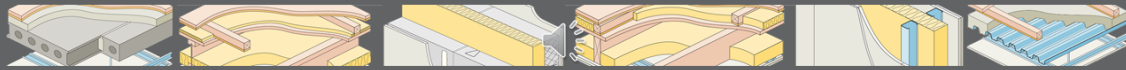


Module 1

Introduction to sound transmission and sound insulation for housing



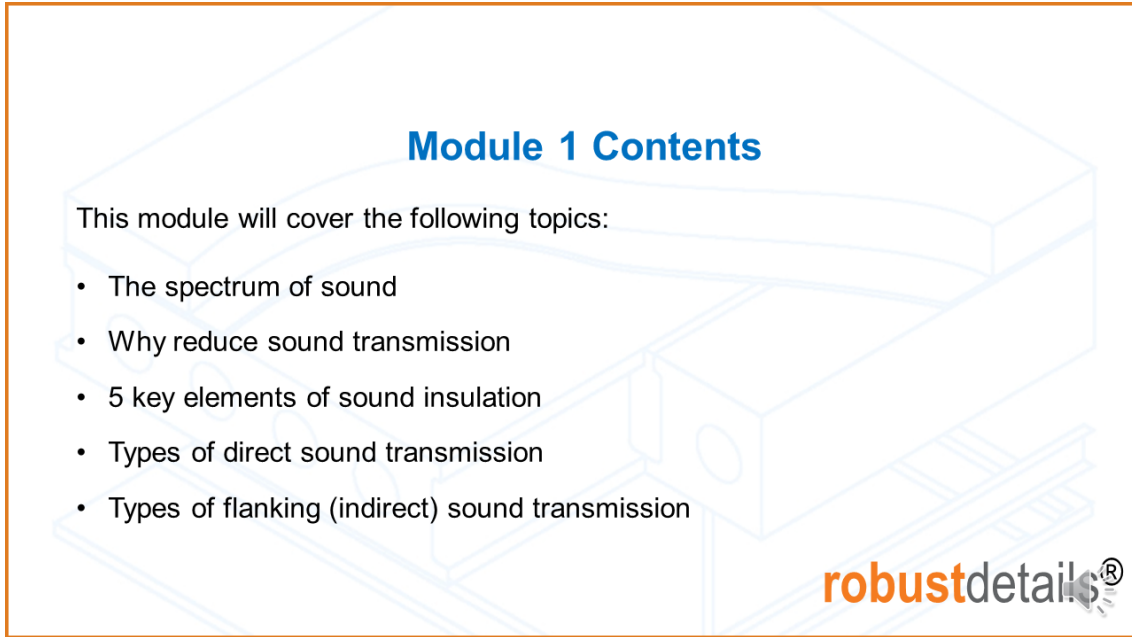
Welcome to Module 1 – Introduction to sound transmission and sound insulation for housing. This is the first module of this short course.

Additional notes:

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Slide 2



Module 1 Contents

This module will cover the following topics:

- The spectrum of sound
- Why reduce sound transmission
- 5 key elements of sound insulation
- Types of direct sound transmission
- Types of flanking (indirect) sound transmission

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This Module will cover the following topics:

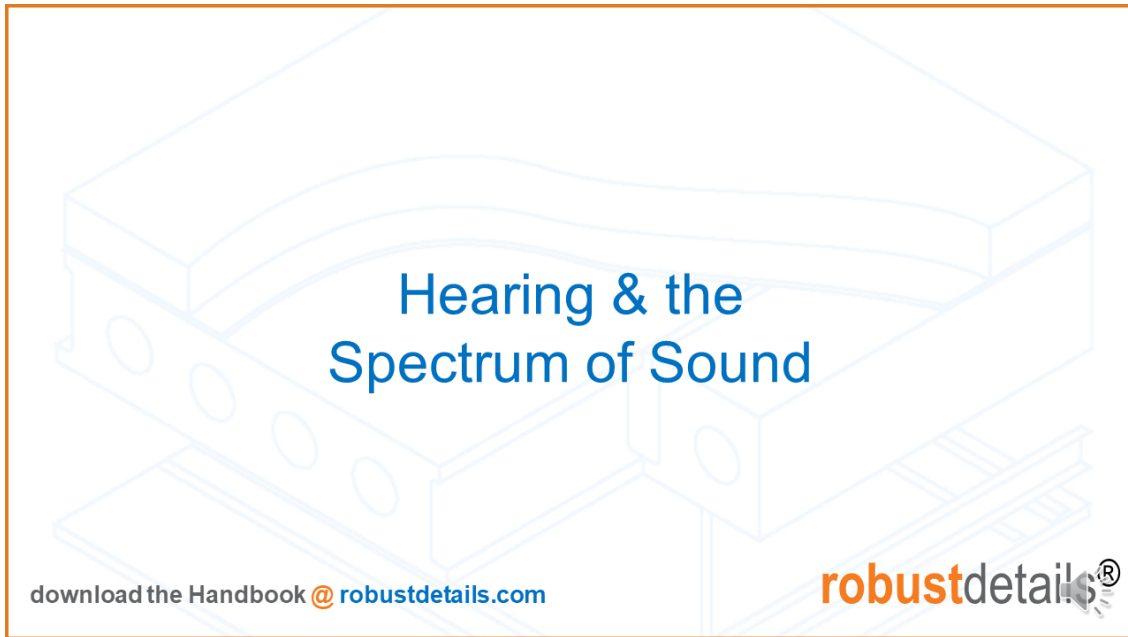
- The spectrum of sound
- Why reduce sound transmission
- 5 key elements of sound insulation
- Types of direct sound transmission
- Types of flanking (indirect) sound transmission

Additional notes:

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Slide 3



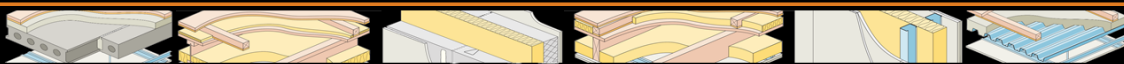
Firstly, lets explain some of the features related to hearing and the acoustic spectrum of sounds and noise.

