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Flooring & Acoustics: Dispelling the Myths of the Role Flooring Plays in Room Acoustics

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Contents

Acoustics has become an ever increasing factor in modern construction. Whether in healthcare, education, residential housing, or any other industry, acoustics plays an important role in nearly every sector of the market. For example, there are guidelines on how loud classrooms should be, how much noise workers can be exposed to, and even the level of privacy required in sensitive office spaces. To accomplish these goals, numerous metrics and standards have been created to assess various acoustic characteristics of building components.

Unfortunately, there is now so much data available that it can become confusing when trying to evaluate the acoustic needs of a space. This is particularly true when referring to flooring. According to Ken Roy, PhD, Senior Principle Scientist with Armstrong World Industries, "While it is true that the choice of flooring surface can alter the acoustics within a room, the effects are generally small when compared to the options available in acoustical ceiling and wall treatments." The bottom line is that the primary purpose of flooring is generally not acoustics-related, and there are more efficient means of tackling acoustical concerns. It is the goal here to dispel some persistent myths and examine the importance of flooring in room acoustics.

Room Acoustics Basics

Before addressing flooring specifically, let us briefly review how sound energy propagates within buildings. In general, sound energy can be generated in two ways: through the air and/or through the building structure. Many noise sources, such as loudspeakers placed in contact with the floor, can produce both airborne and structure-borne acoustic components.

Once sound energy is airborne or structure-borne in a building, it will interact with the surrounding floor, walls, and ceiling. At each boundary, portions of the sound energy will be reflected back into the room, absorbed by the contacted surface, or transmitted through to adjacent spaces. (See Figures 1 & 2.) The surface materials and room construction determine how the sound energy will propagate. Specific metrics, such as NRC, STC, and IIC (defined on pages 2 & 3), have been developed to quantify these properties.

Figure 1: Airborne Sound (Transmitted)

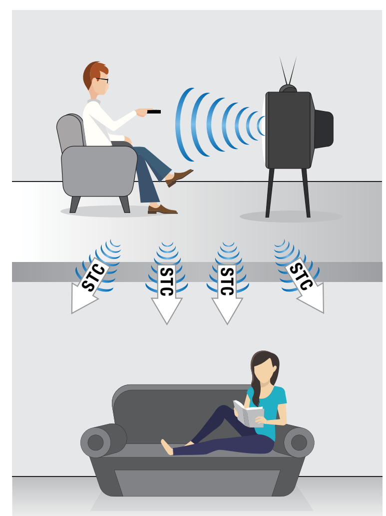
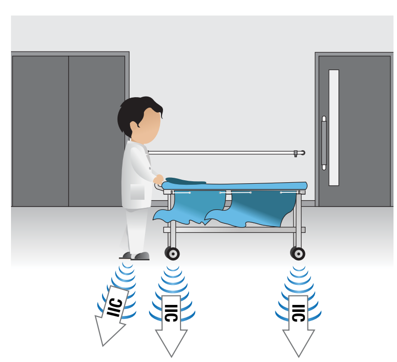


Figure 2: Structure-Borne Sound (Vibration)



Other room acoustic concepts to introduce before describing sound propagation in buildings further include frequency and reverberation time:

Frequency: Sound results from vibrational waves in matter, and frequency quantifies the rate of those vibrations, measured in Hertz (Hz) or cycles per second. Human hearing ranges from 20 Hz to 20,000 Hz, and humans perceive different frequencies as having different pitches. Low frequencies are considered to be below 250 Hz; high frequencies extend above 2000 Hz. For most room acoustical data and analyses, frequencies are grouped into octave bands or 1/3 octave bands. Octave bands labeled from 125 Hz to 4000 Hz are often of interest, as they encompass the primary range for human speech.

Reverberation Time (RT): Reverberation time is the time it takes for sound energy to decay 60 decibels (dB) within a room. The reverberation time of a space is a function of its room volume and total surface absorption. A large room or a room with very reflective surfaces will have a longer reverberation time than smaller more absorptive ones. Optimum RTs for a space depend on how the room will be used. In general, lower RTs (< 1 sec) are preferred for general speech purposes, while longer RTs (~2 sec) are desired for musical performances.

