SOUNDPROOFING

The Coordination of Floor, Wall and Ceiling Solutions

A M King CONSTRUCTION
A BETTER BUILDING EXPERIENCE.

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PREFACE

PROBLEM

Your office, located on the second floor, has a series of windows that are strategically arranged to provide the perfect vantage point to view the production floor below. The fully automated production line, demonstrating its ability to produce, package and prepare your product for its shipment, is running flawlessly, just as you were expecting.

As facility manager, your goal is to maintain the speed and efficiency of the production system. With this comes the need to provide a constant distribution of information through emails, phone calls, staff meetings etc. Each day you are continuously distracted and find it difficult to focus on the matters at hand. You take a moment to collect yourself and realize that you can clearly hear the calling of a driver's name followed by a shout that his truck is in the wrong shipping dock. You hear the clanks of the ductwork as the air pushes through the supply grill above, and the repetition of the rolling casters as the metal trays travel at full speed on the production line below.

How is the noise entering the room so easily? Why is the noise so clear and recognizable? And most importantly, how can the sound be restricted from entering the room to prevent this from happening?

SOLUTION

In order to reduce the amount of noise from entering a space, there must be an understanding of how a room can be composed of a series of parts that, when working together, seal and prevent surrounding noise from entering. The coordination of floor, wall and ceiling assemblies must work together to successfully reduce the intrusion of unwanted noise.

SOUND

Sound is the movement of air pressure (energy) waves that travel through both air and water. The perception of this movement is in the form of vibrations that are created when the energy waves strike a physical surface. As these waves continue to radiate from its source, they can be reflected, refracted or attenuated by each surface they strike until the strength is depleted and all vibrations stop.

How sound travels through the air can be visually compared to throwing a rock into a pool of water. A heavy mass (low frequency-Hz) will increase the distance between one wave swell and the next on the water surface while its intensity of striking the water (pressure-dB) will determine the height of the waves and the distance those waves travel. When a light mass (high frequency-Hz) strikes the water surface with the same intensity (pressure-dB), there will be a much shorter distance between each wave cycle causing an increase in speed and a decrease in travel distance before the waves lose their energy.

TWO ELEMENTS OF SOUND

- **FREQUENCY** is the duration of one energy wave cycle per second (cps). One cps is measured as a single hertz (Hz). As the number of Hz increases per second, the sound being detected will raise in pitch. The human ear is sensitive enough to detect frequencies between 20Hz to 20,000Hz. *(Table 1)*

- **PRESSURE** is the intensity (volume) of a sound and is measured in decibels (dB). The human ear has a range from 3dB to 140dB, at which point physical pain occurs. (Table 2)

ACOUSTICAL TRANSMISSION OF SOUND

When the design goal is to isolate one room from the sounds created within adjacent spaces, there are typically three types of sound transmission that need to be addressed.

AIRBORNE TRANSMISSION

As stated above, sound is the movement of air pressure waves that creates vibrations when striking a solid surface. When referring to a wall partition that separates one space from another, the surface that is located on the source side will induce vibrations once struck and transfer its movement to the opposite side.

IMPACT TRANSMISSION

The direct impact between two masses creates a vibration on the surface that is then transferred through the medium to the adjacent surfaces via contact points.

FLANKING TRANSMISSION

This occurs when vibrations transfer to adjacent spaces through paths or routes other than that of the building system. Examples of this include inadequate seals between wall and ceiling, glass and mullions, poorly fitted or undercut doors and openings at unfitted electrical outlet boxes.