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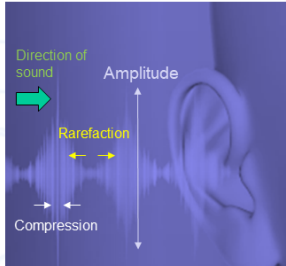
Slide 4

The Spectrum of Audible Sound




Sound pressure or acoustic pressure is the local pressure deviation from the ambient atmospheric pressure, caused by a sound wave.

The compression and rarefaction (stretching) of the air particles causes pressure fluctuations.



In the outer-ear, our ear drum (the tympanic membrane) flexes due to these air pressure waves (fluctuations). This then drives dynamic movement of the 3 ear bones (in the middle ear). The bones movement then dynamically interacts with the inner-ear (cochlear) resulting in the inner-ear nerves releasing neuron transmitters to the brain, through the 8th cranial nerve.

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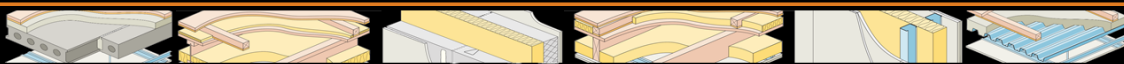
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Additional notes:

Slide 5

The Spectrum of Audible Sound



Hearing & Frequencies of Sound:

Humans can hear frequencies of

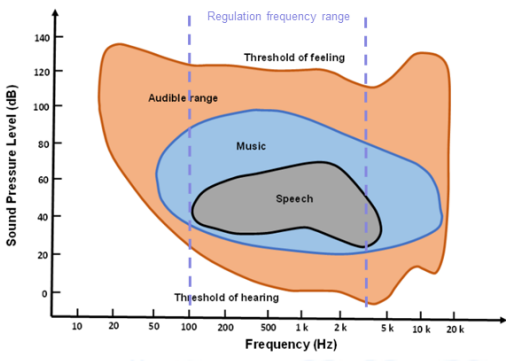
- **15Hz to 20kHz.**

Within this:

- Music is 50Hz to 18kHz
- Speech is typically 100Hz to 5kHz.


Current Building Regulations

- 100Hz to 3.15kHz.



Source: Sound2020
<https://www.sound2020.org/sound/audible/>

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The audible frequency range of humans typically ranges from 15Hz to 20kHz. With aging process as early as 30 years our frequency range can decrease.

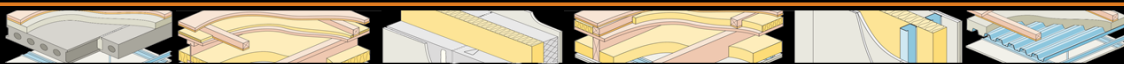
The music range extends from 50Hz to 18kHz and the speech range is typically 100Hz to 5kHz.

Current building regulations across the UK are 100Hz to 3.15kHz as shown here.

Additional notes:

Slide 6

The Spectrum of Audible Sound

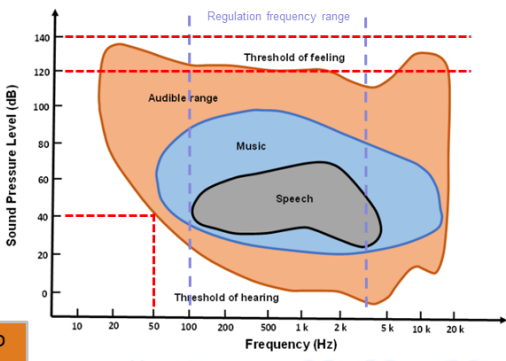


All frequencies are not heard equally.

For most people, sounds at lower and higher frequencies must be louder in order to be heard. (e.g. a sound pressure level of 40 dB is needed for sound to be audible at 50 Hz)


Higher sound levels, at about 120 dB, constitute the “threshold of feeling”.

At higher levels, from 140 dB, the “feeling” becomes too intense, and crosses the “threshold of pain”.



Source: Sound2020
<https://www.sound2020.org/sound-audible/>

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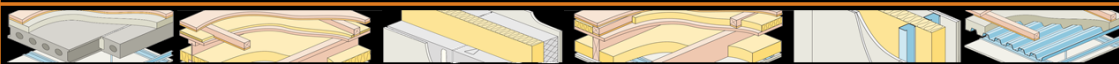
In the frequency band, (500 Hz to 5 kHz), sounds at very low sound pressure levels of about 10 dB are audible to young, healthy ears. For most people at lower and higher frequencies, sounds must be louder to be audible. (e.g. a sound pressure level of 40 dB is needed for sound to be audible at 50 Hz)

At much higher sound pressure levels, at about 120 dB, sound is not so much heard as felt. These levels constitute the threshold of feeling. At even higher levels, say 140 dB, the “feeling” becomes quite uncomfortable and we reach the threshold of pain.

Additional notes:

Slide 7

The Spectrum of Audible Sound



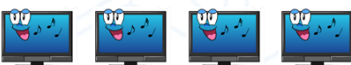


Sound and Noise Volume Levels:


- Sound or noise is typically measured in decibels (dB)
- Decibels are a logarithmic measurement unit.
- For every 3dB increase is twice the sound energy. (i.e. doubling for every 3dB)