Surface Absorption

When sound energy encounters a room surface, a portion of it is absorbed and converted to heat. The amount of sound energy absorbed is quantified by a material's absorption coefficient. These values range from 0 to 1.0, with 1.0 representing complete absorption. In general, smooth materials have very low values (<0.1). In contrast, materials which are fibrous and porous tend to have higher values (>0.6). Material thickness also increases absorption values. Surface absorption is frequency dependent, so materials can have different absorption characteristics at low, mid, and high frequencies.

Noise Reduction Coefficient (NRC): NRC is a single number metric used to represent the average absorption of a surface across the central range of speech (250 – 2000 Hz). In practice, NRC is an efficient means of assessing the effectiveness of a particular material across the most important frequency range, making it a good comparative tool when selecting products. (See Figure 3.)

Figure 3: Comparative NRC for Various Flooring Products[1]

	Frequency (Hz)						
Floor Covering	125	250	500	1,000	2,000	4,000	NRC
Rubber Sheet	0.03	0.01	0.07	0.06	0.05	0.01	0.05
Armstrong® BioBased® Tile	0.00	0.00	0.00	0.03	0.05	0.05	0.00
Armstrong Linoleum Tile	0.01	0.01	0.00	0.02	0.07	0.09	0.05
Armstrong Natural Creations® with Diamond 10™ Technology	0.01	0.00	0.00	0.03	0.06	0.03	0.00
Armstrong Abode Sheet	0.01	0.00	0.03	0.06	0.05	0.06	0.05
Carpet Tile	0.00	0.02	0.04	0.12	0.24	0.39	0.10
Ceiling Tile (Commodity)	0.05	0.15	0.50	0.75	0.65	0.50	0.50
	Low		Mid		High		

Regarding flooring, significant absorption values at higher frequencies can only be achieved by installing heavy carpet with padding, but absorption at lower frequencies is limited. Most low or medium pile carpets simply do not exhibit material properties to provide substantial absorption.

Airborne Sound Transmission

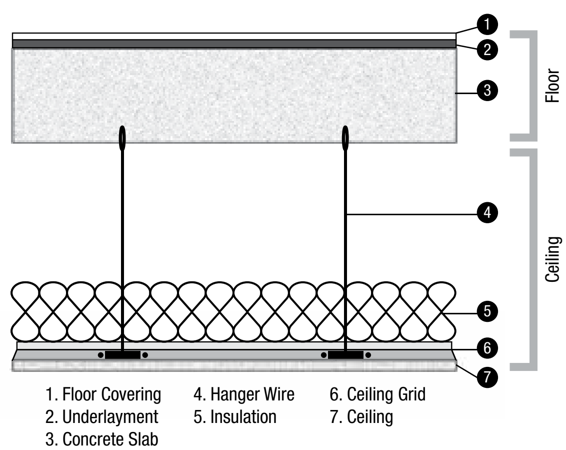
Upon encountering a room surface, another portion of the sound energy may be transmitted through to adjacent spaces. For airborne sound energy, one can quantify the sound transmission loss across different building materials and constructions in a straightforward manner, typically with the test material or construction placed between a source room which houses a sound source and microphone, and a receiving room which houses a second microphone. Some terms that are commonly used to describe acoustics of airborne sound transmission are then as follows:

Transmission Loss (TL): TL is the difference between the source and receiving room levels, accounting for the fact that some sound energy is absorbed as well. Like absorption coefficients, these values will vary across frequency, and are frequently reported in one-third octave bands.

Sound Transmission Class (STC): STC is a single number metric used to quantify the transmission capabilities of a wall (primarily) or flooring assembly based on TL values from 125 Hz to 4000 Hz. The ASTM E413 and E90 standards define the methods involved; in short the TL values across frequencies are matched to a standard contour to determine the single number rating. An STC rating is useful in assessing various material constructions; however, one should be aware that materials and constructions with identical STC ratings can still behave quite differently due to varying TL behavior across frequency.