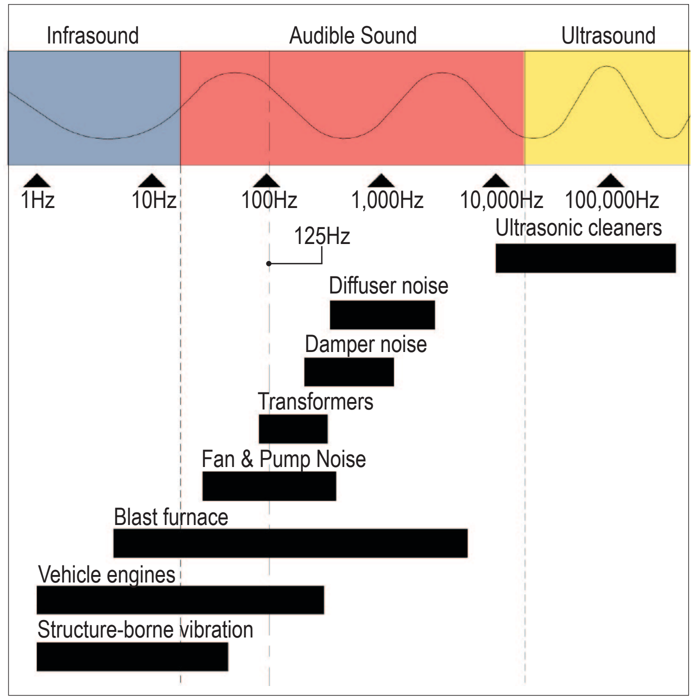

Table 1: Level of frequency (pitch) produced by standard equipment

Decibels	Sound (source)
140	Jet plane takeoff
130	Threshold of discomfort
120	Riveting
110	Thunder-sonic boom
100	Hard rock band
90	Power lawn mower
80	Pneumatic jackhammer
70	Noisy office
60	Average radio
50	Normal conversation
40	Quiet street
30	Quiet conversation
20	Whisper at 4 ft.
10	Normal breathing
3	Threshold of audibility

Table 2: Sound pressure levels for various sounds

MEASUREMENT RATING OF SOUND

NRC – NOISE REDUCTION COEFFICIENT

The NRC is a measurement of the amount of sound energy absorbed upon striking a material's surface. This measurement is taken at four specific frequencies that are most similar to those found within the range of human speech (250Hz, 500Hz, 1000Hz and 2000Hz). This rating system is based on a single number index from zero to 1; zero indicates that the material has no absorption qualities while 1 states that the material provides perfect sound absorption. This rating system is the most commonly used when indicating the acoustical properties of products such as ceiling tile, acoustical wall panels, floor coverings and occasionally construction materials. *(Table 3)*

Because this measurement is based on a frequency range from 250Hz to 2000Hz, those sources of noise both above and below this range will not be accurately tested and further studies will be needed to define the sound absorption properties.

STC – SOUND TRANSMISSION CLASS

The STC rating is based on the reduction of sound vibration as it travels from the source side of a medium to the other side. If an 80dB sound on one side of a wall/floor/ceiling system is reduced to 50 dB on the other side, the Transmission Loss (TL) is said to have an STC of 30. This measurement is typically conducted in one-third octave bands over 16 frequencies (pitches) between the range of 125Hz to 4000Hz. The results of the standard tests are then compiled and an STC rating is assigned. *(Table 4)*

However, the STC number alone cannot provide accurate measurements for frequencies that are below 125Hz because of the increased length between one wave swell and the next, allowing the sounds to wrap around barriers. Examples of sources that project frequencies below 125Hz are traffic noise, heavy equipment operation and industrial equipment. *(Table 1)*

IIC - IMPACT ISOLATION CLASS

The IIC rating system measures the transfer of noise created by physical impact such as footfall through a floor and the ceiling systems below. While this rating is typically used in multi-family construction, the transfer of isolated impact will occur in any multi-story structure. Ratings that indicate the reduction of vibrations within the material surface range from 20 (poor) to 80 (excellent). *(Table 5)*

An example of how impact noise can be the cause of soundproofing failure is a music room where the acoustical materials perform extremely well at stopping airborne sound. Even though much thought was placed on the partition construction which was designed to decrease sound transmission, if the room is on a 6" concrete slab and a musical instrument is dropped, the vibration from the point of contact will travel and actually be amplified in the spaces below. This means that a harder floor finish will provide a lower rating.