Source: Sound2020
<https://www.sound2020.org/roba-sound/>

Noise Level

	1xTV = 65dB	
	↑ +3dB	
	2xTV = 68dB	
	↑ +3dB	
	4xTV = 71dB	

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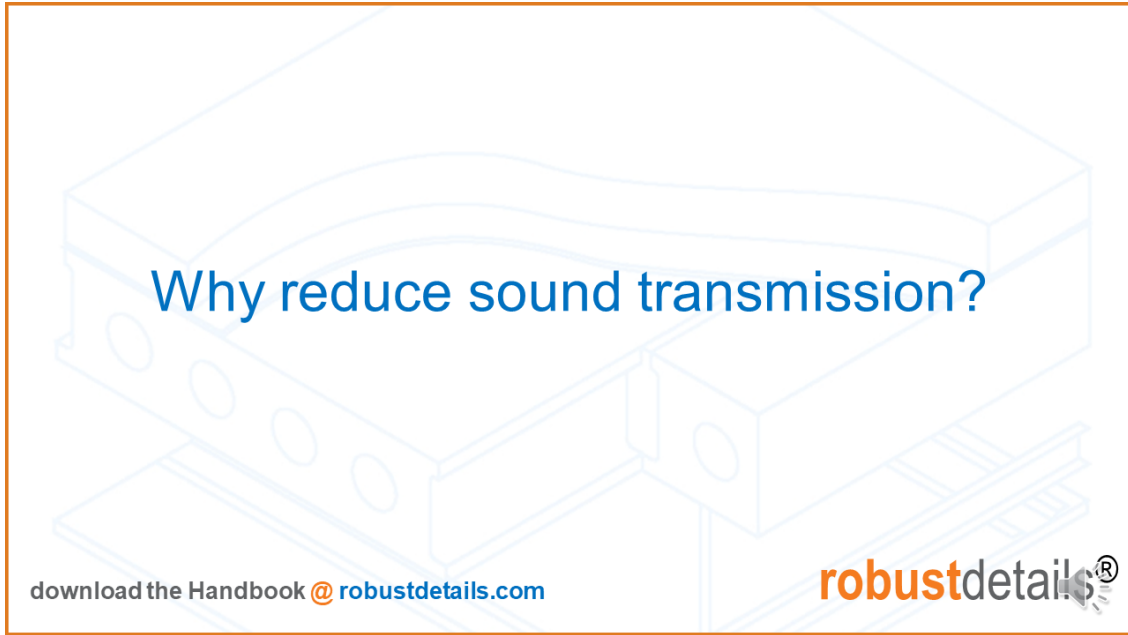
Let's now discuss sound and noise volume levels

Read slide

If one TV emits 65dB of sound – adding a second TV with the same volume level as the first TV now adds 3dB = 68dB and so on for every doubling of the sound source volumes - so 4 TVs at the same volume would be 71dB

Additional notes:

Slide 8



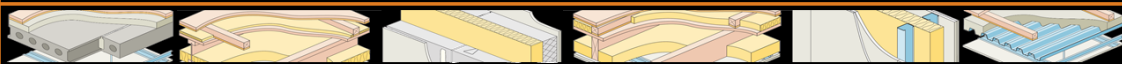
So why is sound insulation important and why reduce sound transmission between attached houses and flats?

Additional notes:

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Slide 9

Living with Sound and Noise



- Insufficient sound insulation can lead to **disturbance, annoyance and also affect people's health** through stress and anxiety.
- Types of sound and noise can vary in volume level (decibels, dB) and the pitch of sound (frequency, Hz)
- Noise from normal 'living behaviour' can also vary throughout a **24hr period**, depending on work shift patterns and activities of neighbouring occupants.
- Hence, designing in for sufficient sound insulation is important.

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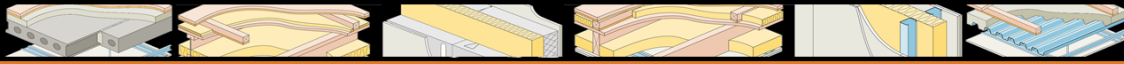
Additional notes:

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Slide 10

Living with Sound and Noise

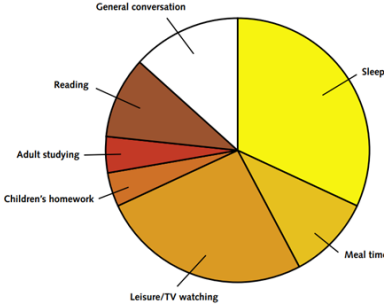


Government Regulations and building standards for sound insulation **do not require dwellings to be sound-proof.**

Studies on disturbance by noise from adjoined dwellings show that the most common activities disturbed are:

- sleep
- leisure / watching TV.

Source: Smith, Wood & Mackenzie. *Housing & Sound Insulation*. Arcamedia.



Proportion of the types of household activities which are typically disturbed due to noise and sound transmitting from an attached neighbouring property.

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Government Regulations and building standards for sound insulation in attached housing aims to address the most common sound and noise sources by providing a reasonable level of insulation to address typical normal levels of living sound/noise. Attached housing includes attached houses and flats.

Noise is generally defined as unwanted sound. Noise and sound within housing can involve a wide range of sources such as TVs, conversations, kitchen appliances and other appliances, sound systems and footsteps. Studies on disturbance by noise often show similar patterns of the types of home activities which can be affected by neighbor noise (as shown on the right). The most common activities disturbed are sleep and leisure / watching TV.

Continued Overleaf

Additional notes:

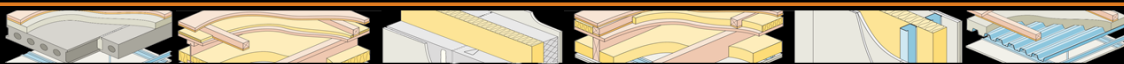
In the diagram on the right, we can see that disturbance to sleep and leisure / tv watching can be the most affected.
Other activities affected include reading, conversations, meal times and adults studying or children doing homework.

Additional notes:

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Living with Sound and Noise



Potential noise sources from adjoining dwellings	Airborne Noise	Impact Noise	Noise frequencies influenced
Teenagers or adult voices	■		mid-high
TV	■		mid-high
Doors closing		■	low-mid
Radio/Music	■		all*
Domestic equipment (e.g. vacuum cleaners)	■		all
Plugs being inserted into sockets		■	low-mid
Switches being turned on or off		■	mid
Cupboard doors closing		■	low-mid
Services noise (e.g. downpipes, water pumps)	■		all
Footsteps		■	low-mid
Children playing	■	■	all
DIY	■	■	all
Dogs barking	■		low-mid

* Amplified modern music often has a high level of bass frequency output.

FREQUENCIES:			
Low	Mid	High	All
40Hz-200Hz	250Hz-1KHz	1.25Kz-5KHz	wide range of frequencies

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Source: Smith, Wood & Mackenzie. Housing & Sound Insulation.

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Sound transmission within attached housing is normally grouped into two main areas:

- 1) Airborne sound, and
- 2) Impact sound.

Airborne sound includes that from speech, TV and general living noise.

