The Impact of Flooring on Acoustics in Athletic Facilities

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Athletic facilities are growing in popularity across the country as demand for more wellness and physical activity increases. The types of activities people engage in for exercise, as well as how they incorporate it into their daily lives, are rapidly changing the way athletics environments are constructed. Educational institutions now incorporate fitness into their daily lessons and dedicate more resources to the design of their sports complexes, while residential and hospitality industries are updating their amenities to include more robust fitness-based resources to cater to an increasingly health-conscious audience.

Simultaneously to meet fitness demand, athletic and fitness amenities are being added into multipurpose buildings such as apartment complexes, schools and commercial centers. These structures must accommodate a variety of uses, such as offices, libraries, studios and conference rooms. When incorporated in a multiuse building, the acoustical performance of a modern athletic facility can have a ripple effect on the performance and safety of its athletes, as well as the environment of adjacent spaces. The distracting noise of a bustling fitness center can annoy co-occupants and hamper productivity in an adjacent office space.

Building architects, designers and engineers must take acoustics into consideration when constructing modern athletic facilities. Effective acoustic design should be a fundamental requirement of almost every fitness space. Yet, many of the most cost-effective and beneficial measures are often overlooked, including the specification of appropriate flooring.

Basics of Sound

To properly manage sound in a structure, designers must understand the basics of sound and noise. Sound is vibration and sound waves travel from the source of the sound to the ear. Different sounds vibrate with waves of different lengths. These wavelengths are measured as the distance from crest to crest within the sound wave.

The wavelength of a sound is related to its frequency measured in Hertz (Hz), which gauges how many times it vibrates per second. Sounds with shorter wavelengths have higher frequencies – such as voices. Longer wavelengths correspond to lower frequencies – such as dropped items and pounding. The magnitude of sound, commonly referred to as loudness, and is expressed as a sound pressure level measured in decibels (dB).

While we usually think of sound waves as traveling through the air, sound waves can also interact with building elements, such as ceilings, floors, and walls. Depending on the materials and the characteristics of the room, sound waves might be absorbed, reflected or transmitted to adjacent spaces.

The human ear can distinguish an extremely wide range of sounds, from very faint to extremely loud. In terms of frequency, most human speech is in the range of 125 to 4,000 Hz, but humans can perceive frequencies from 20 to 20,000 Hz.

Decibels are measured on a logarithmic scale with every increase of 3 dB representing a doubling in sound energy. For instance, if one person talking produces a sound level of 60 dB, adding another person speaking just as loudly will only raise the sound level to 63 dB. However, humans typically associate a doubling in perceived loudness with an increase of 10 dB, so to double the perceived loudness we would need to add people until the total sound level reached 70 dB.

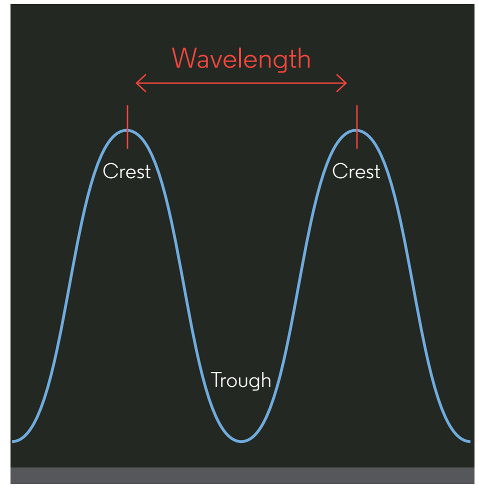


Figure 1: Illustration of Wavelength

Common Sound Levels

Sound Intensity -dB	Subjective Interpretation	Sound Sources
140	Painful (and dangerous)	Jet take-off (75 ft away)
130	Threshold of pain	Jet aircraft during take-off (300 ft away)
120	Deafening	Accelerating motorcycle (a few ft away)
100	Very loud	Car horn at 10 ft, operating jack hammer; printing press
80		Cafeteria with sound-reflecting surfaces
70	Loud	B-757 aircraft cabin during flight
60		Nearby highway traffic
50	Moderate	Office activities
40		Soft stereo music in residence
30	Faint	Residence without stereo playing (late at night)
20		Rustling leaves, whisper
10	Very faint	Human breathing
0	Threshold of hearing	

Figure 2: Common Sound Levels

Sound vs. Noise

While "sound" is clearly defined by science, "noise" is often a much more subjective designation. In general, sounds that register as "noise" have common characteristics:

- Loud enough or of such high intensity that they are uncomfortable
- Intermittent and unpredictable rather than continuous
- Competing or interfering with the sounds people are trying to hear

The goal of acoustic design is to reduce unwanted sound and make desired sound clearer and easier to understand. In doing so, designers can improve safety and comfort for those in and around the space.