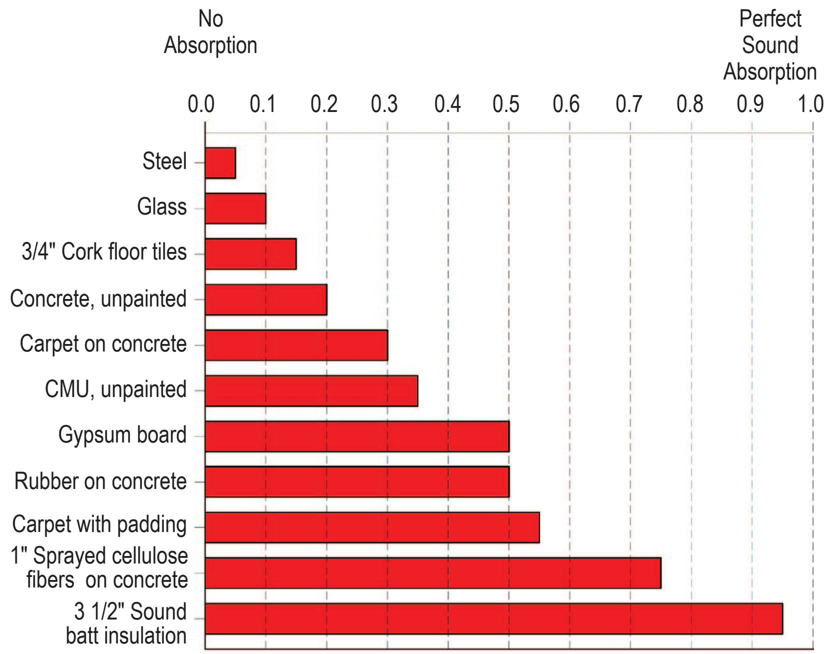

Table 3: Approximate NRC ratings for standard finish materials

	OCTAVE BAND CENTER FREQUENCIES, Hz						Listed STC
	125Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz	
1/2" - Plywood	17	20	23	23	23	24	21
5/8" - Plywood	19	23	27	25	22	30	24
1/8" - Glass	16	19	15	29	30	20	24
1/2" - Gypsum board	18	22	26	29	27	26	26
5/8" - Gypsum board	19	22	25	28	22	31	26
1" Insulated glass system	17	33	40	41	40	54	39
6" Precast concrete	38	43	52	59	67	72	55

Table 4: STC ratings of materials at standard frequency measurements vs. approximate STC ratings listed by manufacturer

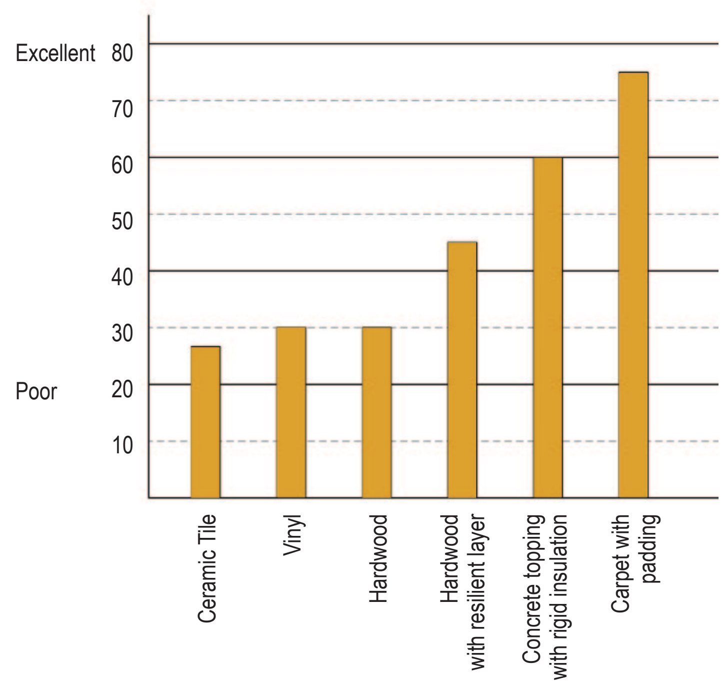

Table 5: Approximate IIC ratings for floor toppings on a 6" concrete slab

4 ELEMENTS OF SOUNDPROOFING

DECOUPLING
Decoupling is the removal of direct contact between components within a building system to prevent sound vibrations from passing from one space to another. By separating the building components, each time the wave encounters a break between adjacent surfaces the wave's energy is weakened and its transfer of noise is reduced.