Impact sound is generally from footfall. *It does not include horizontal impact sound through walls.*

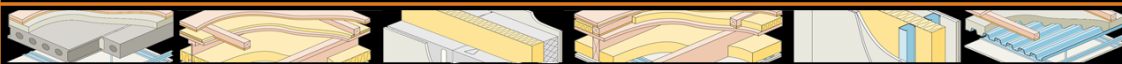
This table provides an indication of the types of everyday household noise sources, their categorisation for airborne and impact as sound sources and the range of frequencies low, mid or high they are likely to include.

Noise and sound sources within housing can cover a wide range of frequencies. Sound transmission within attached housing is normally grouped into two main areas: **Airborne sound**, and **Impact sound**.

Airborne sound insulation focuses on addressing airborne noise from speech, TV and general living noise. Impact sound insulation focuses on impact noise from footfall. NOTE: regulations in the UK do not include horizontal impact sound through walls such as cupboard doors closing, wall switches or door closing noise.


Additional notes:

Living with Sound and Noise



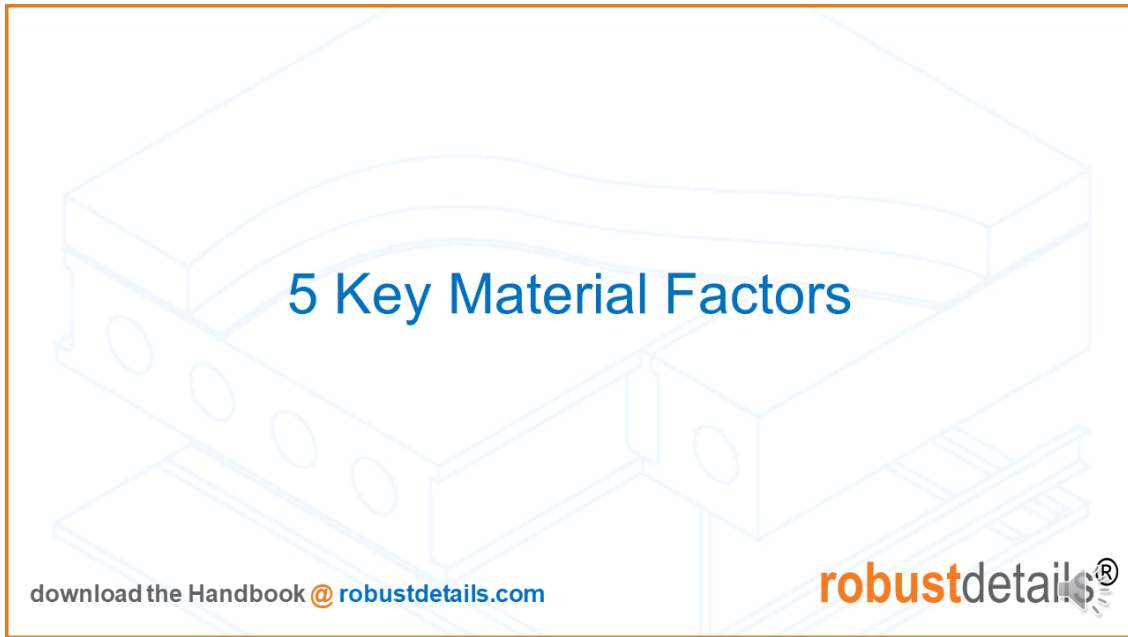
Potential Noise Sources in Attached Dwellings	Frequencies (Hz) - Common building standards frequency range														
	100	125	160	200	250	315	400	500	630	800	1k	1.25k	1.6k	2k	2.5k
Teenagers or adult voices	Primary frequencies														
Television noise	All frequencies														
Doors closing	Mainly lower frequencies														
Radio music	Lower frequencies cause most annoyance														
Household equipment	Mainly lower frequencies														
Plugs inserted into sockets															
Switches being turned on/off	Mainly mid-frequencies														
Cupboard doors closing															
Services noise (fans, water)	All frequencies														
Footsteps	Lower frequencies cause most annoyance														
Children playing	All frequencies														
DIY	All frequencies														

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Source: Smith, Wood & Mackenzie. Housing & Sound Insulation. 

This table gives another format for comparing the types of noise sources and the frequency ranges they commonly include.

Additional notes:

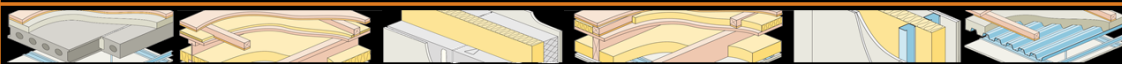


There are 5 KEY material factors or elements when designing for sound insulation.

Additional notes:

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5 Key Elements / Factors of Sound Insulation



To reduce sound transmission and improve the sound insulation there are commonly five key factors which technical designers can draw upon:

FACTOR	Benefit frequency area
• Mass	All frequencies but particularly low and mid frequencies
• Isolation	All frequencies
• Absorption	Mainly 200Hz and higher and specifically airborne insulation
• Stiffness	Mainly low frequencies and useful for lightweight structures
• Resilience	All frequencies depending on the application, for most housing construction systems it is likely to be 250Hz and above

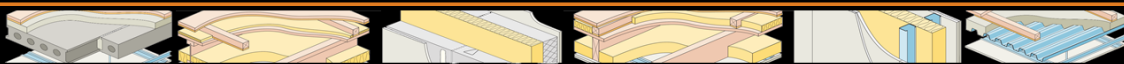
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Additional notes:

Role of MASS in Sound Insulation



Mass:
Some materials (mainly concrete) have a much higher density than others.

Material Component	Density (kg/m ³)	Mass per Unit Area (kg/m ²)	Notes
Concrete	2,400	360	150mm floor slab
Cement mortar	2050	205	100mm mortar joint
Dense concrete blocks	1850	185	100mm block
Lightweight aggregate blocks	1600	160	100mm block
Aircrete blocks	700	70	100mm block
Gypsum board	800	12	15mm higher density boards
Gypsum board	660	8	12.5mm standard boards
Chipboard	630	11	18mm boards


Example:
12.5mm gypsum board density is 660kg/m³

The Mass per Unit Area
= Density (kg/m³) x thickness (m)
= 660 x 0.0125
= 8.25 kg/m²

The **density and thickness** of the construction component is key. So **mass per unit area (kg/m²)** is the primary material property. *Note: Mass per unit area is also called 'area density' or 'surface density'*

Mass per Unit Area (kg/m²) = density (kg/m³) x thickness (m)

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Mass: Material components such as concrete slabs, dense concrete blocks and cement mortar are generally high density materials. Whereas aircrete blocks, gypsum board and chipboard are lower density materials.