In fact, prolonged exposure to dangerous sound levels – which begins at 80db – can lead to health problems. To protect an individual's hearing, the Occupational Safety & Health Administration (OSHA) guidelines allow for eight hours of exposure to 90 dB of sound, but only two hours of exposure to 100 dB sound levels per day. The National Institute for Occupational Safety & Health (NIOSH) recommends limiting eight-hour exposure to less than 85 dB and only 15 mins of 100 dB exposure daily.[i]

Time to reach 100% noise dose	Exposure level per NIOSH REL	Exposure level per OSHA PEL
8 hours	85 dBA	90 dBA
4 hours	88 dBA	95 dBA
2 hours	91 dBA	100 dBA
1 hour	94 dBA	105 dBA
30 minutes	97 dBA	110 dBA
15 minutes	100 dBA	115 dbA

Figure 3: Centers for Disease Control and Prevention – Noise and Hearing Loss Prevention https://www.cdc.gov/niosh/topics/noise/reducenoiseexposure/regsguidance.html

To keep decibel levels low in a space, designers must consider how sound waves move. There are three basic physical possibilities for a sound wave:

Reflected

When reflected, sound bounces off of a surface back into the room. This may create echoes and reverberation. Hard surfaces are highly reflective, and the more reflective surfaces there are in a room the more the echoes will bounce back and forth. If there are parallel hard surfaces in a room, the bouncing sound waves can create flutter echoes, which further increase perceived noise levels.

Absorbed

Sound waves are absorbed when they hit a soft, fibrous material where energy is converted into heat via friction. These materials absorb sound by dissipating the acoustic energy within the material itself rather than reflecting it back into the room.

Transmitted

When a wave goes right through a thin material or an opening – such as a crack or gap – it is transmitted. This also can occur when the wave causes part of the structure itself to vibrate and transmit the sound. These structural vibrations often transmit sound through floors, partitions, piping or building frames.

Higher frequencies are more likely to be reflected by materials in a room, while the long wavelengths of lower frequencies can more easily pass through and around materials. For example, if an exercise instructor is playing music, both the melody and bass lines may be heard in the exercise room, while only the thumping bass line is heard in the office space below.

In most spaces, absorbing sound within the room and blocking transmission of sound between adjacent spaces are equally important. In a fitness facility, athletes must be able to hear instructions from their coaches and trainers without being distracted by music or the sound of heavy weights dropping from other areas of the building.

Therefore, how much sound is reflected and how much is absorbed or transmitted must be controlled using materials within the room. Materials such as insulation, foam or rubber can mitigate, muffle, or dampen noise, while hard surfaces like tile, stone and glass can dramatically increase noise levels. Designers must understand the testing and rating of these materials so as to predict how products will impact sound and acoustics within the space.

Measuring Acoustics

Small variations in the ratings of a material can greatly impact acoustics. For flooring, there are four ratings designers should understand and use when selecting materials: Noise Reduction Coefficient (NRC), Impact Insulation Class (IIC), Delta IIC, and Sound Transmission Class (STC).

Noise Reduction Coefficient (NRC)

NRC measures how much sound a finish material absorbs when hit by a sound wave. Any sound the material does not absorb will either be reflected or transmitted. NRC is a single number rating from 0 to 1 with 0 being totally reflective and 1 being totally absorptive. A basic smooth surface flooring might have an NRC rating of 0.10.

Rooms with very hard surfaces and low NRC ratings absorb very little sound. Most of the sound from voices, laughter, footsteps and music are reflected back into the room and bounce around with other sound waves to cause echoes, reverberations and poor speech intelligibility.

Impact Insulation Class (IIC)

IIC is a measure of the reduction of impact noise provided by a floor-ceiling assembly. Impact noise is not airborne sound like music or people talking. IIC tests address sound from light impacts like footfall during a dance class. The higher the IIC rating, the more effective the floor-ceiling assembly is at isolating the vibrations and impact sound.

IIC ratings are greatly affected by the flooring materials used in a space. More rigid materials are less effective than those that offer internal damping of sound. For example, the rating of a basic hardwood floor with no underlayment might be IIC 30. Adding an effective underlayment might boost the IIC rating to 50-55, by dramatically reducing the transferred vibrations and noise.