An important concept to note about STC is the fact that sound transmission is a function of the entire assembly construction. (See Figure 4.) The primary structural components (concrete slab, wood frame, etc.) and the manner of construction (stud spacing, wall thickness, etc.) are both significant factors in determining the STC of a floor or wall. Consequently STC values provided by manufacturers should be interpreted with care, depending on if the product will be installed as it was tested; similarly, product STC ratings are not comparable unless testing is done on the same substructure. Overall, surface treatments are considerably less important to airborne sound transmission.

Figure 4: Illustration of Structure for STC/IIC Testing



Another important factor to consider with regards to sound transmission is that sound energy can pass through building constructions in other ways, such as through open penetrations (referred to as leakage) or indirect paths (i.e. ductwork connections) found in the field but not in laboratory testing situations. These other paths significantly reduce the insulation capabilities of the structure, resulting in field STC values that may be 7 points lower than laboratory reported ones.

Impact Sound Transmission

Structure-borne noise is generated by sound sources in direct contact with the building structure, typically due to short term impact (i.e. footfall noise) or more periodic vibration (i.e. from a vibrating piece of machinery). Sound travels much faster through building structure than through the air.

Impact Insulation Class (IIC): To quantify the impact sound insulation capabilities of a floor assembly, the IIC metric was created. It is similar to STC in that it compares the sound levels in two (vertically) adjacent rooms. A contour matching method is used to produce a single number to represent the assembly's effectiveness against impact noises. There are two main differences between IIC & STC. First, the noise source utilized in IIC measurements is a tapping machine contacting the floor of the upper space. Second, the surface of the flooring does indeed play an important role in reducing impact noise. Carpet and padding, including low or medium pile, reduce the 'clacking' of impact sources on a building structure, thus significantly increasing IIC ratings, especially in wood construction. A floor construction with carpet and padding may have a high IIC rating then, but demonstrate low STC (against air-borne noise). When adding a floor covering increases the IIC of a building construction by 10, the sound level is perceived to be half. For the human ear to hear the difference, the sound level must change by at least 3 dB. Figure 5 shows comparative IIC data for a variety of flooring materials conducted on the assembly shown in Figure 4.

Figure 5: Comparative IIC & Delta IIC for Floor Coverings[1]

Floor Covering	IIC	Delta IIC
Rubber Sheet	47	6
Armstrong® BioBased Tile	50*	6
Armstrong Natural Creations® with Diamond10™ Technology	51*	11
Armstrong Abode Sheet	56*	12
Armstrong Natural Creations with Diamond10 Technology and Quiet Comfort Underlayment	65*	NA
Carpet Tile	68*	14

** International Building Code requires an IIC minimum of 50.*

Delta Impact Insulation Class (IIC): ASTM E-2179, also known as the "Delta" test, determines the noise reduction that a product adds to the assembly. This test consists of two IIC tests conducted over the same concrete subfloor. One test is over the bare concrete subfloor (no flooring materials) and the other is over the concrete subfloor with floor covering material. The measured IIC values are compared to the reference floor levels defined in the standard and adjusted to provide the IIC the covering would produce on the reference concrete floor. Figure 6 provides comparative Delta IIC data for a variety of flooring materials.

Industry Segments

So far, the properties of sound propagation and the metrics used to measure these phenomena have been discussed, which are valid across all business segments. The next sections discuss specific flooring concerns that arise in specific industries. (See Figure 6.)

Figure 6: Metric Importance by Segment for Flooring[1]

Segment	NRC	STC	IIC
Healthcare	Low	Moderate	High
Education	Low	Moderate	Moderate
Multi-Family Residential	Low	High	High
Retail	Low	Low	Low
Office	High	Low	Low

Healthcare: In hospitals and doctors' offices, the most prevalent surfaces are hard, sealed floors due to its many inherent benefits. A recent study by Health Care Without Harm showed that when choosing, "the four priority issues that went into flooring decisions for all of the user types were cleanability, aesthetics, durability and initial cost." Acoustical considerations with regards to flooring are more secondary. Hospital facilities involve massive structural elements, which can naturally lead to low sound transmission between levels. And if absorption is required, using floor coverings is an inefficient way to achieve that as reviewed earlier. The issue that arises with these hard floors is the propagation of structure-borne impact noise, particularly from carts and footfall. Such noise has been found to affect patient health due to the additional stress imposed. Consequently, carpet is becoming more prevalent in high traffic areas of hospitals, like hallways and waiting rooms. However, a recent study by the Center for Health Design at Palomar Health concluded that the combination of hard flooring and the addition of acoustical ceiling tiles may be more effective than carpeting at reducing maximum noise levels[3].