ABSORPTION
Absorption is the function of a material that collects the energy of the sound wave upon contact and then changes that energy into heat. As the wave's attenuation (loss of intensity) increases, the amount of vibrations being transferred will be reduced.

MASSING
In order for sound to transfer through a floor, partition or ceiling, it must have the ability to move or vibrate that surface. By adding to the mass of a medium, the amount of vibration transferred is reduced because as the weight of a medium increases, its ability to move decreases.

DAMPING
Damping is the separation of two rigid materials with the insertion of a flexible material that provides the ability to partially absorb the energy of a sound wave. One common material used is a viscoelastic polymer, typically placed between two layers of gypsum board or within a floor underlayment system. The properties of a viscoelastic polymer are similar to that of a thin layer of rubber that reflects the force it encounters. However, a viscoelastic polymer also has the ability to absorb wave energy and dissipate it as heat.

SOLUTIONS

FLOORING (Impact Noise)
A floating floor system, acoustical carpet and/or a flooring underlayment can be used to reduce unwanted sound transmission, typically transferred by impact noise. Materials such as nylon, wool, rubber, natural cork, mass loaded vinyl, rigid foam board and gypsum concrete are options to combat these noises. Because this paper is focusing on commercial and not residential buildings, the following information is looking at a concrete fill on metal deck.

- ***Carpet***

Carpet is a floor finish typically chosen for its appearance and durability, but when properly selected it also has the ability to absorb both airborne and impact transmissions. A standard carpet is composed of a finish material, typically nylon, olefin, polyester or wool or a blend of these; structural backing; and the optional addition of padding placed directly on the subfloor.

The qualities that the exposed fibers provide are similar to those of sound insulation, absorbing the airborne noise waves and converting the sound energy into heat. In addition, the carpet surface lacks rigidity and absorbs much of the impact vibrations before they are transferred to the structure below.