The IIC rating is the most important for the accurate evaluation of acoustic flooring products, particularly when they are to be used anywhere in buildings of more than one story. According to the International Building Code (IBC), the minimum IIC rating is 50 for multi-family buildings. Most local building codes are based on the IBC and most have minimum acoustic requirements for multi-family buildings. However, these are minimums and are not likely to come anywhere near meeting the needs of most carefully designed spaces.

Although IIC ratings may not be a code requirement for other types of buildings, they can be a useful tool when trying to reduce the effect of impact noise on noise-sensitive spaces such as classrooms, conference rooms and hospital rooms.

Delta IIC

Delta IIC is a way of determining the rating of the flooring product itself, subtracting it from the total measurement for the rest of the building assembly.

Testing under this ASTM standard first measures the bare 6-inch concrete slab assembly without any flooring products to get a baseline IIC rating. Then the entire assembly is tested again after flooring products are installed for an overall IIC rating. The difference between those two test results is the Delta IIC rating for the flooring products only.

Understanding this distinction helps simplify product comparisons. When evaluating the ratings, be sure to note what products are included in the testing. It is important to know which floor coverings are tested in conjunction with an underlayment to generate an accurate Delta IIC rating. Be sure to also remember that the Delta IIC testing was conducted on a concrete slab, and while the ratings are helpful in understanding product performance, they may not be directly applicable to non-concrete structures.

Sound Transmission Class (STC)

STC is a measure of how partitions and/or floor-ceiling assemblies reduce the airborne sound being transmitted through them. Higher values indicate less transmission of airborne sound. The International Building Code specifies the same minimum for STC as for IIC: 50.

STC is significantly affected by mass and is typically not significantly affected by flooring materials. For example, whether a floor-ceiling assembly is made of a concrete slab or wood joists will be more of a determining factor in the STC rating than the type of floor covering used. However, there are some instances where providing significant mass, like a concrete slab, on top of an acoustical underlayment, like a thick rubber mat, can provide improved STC ratings.

Quick Guide to the Ratings	
STC (Lab Test)	ASTM E90
STC (Field Test)	ASTM E336
IIC (Lab Test)	ASTM E492
IIC (Field Test)	ASTM E1007
Delta IIC	ASTM E2179

Figure 4: Quick Guide to Ratings

Important points to remember about all ratings:

- All ratings are very useful for comparison, but they are not absolute indicators of real-world performance. Tests are performed on small models or specimens of the assembly and product, not on an entire floor.
- All ratings are for an entire specific assembly, not for an individual material. (ΔIIC is an indicator of the products contribution but still tests a complete assembly.)
- Differences in the specific flooring assembly tested are critical. For instance, you can't compare Product A tested on an 8-inch slab with a gypsum board ceiling to Product B tested on a wood truss assembly with no ceiling.
- A very effective flooring material can allow even basic assemblies to exceed building code requirements.

Acoustic Concerns in Athletic Facilities

The acoustic issues found in typical athletic facilities stem from the nature of their construction and the specified materials or surfaces. Many facilities are built as large, open spaces dominated by hard walls and ceilings that reflect sound. The materials used on parallel walls, floors and ceilings must be strong and durable, which often leads to the specification of hard surfaces such as concrete, metal, brick or plasterboard.

Common sources of sound that should be isolated or dampened throughout an athletic facility include:

- Weights dropping or hitting each other
- Cardio machines
- Footsteps or pounding
- Exercise class music
- Structural sounds – HVAC systems, pipes, motors, generators, etc.

Many of these sounds can travel quickly and create unwanted noise in other spaces within a building by sending vibrations through pipes, frames, duct work, ceilings or electrical junctions. To isolate the sounds within an inclosed space and dampen their impact, absorptive materials must be used to shorten or eliminate reverberation while irregular surfaces should be arranged to reflect sound in different directions.

New technology in flooring materials enables athletic facilities to provide a strong, durable foundation for a variety of intense activities while helping to dissipate acoustic energy for improved acoustics.

Different Flooring Material Options for Athletic Facilities

Athletic surfaces can play a key role in determining the athletic performance, safety, acoustics, aesthetics and usability of a space. When selecting a sport or fitness surface, there are many factors to consider including environmental sustainability, material strength, durability, appearance, and impact on athletic biometrics and safety.