For sound insulation purposes, the density and thickness of the construction component is key. Therefore, the mass per unit area (kg/m²) is the primary material property of interest.

Mass per Unit Area (kg/m²) = density (kg/m³) x thickness (m)

Continued Overleaf

Additional notes:

The table shows a variety of different construction product materials, their density and typical mass per unit area.

Also, an example for calculating mass per unit area for a 12.5mm gypsum board of density 660kg/m³ is shown resulting in a mass per unit area of 8.25kg/m²

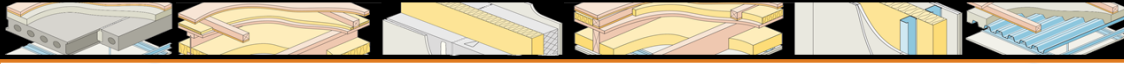
Always remember to use the same science-based units for kg and metres in your calculations (e.g. a 12.5mm board is written as 0.0125m)

Additional notes:

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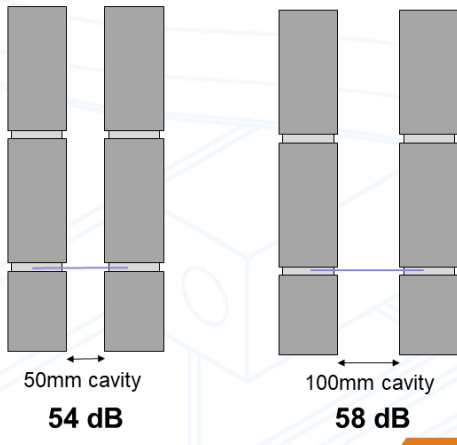
Role of ISOLATION in Sound Insulation



Isolation:
Isolation of construction components breaks the sound transmission.

Increasing the isolation:

- reduces sound transmission;
- increases sound insulation.



50mm cavity **54 dB**

100mm cavity **58 dB**

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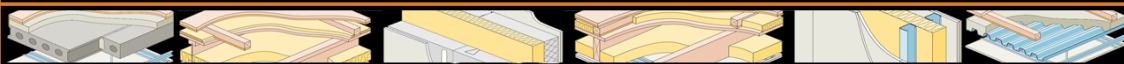
Isolation: The isolation of construction components can break the transmission of sound.

Taking the same twin leaf cavity block wall and increasing the cavity width, increases the isolation: reducing sound transmission; and increasing sound insulation.

Additional notes:

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Role of ABSORPTION in Sound Insulation



Absorption:
The ability for materials to absorb sound and prevent reflection of sound.

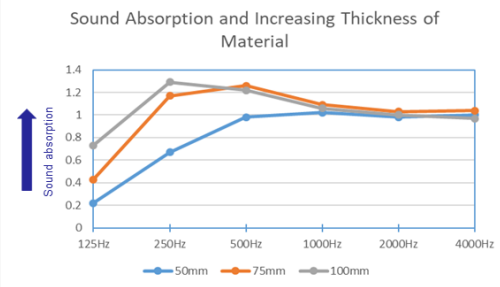
Mineral wool is widely used, as this has high levels of absorption.

Increasing the thickness increases the absorption.

As the **density of fibre increases**, so does the acoustic absorption

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Sound Absorption and Increasing Thickness of Material



Frequency (Hz)	50mm	75mm	100mm
125	0.2	0.4	0.8
250	0.6	1.1	1.3
500	1.0	1.25	1.2
1000	1.0	1.1	1.1
2000	1.0	1.0	1.0
4000	1.0	1.0	1.0

EXAMPLE: Mineral Wool
Sound absorption increases rapidly at low frequencies. As material thickness increases (50/75/100mm) the better the absorption at low and mid frequencies.

Note: At higher frequencies 1kHz and above all thicknesses have similar absorption performance.

Absorption: Is the ability for materials to absorb sound and prevent reflection of sound. This is commonly used to improve airborne sound insulation. Materials such as mineral wool have high acoustic absorption.

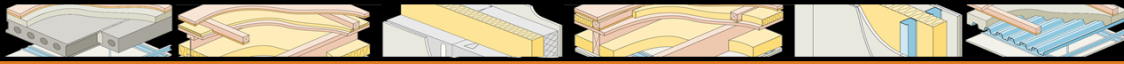
Other soft materials can also provide acoustic absorption but always check that the product is certified and approved for the specific intended application.

Generally, effective absorption can occur from frequencies of 200Hz and above. Increasing the thickness of the material increases the absorption.

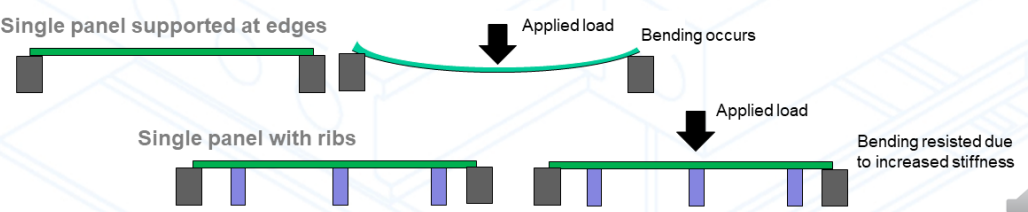
As the density of fibre increases, this also increases the acoustic absorption performance.

Additional notes:

Role of STIFFNESS in Sound Insulation



Stiffness:
The ability for materials to reduce flexing (bending) and maintain their shape.
Connecting thin materials to frame structures increases the overall stiffness.
Ribs assist in stiffening the panel and reducing bending or deflection taking place.



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Stiffness: Is the ability for materials to reduce flexing (bending) and maintain their shape. If a construction material is too thin or the structure of the materials allows bending to occur, then this leads to flexural movement. Thin panels such as gypsum board or plywood will more easily flex. Connecting such materials to frame structures such as timber studs or joists reduces the flexibility and increases the overall stiffness. Double linings (e.g. gypsum) increase wall panel stiffness.