Education: As with the healthcare industry, most flooring found in schools are hard, resilient surfaces for functionality and durability purposes. Carpet can and is installed, especially inside classrooms to reduce impact noises such as chairs scraping against floors. Classrooms generally require lower background noise levels and lower reverberation times to ensure that students can clearly hear instructors, but absorptive materials with high NRC for achieving this in classrooms are more effectively placed on the ceiling or upper wall.

Office: Unlike healthcare and education, carpet has been a trend in the office segment for several years. Carpet, as well as ceiling tiles and partitions, is installed to address unwanted sound. In an office the main distracters are "people sounds"— phone conversations, throat clearings, vacuum cleaners—anything a listener can detect and that distracts. Background sounds, like an HVAC system, that are regular and predictable are easier to block out than disruptive sounds, like conversation over a cubicle wall. When ceiling tiles, which are highly absorptive, are used in conjunction with other highly absorptive products like partitions, they can play an essential role in office acoustics.

Residential: Single residential homes are not generally concerned with having high STC, IIC, or enough acoustic absorption, except perhaps in large volume atriums or such spaces. Room furnishings often provide enough absorption. However, multifamily residential complexes can play host to a number of acoustic issues, such as maintaining acoustic privacy while reducing footfall noise, bass heavy music, and many other noise sources found in home environments. In these cases, it is important to use floor assemblies with high STC and IIC; NRC remains of less importance. STC and IIC are so important that the International Building Code requires floor/ceiling assemblies between dwelling units or between a dwelling unit and a public or service area within the structure to have an IIC rating of not less than 50 when tested in accordance with ASTM E 492 and an STC of not less than 50 when tested in accordance with ASTM E 90.[8]

Choosing the Correct Flooring Solution

When addressing the acoustical needs of a building and subsequent flooring concerns, there are many factors that must be considered:

- **Acoustic Goals:** Among the first questions that must be answered are: What are the acoustic goals of the space? Is there significant noise? How quiet does it need to be? Are there specific requirements for reverberation time or other acoustic metrics that must be adhered to? Would acoustical treatment be useful, feasible, or financially justifiable? These goals should be identified before selecting solutions.

- **Building Layout:** If a building includes a particularly noise sensitive space, the location of that space should be placed to minimize sound transmission from interior or exterior noise sources. Conversely, particularly noisy rooms or equipment should be isolated.

- **Building Construction:** As has been discussed, the type of construction determines many acoustical parameters, including STC and IIC. A structure built using concrete slab will exhibit different acoustical strengths and weaknesses compared to steel or wood. If minimizing sound transmission between vertical spaces is an important goal, it should be addressed early in project development by carefully considering the building construction and flooring material in tandem.

- **Acoustical Treatments:** Using absorptive acoustical treatments to reduce reverberation and increase speech intelligibility within a space is more efficiently met by applying acoustical wall and ceiling treatments, rather than flooring solutions. Acoustical ceiling tiles are especially useful, given the large potential surface area, ease of installation, and the availability of high absorption materials. Hanging acoustic wall panels are also very popular and can be designed to accommodate any décor.

In summary, the absorption and transmission of sound energy in a built environment is impacted by the type of construction and building materials selected, and this is true for flooring. The greatest impact flooring has on the acoustic environment is related to the transmission of impact noise (IIC), but it has much less influence on the transmission of air-borne noise (STC) as those characteristics are more dependent on the construction of the subfloor. Flooring is also not an efficient way to deal with absorption of sound within spaces (NRC), compared with acoustic wall and ceiling treatments. Careful consideration of the acoustic goals for your building spaces is essential prior to making construction and material selections, and flooring does have a role in achieving optimum indoor environmental quality for building occupants — just not a major one.

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