Hardwood

For basketball courts, some athletic directors will accept nothing but hardwood, preferably maple. It is hard enough to provide good ball bounce and, if installed over the appropriate grid sleeper system, also provides area resiliency and shock absorption. However, hardwood can require a lot of maintenance and some finishes are vulnerable to abrasion, limiting its use for multifunctional spaces. Rubber tiles and rolled products can be used to temporarily transform the space, provided there is storage space available when the tiles are not in use. A relatively new alternative to hardwood uses a vinyl wear layer that looks like wood fusion bonded to a composition rubber backing.

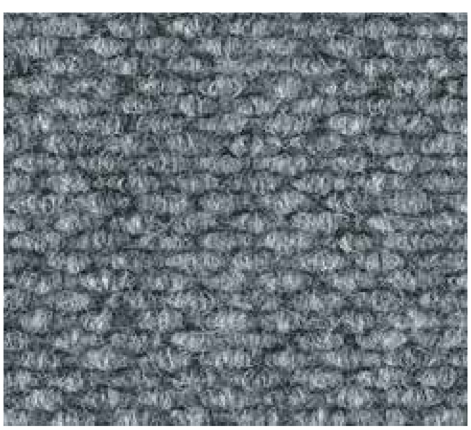
Synthetic Turf

For indoor installations, synthetic turf made with a composition rubber backing is ideal and is available in both rolls and interlocking tiles. The grass-like wear layer is typically a dense, textured nylon material, and the interlocking synthetic-turf tiles do not require adhesive. This option works well for multipurpose areas, enabling occupants to transform a basketball court, cafeteria, or auditorium into a portable playing surface without damaging the floor underneath. Synthetic turf may also be installed over a resilient underlayment to increase shock absorption. A resilient underlayment or a turf product with a fusion bonded rubber backing also eliminates the compaction of composite material that is required under traditional turf surfaces, increasing the life-span of the surfacing.

Resilient Flooring

Performance rubber is the premium choice among resilient flooring options, which also include PVC (polyvinyl chlorate) and polyurethane. It's hard to beat the resiliency, durability, slip-resistance and moisture-resistance of rubber, making it the flooring of choice for weight rooms, locker rooms, aerobic rooms, training areas and multipurpose gyms. Rubber can withstand incredible abuse, be it impacts from dropping free weights or the repetitive concussion of exercise machines. Available in rolled sheet goods and interlocking tiles, rubber provides the most design flexibility. Polyurethane, typically poured in place over a rubber mat, is an alternative.

Vinyl fusion bonded to a rubber backing is a good option for multi-purpose areas, basketball courts and other spaces that demand a durable surface with area resiliency. The vinyl pattern can provide the look and feel of a hardwood surface without the intensive maintenance issues required for hardwood. The stiff vinyl surface provides optimal foot slide characteristics (to reduce foot/knee overturning accidents) and excellent ball bounce, while the rubber backing ensures good force reduction to reduce the incidence of ankle and knee injuries due to impact.



Carpeting

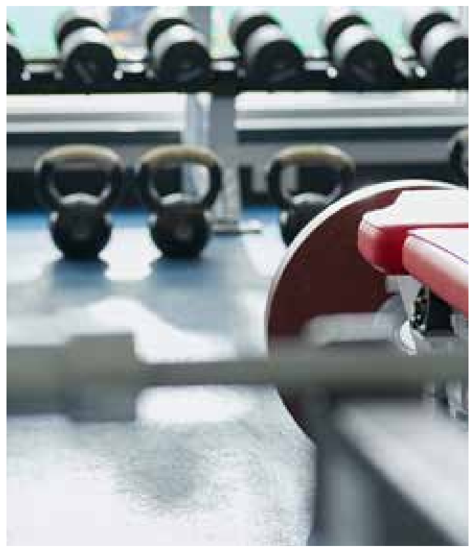
A low-end option sometimes used for fitness rooms and recreation centers, carpet is seldom a good choice. While it provides some cushioning and adds absorption to interior room acoustics, it doesn't wear well and is easily damaged by equipment. Carpets also absorb spills, sweat and holds odors. It may be appropriate for entryways, offices and classrooms in an athletic center, but not for any area where exercise, training or sports activities will take place.