Continued Overleaf

Additional notes:

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For example, for floors, if they are able to flex and bend this can couple with the sound waves more easily leading to a dynamic motion and strong coupling between the sound pressure waves in the air and the vibration of the floor, resulting in sound transmission due to 'forced motion'.

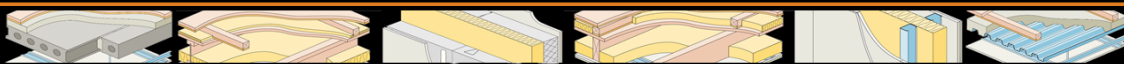
The diagrams below show flexibility of a simple panel; and a panel with ribs. The ribs assist in stiffening the panel and reducing bending or deflection taking place.

Additional notes:

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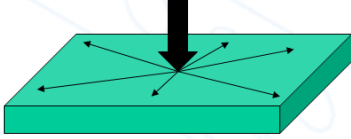
Role of RESILIENCE in Sound Insulation



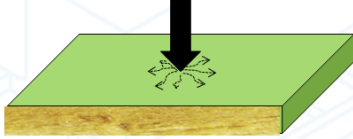
Resilience:
The ability to provide acoustic or vibration damping.

Examples include resilient ceiling hangers or resilient layers within floating floors.


Resilient lining materials convert the vibration energy into heat within the material also known as an internal loss factor.



(A) **Non-resilient material** – impact vibration is able to easily transmit to other parts of the structure.



(B) **Resilient material** – impact vibration is absorbed locally by the material due to high damping material properties.

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Resilience: Is the ability for materials or products to provide an effective acoustic or vibration damping. Often involving a combination of acoustic factors such as absorption and the ability to retain their shape and form, but also to dynamically absorb displacement forces. Examples include resilient ceiling hangers or resilient layers within floating floors, under-screed layers and bonded soft floor coverings, which absorb impact vibration from footfall.

Resilient lining materials convert the vibration energy into heat within the material also known as an internal loss factor. The higher the internal loss factor of a material the better the acoustic / vibration damping factor and the better vibration reduction performance.


Explanation of... diagram (A) and (B)

Additional notes:

Example (A) of 5 Key Acoustic Factors Together

- **Mass** via the decking boards + **Stiffness** enhanced due to double linings.
- **Absorption** within the upper cavity voids via the mineral wool insulation
- **Resilience (damping)** via the floating floor treatment
- **Stiffness** via the sub-deck + joist spacing + joist depth combination
- **Absorption** via the mineral wool quilt in main floor cavity
- **Isolation** via the depth of joists (deeper the joists the better the isolation)
- **Resilience (damping) + Isolation** via the acoustic resilient ceiling bars and only connected at points (perpendicular to the joists)
- **Mass** via the gypsum ceiling boards + **Stiffness** enhanced due to double linings

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Additional notes:

Example (B) of 5 Key Acoustic Factors Together

- **Mass** via the decking boards
- **Resilience (damping)** within the floating floor treatment
- **Mass + Stiffness** via the screed layer
- **Mass** via the precast concrete slab
- **Stiffness** via the slab depth (and limited span)
- **Mass** via infill using cement grout fully filled at slab joints
- **Isolation** via the ceiling frame suspended on hangers
- **Absorption** (if mineral wool is placed in the ceiling cavity zone)
- **Mass** via the gypsum ceiling boards

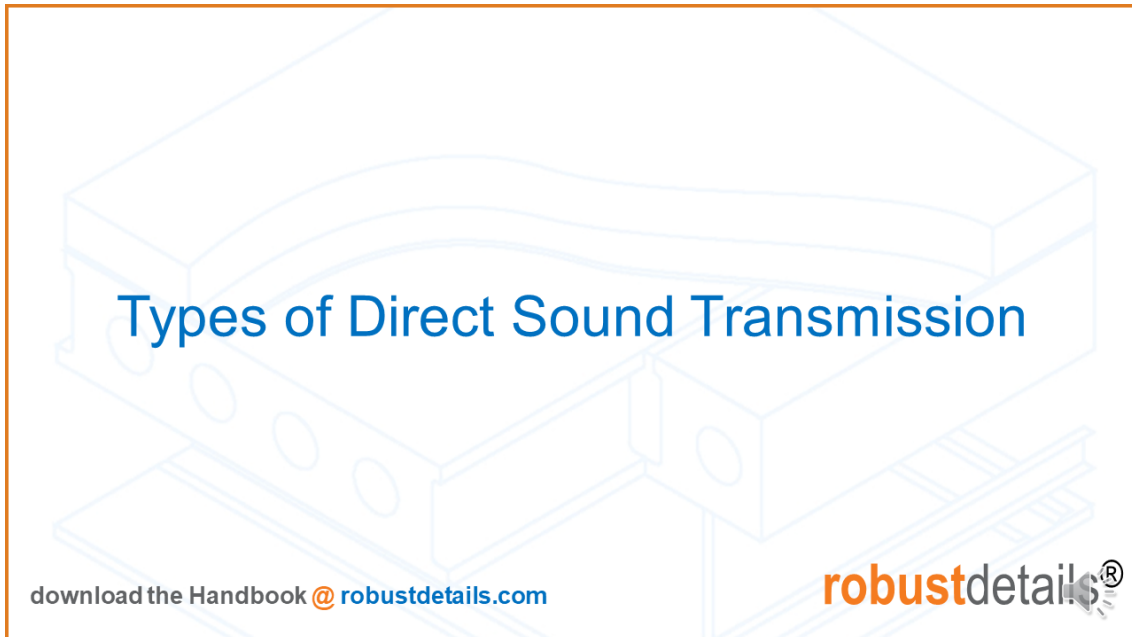
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Additional notes:

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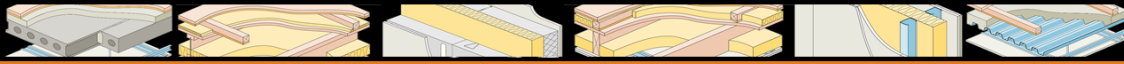


