Soundproofing Principles, Practices & Pitfalls

The keys are adding mass and making resilient connections

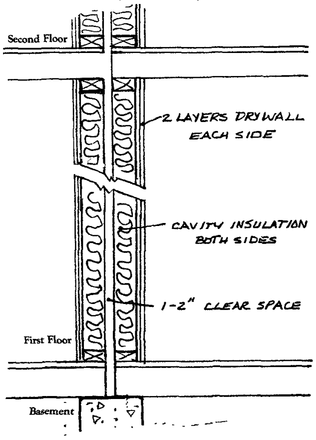
by Timothy Foulkes

"What can we do?" asked the distraught mother. "We live in an apartment and our ninth-grader plays the drums. We stapled egg cartons over the entire ceiling and walls in his room, but the neighbors still complain."

Just because egg cartons resemble sound-absorbing wedges doesn't mean they will endow your living room with the acoustical properties of a recording studio. Even though cardboard will absorb more sound than plaster, and the irregular shape will scatter the high-frequency sound, the main attraction of egg cartons is low price.

The egg-carton story illustrates two common pitfalls in solving acoustical problems. The first mistake was to use a three-decibel solution to solve a 30-decibel problem. The second mistake was to confuse the effects of sound *absorption* with the effects of sound *isolation.*

Townhouse Party Wall (STC 60)



Wood framing is extremely stiff, so it transmits low-frequency sounds and impact noises well. Resilient channels or a double wall with a one- to two-inch clear space between are the best solutions for wood-framed party walls.

Adding sound-absorbing materials to either the source room (where the noise is made) or the receiver room (where it is heard) can reduce the level of transmitted noise a little. But its main effect is to change the acoustics within the room.

What the drummer's parents should have done first was to add sound gaskets to both the bedroom door and the apartment entry door. The next step would have been to upgrade any walls, floors or ceilings common to both the drum room and other apartments. It is unlikely that the situation would ever be resolved completely without major renovation since few buildings are built with the sound-isolation capabilities needed for drums.

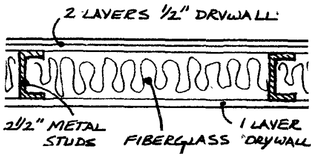
Isolation vs. Absorption

The two main strategies for controlling sound in buildings are absorption and isolation. Sound absorption is generally accomplished with soft, porous, low-density materials such as carpeting, ceiling tile, and furnishings. These materials absorb sound by friction, damping the particle motion of the vibrating air molecules.

Sound absorption alte5rs the acoustics of a room by reducing the amount of reverberation. A room with too little absorption has the hollow sound of a new, unfurnished house. Also, the same source sound will be louder in a room with less absorption.

Absorbing materials are less useful, however, for blocking sound transmission from room to room. Typical carpeting and furnishings will reduce transmitted sound by only a few decibels. Adding more acoustical materials will improve little on that.

Overrated Partition



This popular multifamily partition system draws many complaints from new condo owners. It rates up to STC 50 in the lab, but it is closer to STC 43 in the field.

Sound isolation is the ability of a material or assembly to block sound transmission. In the laboratory, sound isolation can be measured for specific construction assemblies (for example, partitions, windows, and doors), yielding an STC rating. But how well a room isolates sound in the field will depend on the performance of all the building components, and is only as good as the weakest link (see section on Flanking Transmission).

Sound can travel in both solid materials and gases. Each time sound changes from a gaseous medium (air) to a solid medium (the structure), some of the sound energy is reflected back toward the source. More massive materials, such as concrete or plaster, reflect back more sound than do low-mass materials. So for a single-layer barrier, heavier materials provide better sound isolation.

At some point, however, it becomes more cost-effective to stop increasing the weight of the barrier and to upgrade to a double-layer barrier. A double barrier forces the sound energy to make twice as many transitions from air to solid. Absorption material, such as fiberglass batts, between the layers further increases the sound isolation.