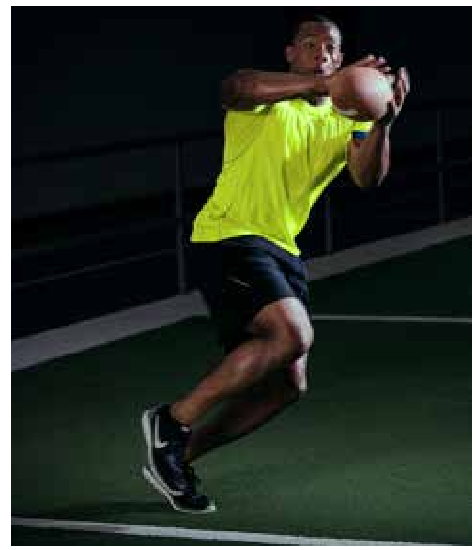
Because many athletic facilities will utilize space for multiple purposes, it makes more sense to opt for a versatile flooring material that can improve acoustics and dampen sound from a variety of activities.

Using Composition Rubber to Improve Athletic Facilities' Acoustics

The array of sports and fitness programs available at different athletic facilities are constantly growing and changing. In addition, the variety of indoor space allocated for sports and fitness activities presents tremendous opportunities for architects to find unique solutions to acoustical problems.

New technologies in flooring allow for products , such as vinyl fused to a composition rubber backing, to provide the look of wood combined with the area elasticity required for the activity. For the majority of sports applications, vinyl, rubber or synthetic turf wear layers with a composition rubber backing provide an optimal flooring choice for improving acoustics while keeping athletes safe and performing at top levels. Some applications of rubber in athletic spaces include:





Training Centers

Training centers are spaces dedicated to everything from strength and conditioning to martial arts, aerobics and gymnastics. These spaces require safe and durable surfaces. The floor should be able to absorb the shock of running and jumping to protect athletes' joints; falls also may be a concern. Composition rubber offers one of the safest flooring options available for these conditions.

Weight Rooms

Weight rooms are specialized training areas that must have an especially durable surface capable of supporting the heavy impact of weight-training and cardio equipment. Ultra-thick composition rubber molded tiles or multi-layer engineered rubber surfaces are an ideal choice for weight rooms, because rubber provides superior shock absorption. Moreover, if tiles are installed and an area is damaged or wears out, individual tiles can be replaced without the expense of the whole floor.

Indoor Playing Fields

Synthetic turf with a composition rubber backing works well on indoor fields for competitive hockey, lacrosse and soccer, as well as for indoor sports training facilities. The wear layer is durable enough for heavy-training activities, such as football conditioning using speed drags and blocking sleds, and is spike resistant.

Indoor Tracks

For tracks, runners need a surface that does not absorb a lot of energy, and yet is not so hard that it will cause shin splints and other stress syndromes associated with running on hard surfaces. A dense recycled rubber wear layer fused to a resilient recycled rubber underlayment provides an optimal choice for many indoor track applications.

Indoor Courts

Indoor courts require a firm surface and an even density so every part of the playing surface responds with a consistent and energetic ball bounce. Vinyl surfacing that is fusion-bonded to a composition rubber backing provides exceptional safety and performance for athletes on indoor courts by providing exceptional ball bounce while still providing good area elasticity to prevent impact injuries. The surface also allows better foot slide than many resilient surfaces, an important feature for fast-moving sports where a high coefficient of friction can lead to foot/knee-overturn injuries. This type of surfacing is durable and easy to install and maintain.

Exercise Rooms

Group exercise rooms require both durability and resilience. The trend for these spaces is moving away from vinyl with a foam underlayment to composition rubber or vinyl fusion-bonded to composition rubber for better performance. Spin rooms are moving away from wood and opting for vinyl with a rubber backing because it holds up better and requires less maintenance.

Making the Decision

The variety of flooring materials may seem limitless, but narrowing down your options based on the acoustic needs of the space will help simplify the selection process. For good acoustic performance, there are three basic choices to consider:

1. Resilient flooring composed of material such as cork or rubber that can inherently mitigate the vibrations that transmit sound.
2. Hard or smooth flooring surface with a performance backing or underlayment composed of a sound-mitigating material.
3. An engineered system combining a variety of surfaces with built-in performance underlayment.

In an athletic facility, a detailed analysis and balancing of sound absorption, reflection and transmission may be required to protect adjacent spaces from experiencing unwanted noise. Flooring specifiers should partner with product technical experts who offer a range of expertise working with different types of facilities and products. Seek out providers that offer research and testing on their products, as well as customizable solutions to meet the unique needs of the space.

The acoustics of an athletic facility can have a considerable effect on the performance and safety of its athletes. Therefore, it is imperative that all activities be considered and the best materials selected for effectively managing sound when designing any fitness-focused space.

Resources

[i] https://www.cdc.gov/niosh/topics/noise/reducenoiseexposure/regsguidance.html