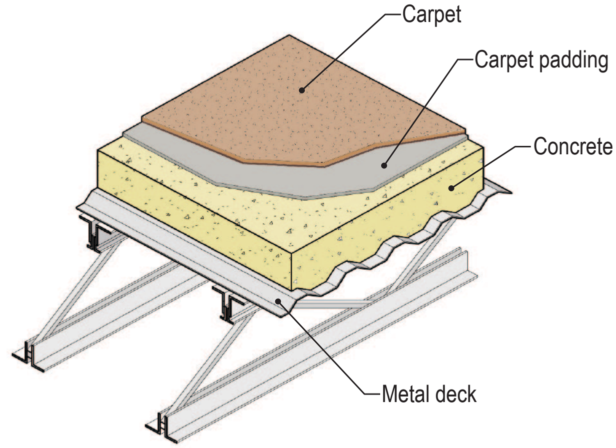

Figure 1: Carpet and padding for sound absorption

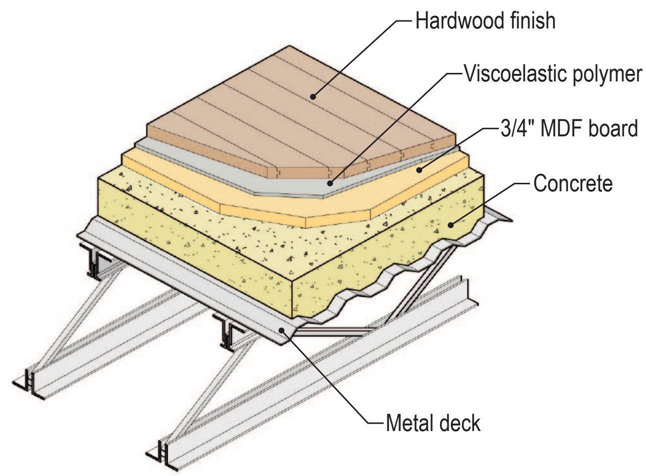

Figure 2: Subfloor and viscoelastic membrane for sound damping

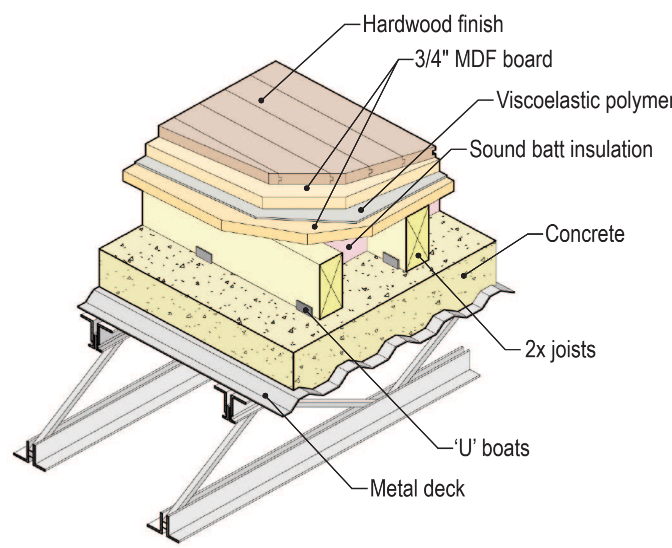

Figure 3: Floating floor system for sound decoupling

Carpet backing is composed of two layers. The primary layer is a course material to which the fibers of the carpet are woven or tufted. The second is a smoother, semi-rigid material that is placed on the structure below to provide a barrier from moisture, bacteria and mold.

If additional soundproofing is required, carpet padding can be placed between the carpet backing and subfloor surface. The flexible padding separates the semi-rigid carpet backing and the structural subflooring and, in doing so, reduces the path of impact noise by damping the transmission. *(Figure 1)*

- ***Rubber Underlayment***

Similar to the viscoelastic polymer used in wall partitions, the placement of a resilient underlayment works best when installed between two rigid surfaces. With a standard thickness of 5mm (1/4") the rubber material is placed between the structure and the subfloor above to separate the two rigid mediums. *(Figure 2)*

- ***Floating Floor***

The reduction of direct contact between materials (decoupling) is the best way to stop impact noise transmission; this can be accomplished through the use of a floating floor system. The separation from the rigid structure and surrounding walls can be achieved with the construction of a secondary floor that is not permanently fixed.

The placement of glass fiber, felt or cork layers, neoprene pads or wood joist framing between the raised floor and the structure below can be used to reduce or eliminate the direct contact points between the two rigid systems. The separation between the floating floor and its surrounding walls can be hidden by skirting boards or molding to prevent debris from falling into the space below.

The placement of sound batt insulation between the subfloor and primary structure will increase the absorption of the sound wave energy, thereby reducing the transfer of impact noise.

While floating floors provide the highest performance when stopping impact noise vibration, this system should not be used near exterior openings or areas that need to be cleaned regularly with chemical or water based solutions. *(Figure 3)*

- ***Natural Cork***

Compared to rubber underlayment, natural cork exhibits a much lower level of performance. It will take more than a 20mm (1") thickness of cork to provide a comparable level of sound damping and has been tested to perform only 1/3 as well as the solid rubber layer when at the same depth. In addition, with floor finishes such as hardwood and laminates, a moisture barrier might be required.

- ***Mass Loaded Vinyl (MLV) and Rigid Foam Board***

These are materials that can be placed between the finish surface and subfloor below, however the level of sound damping for these options are low and are not primary choices.