Let's now look at the types of sound transmission

Additional notes:

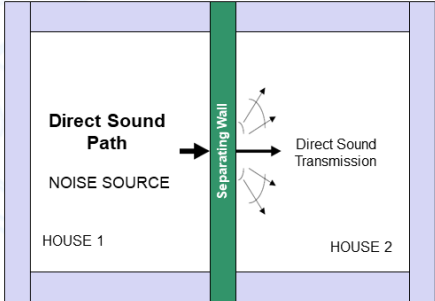
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Direct Sound Transmission

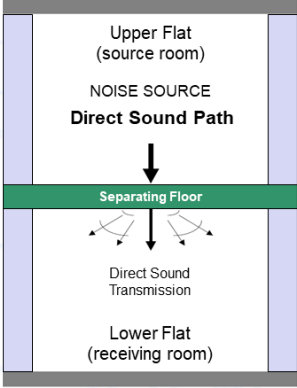


Direct (D) sound transmission is when sound is transmitted directly room to room through the main separating wall or separating floor.

Separating Wall
Direct sound transmission path



Separating Floor
Direct sound transmission path



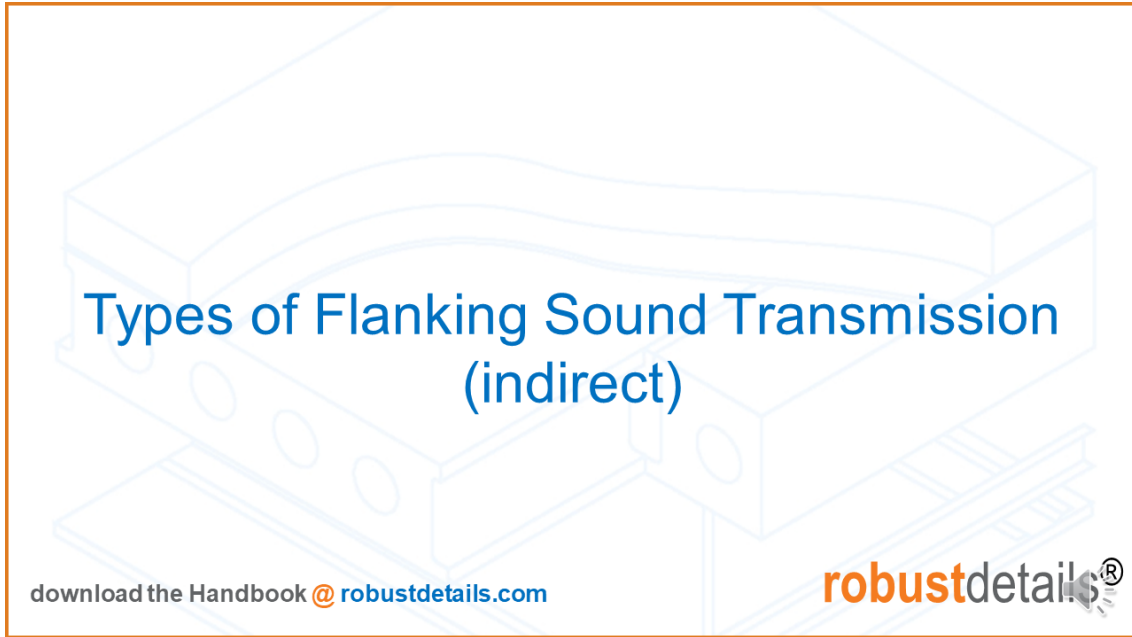
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Direct (D) sound transmission is when sound is transmitted directly room to room through the main separating floor.

The diagrams shown here, for separating wall and separating floor, illustrate the direct paths.

Additional notes:

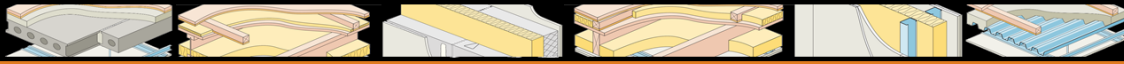


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Additional notes:

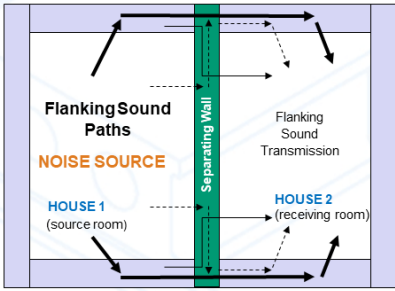
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Flanking (indirect) Sound Transmission



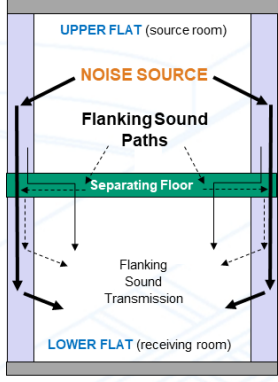
Flanking (F) sound transmission is when sound is transmitted via the adjoining structures **and is going indirectly** (room to room) and can bypass the main separating wall or separating floor.

Separating Wall
Flanking sound transmission paths



(plan)

Separating Floor
Flanking sound transmission paths



(Section)

