4000 Hz. The number of sabins developed by other acoustical materials are determined by the amount of material used and its absorption coefficients.

### Sabine Formula:

A formula developed by Wallace Clement Sabine that allows designers to plan reverberation time in a room in advance of construction and occupancy.

### Signal to Noise Ratio:

The sound level at the listeners ear of a speaker above the background noise level.

### Sound:

Sound is an oscillation in pressure, stress particle displacement, particle velocity in a medium. Sound produces an auditory sensation caused by the oscillation.

### Sound Absorption:

The property possessed by materials, objects and air to convert sound energy into heat. Sound waves reflected by a surface causes a loss of energy. That energy not reflected is called its absorption coefficient.

### Sound Absorption Coefficient:

The fraction of energy striking a material or object that is not reflected. For instance, if a material reflects 70% of the sound energy incident upon its surface, then its Sound Absorption Coefficient would be 0.30. SAC = absorption/area in sabins per sq. M.

### Sound Level:

A subjective measure of sound expressed in decibels as a comparison corresponding to familiar sounds experienced in a variety of situations.

### Sound Pressure:

The sound pressure is the total instantaneous pressure at a point in space, in the presence of a sound wave, minus the static pressure at that point.

### Sound Transmission:

Sound that passes through a material.

### Speech Intelligibility:

The ability of a listener to hear and correctly interpret verbal messages. In a classroom with high ceilings and hard parallel surfaces such as glass and tile, speech intelligibility is a particular problem. Sound bounces off walls, ceilings and floors, distorting the teacher's instructions and interfering with students' ability to comprehend. Centres between 250 and 4000 Hz.

### Speech Privacy:

The degree to which speech is unintelligible between offices. Three ratings are used: Confidential, Normal (Non Obtrusive) and Minimal.

### Wavelength:

Sound that passes through air produces a wavelike motion of compression and refraction. Wavelength is the distance between two identical positions in the cycle or wave. Similar to ripples or waves produces by dropping a stone in water. Length of sound wave varies with frequency. Low frequency equals longer wavelengths.

**If you want to know more, please go to**

www.inter faceflor.eu/acoustics

**For more information about our products please visit**

www.interfaceflor.eu

InterfaceFLOR