WALL PARTITIONS (Airborne and Flanking Noise)

The wall partition has the largest surface subjected to the challenges of stopping sound transmissions from entering adjacent spaces. While impact transmission is included in the three forms of sound transmission, airborne and flanking transmissions are the two most frequent areas of concern.

As air pressure (energy) waves strike a solid surface, they take the form of vibrations that travel from the source side to the adjacent space. The standard partition, in this case a metal stud wall with a single layer of gypsum board on each side, provides a poor form to block the sound transmission. Two basic reasons for its failure are:

- The gypsum board is rigidly connected on both sides to a single metal wall stud, allowing vibrations to pass through, creating an identical vibration on the opposite side.

- The open cavity located between the studs captures the airborne vibrations and allows them to randomly reflect within, which adds to the surrounding gypsum board movement.

By incorporating the four elements of soundproofing (decoupling, absorption, mass and damping) the following steps will greatly increase the wall's ability to reduce sound transmission.

- ***Single Stud***

A reduction of the rigid connections or decoupling is the best way to restrict the sound transmission. The addition of horizontal soundproofing hat channel clips placed between the gypsum board and vertical metal studs reduces the surface contact area. *(Figure 4)*

- ***Staggered Stud***

The use of a staggered stud configuration increases the width of the floor and ceiling runner but breaks the rigid connection of two wall surfaces that originally shared a single metal stud. *(Figure 5)*

- ***Double Stud***

A more effective solution is the use of a double stud wall system. While the width of the partition increases, the use of separate floor and ceiling runners removes all points of contact. *(Figure 6)*

Each of the options above can be viewed as separate solutions, but many of the specific components can be combined to create a hybrid system that addresses the specific conditions at hand.

While the reduction of direct contact reduces sound transmission, the open cavity between the studs still allows the passage of airborne noise to be trapped and resonate. Filling the cavity with acoustical insulation means more sound waves are absorbed and converted to heat. This insulation should have interconnecting air pockets or cells that maintain a light, airy composition and absorb the energy waves.

Because it is the thickness of this material and not its weight that raises the absorption level, fiberglass insulation provides a better noise barrier than rock or mineral wool.

Increasing the wall density will reduce its ability to transfer vibrations due to its weight; however, this weight must be applied to the surface of the wall and not its core. Additional layers of gypsum board will provide this mass and will be most effective if applied to the source side of the partition.

To increase the performance of a partition, a viscoelastic polymer film or a damping adhesive can be placed between two layers of gypsum board on the source side to eliminate the direct contact between the two finish layers.

The solutions described above will increase the sound separation assembly as a whole, however the issue of flanking transmission or paths of travel around the designed barrier must also be addressed.

- ***Doors***

A hollow core door is poor at blocking sound vibrations so the use of a solid wood door or one with an insulated core will play a larger role in the reduction of sound vibrations.

The contacts between the doors and frames should be separated with proper gaskets while fitted seals should be located at the head, jamb and sill.

- ***Windows***

A single pane window is extremely vulnerable to sound vibrations so the use of a double glazed, Low-E, argon gas filled storefront window system with proper caulk and sealant located at the mullion, wall and deck connections will provide a much better sound barrier.

- ***Mechanical, Electrical & Plumbing Systems***

Electrical outlet boxes should be placed in an alternating pattern and not share a single stud cavity. All cutouts for electrical boxes, plumbing pipes and ductwork should fit tightly, and these openings should then be caulked and sealed.

Exposed surfaces of ductwork should be wrapped in an insulating material and internal acoustical dampers should be used where the ductwork enters an adjacent space.

CEILING SYSTEMS (Airborne, Impact & Flanking Noise)

As the third and final component of a typical soundproofing assembly, a ceiling system must have the ability to break impact noise vibrations; reflect the flanking noises that pass through wall penetrations; and absorb airborne noises that enter the space at each ceiling/wall connection.

Ceilings can be a suspended system hung by metal wires or a rigid system attached directly to the structure above, or the structure can be left exposed. The choice of the system might be based on aesthetic desires, cost limitations or acoustic balance. Leaving the structure exposed provides little to no acoustical qualities and therefore will not be reviewed.