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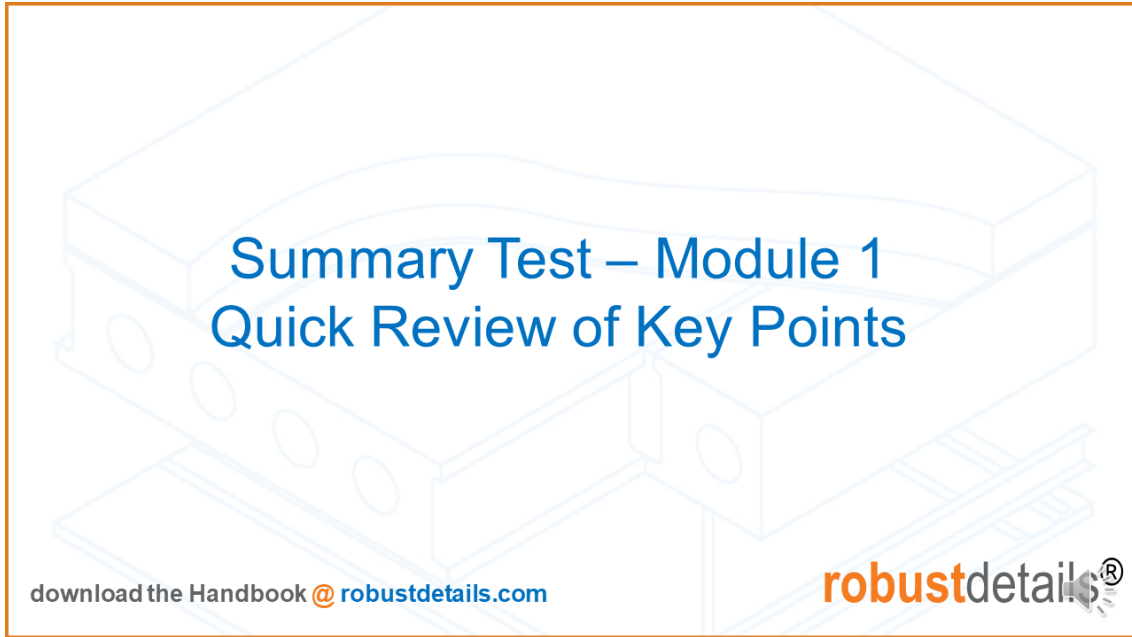
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Note how many flanking sound transmission paths can occur past just one separating wall or floor.

Even for a very high performing core separating wall or floor – the flanking sound transmission can be the weak point and can be a controlling factor to achieve sufficient sound insulation.

Additional notes:



Now for a quick TEST to recap on Module 1

Additional notes:

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Slide 28

Summary Test – Module 1

No.	Question
1	What is the measurement unit for sound insulation?
2	What is the typical frequency range used across UK sound insulation building standards?
3	What is the change in sound energy for a 3dB increase?
4	When designing attached housing, should designers consider a 12hr, 18hr or 24hr household living period?
5	What are the most common home living issues affected by poor sound insulation?
6	Sound transmission is normally grouped into two main areas, linked to sound sources, what are they?
7	Do building regulations in the UK include horizontal impact sound through separating walls?
8	What are the 5 main key factors to consider when designing for sound insulation?
9	When considering the mass of a solid product, what is a key material property?
10	If the insulation thickness increases what happens to the acoustic absorption performance?
11	If the insulation product density is increased what happens to acoustic absorption performance?
12	What is the terminology used to describe sound transmission which passes only through the main separating wall or floor?
13	What is the terminology used to describe sound transmission which transmits indirectly?
14	Why are outer leaf walls important when designing for sound insulation?

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Here are 14 questions – you may wish to PAUSE the recording and test yourself against these questions.

Once you have answered all of them – the next slide provides the answers. In 10 seconds, the slide will change so press pause now if you want to test yourself first.

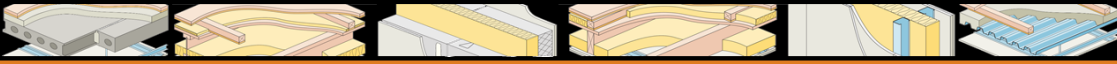
Thank you for following Module 1.

Additional notes:

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Summary Test – Answers



No.	Answer
1	decibels (db)
2	100Hz to 3150Hz
3	double the sound energy
4	24hr
5	Sleep, Leisure / Watching TV
6	AIBORNE sound transmission and IMPACT sound transmission
7	No
8	Mass, Isolation, Absorption, Resilience, Stiffness
9	Mass per unit area
10	Increases
11	Increases
12	Direct sound transmission
13	Flanking sound transmission
14	They may provide sound flanking paths and reduce sound insulation performance

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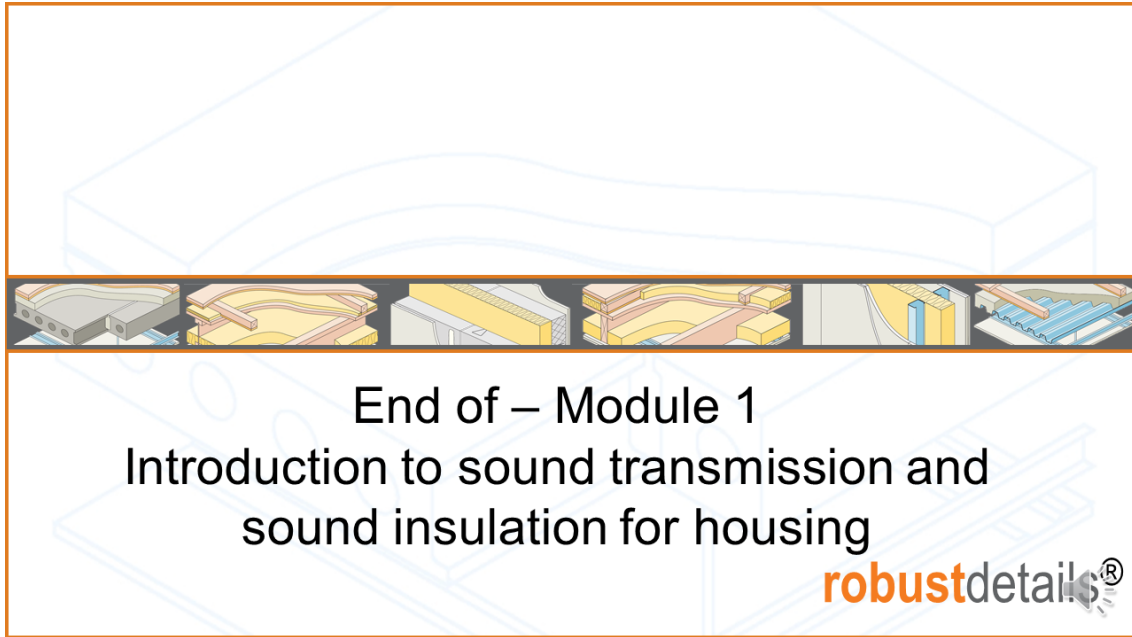
Here are the answer to Module 1's quick test.
How did you do?

Thank you for following Module 1

Additional notes:

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End of – Module 1
Introduction to sound transmission and
sound insulation for housing


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Additional notes:

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Slide 31



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Additional notes:

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