- ***Suspension Ceiling System***

A drop ceiling creates an open space, or plenum, between it and the structure above. Its primary purpose is to conceal pathways for mechanical equipment and/or open return airflows. The suspended ceiling is hung in a grid-like canopy by metal hangers, metal wires and clips that connect directly to the metal channel supports above.

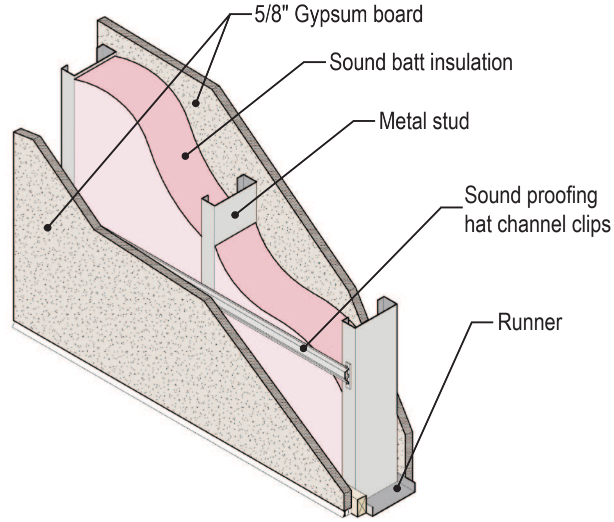

Figure 4: Single stud and sound batt insulation for sound absorption

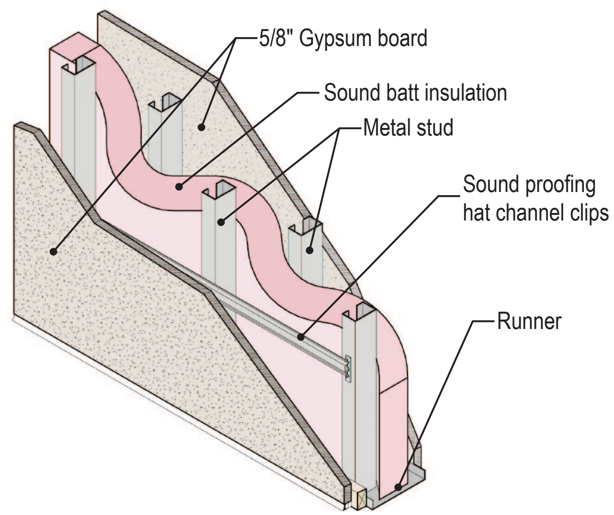

Figure 5: Staggered stud and sound proofing hat channel clips for sound decoupling

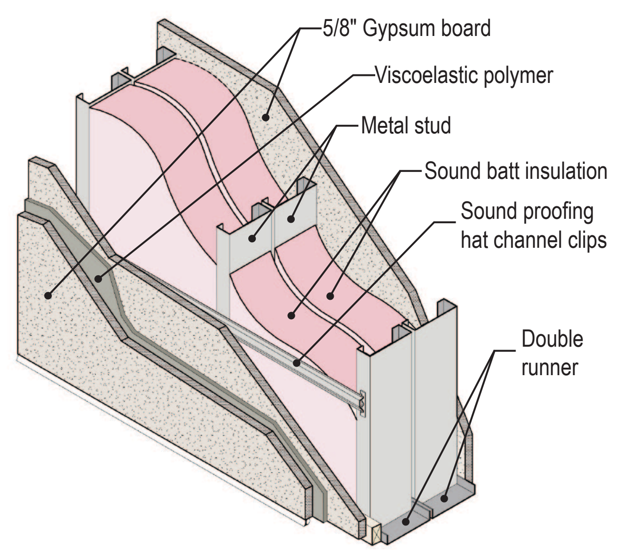

Figure 6: Double stud viscoelastic membrane for sound damping

The transfer of impact noise can be reduced by adding a rubber/spring isolator hanger and/or a cable isolator hanger to the suspension cable system. These hangers will break the vibration's direct path of travel between the structure and ceiling grid.

A light, fiberglass insulation placed above the tile within the plenum will absorb both flanking and airborne noise by reducing the sound wave energy. In addition, the use of ceiling tiles with a high NRC rating will assist in the attenuation of the sound. *(Figure 7)*

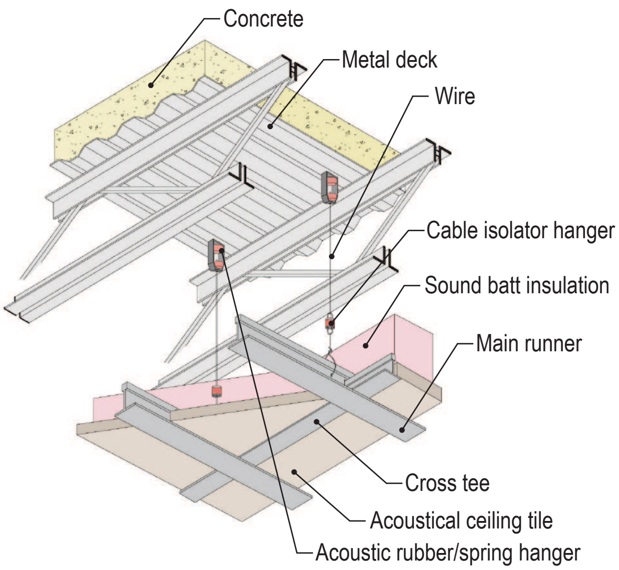

Figure 7: Suspended ceiling system with acoustical tile and isolator hangers for sound decoupling

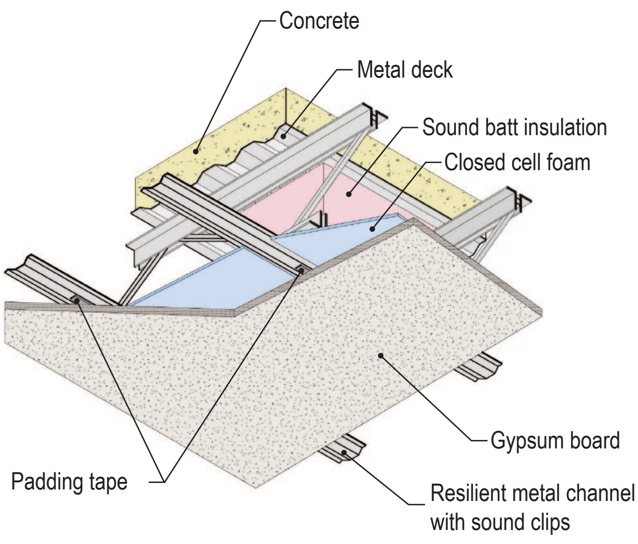

Figure 8: Rigid ceiling system with sound batt insulation and closed cell foam for sound absorption

- ***Rigid Ceiling System***

Unlike the suspended ceiling, the rigid metal ceiling system has a much greater area of direct contact between the finish material and the structure above. For best results, resilient channels with sound clips should be attached to the structure system, perpendicular to the joists/beams.

The addition of sound batt insulation between the joists will assist in the absorption of the airborne and flanking transmission. If conditions require additional reduction, the attachment of a second layer of gypsum board via liquid nail glue will increase both mass and damping ratings. *(Figure 8)*

CONCLUSION

Sound is the movement of air pressure (energy) waves that travel through both air and water, transferred in the form of vibrations that are created when energy waves strike a physical surface. The transfer of airborne, impact and flanking transmissions will use the floor, wall and ceiling assembly to travel from one space to another.

A well-designed soundproofing assembly will provide barriers that decouple, absorb, block and reflect the sound waves by reducing their ability to travel to the adjacent space. Every space will have its own combination of challenges, but the design of the barrier along with the appropriate use of materials will assist in the reduction of noise transmission.

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