Diminishing Returns

Acoustical treatment is subject to the law of diminishing returns. That is, the first steps you take to soundproof will have the biggest effect.

If you start with a completely bare room, putting carpet on the floor will make a major improvement in room acoustics. If the room already has carpet, though, adding an acoustical ceiling will have a less dramatic effect than adding the carpet.

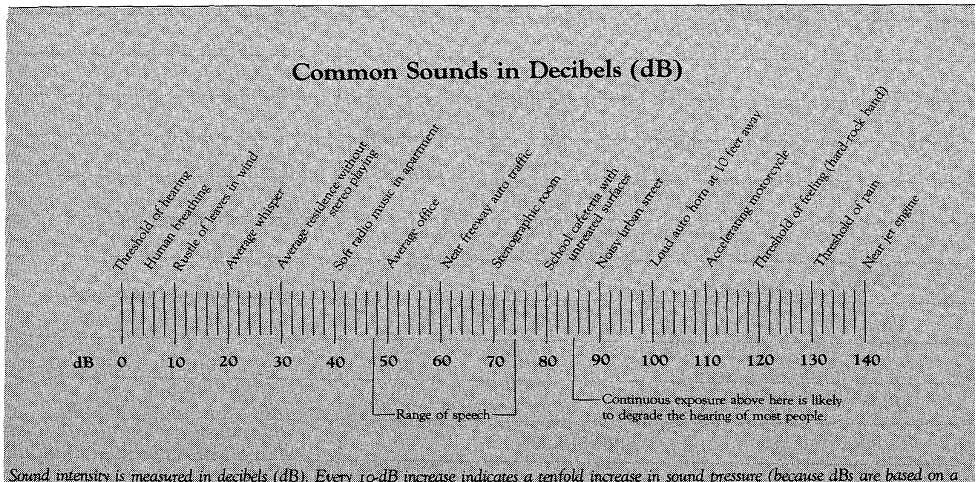
If you start with both carpeting and an acoustical-tile ceiling, adding acoustical wall panels or other sound absorbers will barely change room acoustics at all. Such extensive treatment makes sense only where room acoustics are critical—for example, in music practice rooms or recording studios.

The law of diminishing returns also applies to sound isolation. Above STC 50, sound-isolation improvements are achieved only with significant increases in the thickness and mass of the partition. For rooms supported on a common wood-frame structure, STC 55 is the practical limit. Beyond STC 55, structural transmission through the common lightweight floor will limit the attainable sound isolation.

With double-wall wood construction, STC ratings of 60 and above can be achieved. For rooms supported on a common concrete slab, the practical limit is STC 60 to 65, depending on the thickness of the concrete floor slab.

Structure-Borne Sound

The problem of structure-borne noise is common with wood-frame construction and is virtually impossible to solve completely once the structure is built. In multifamily housing, many

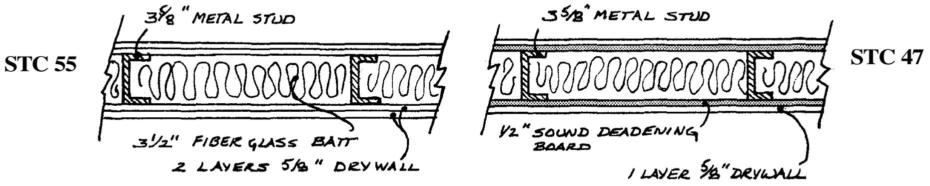


Sound intensity is measured in decibels (dB). Every 10-dB increase indicates a tenfold increase in sound pressure (because dBs are based on a logarithmic scale). The human ear, however, hears each 10-dB increase as roughly a doubling of sound.

noise complaints stem from sound that is directly imparted to the structure by impact or vibration.

Even though party-wall construction is typically STC 50 or greater (see sidebar on measuring sound), impact sounds from footsteps and structure-borne sound from vacuum cleaners and wall-mounted doorbells and telephones are still audible in adjacent living units. The STC rating measures only isolation of airborne sound, and does not consider this troublesome type of noise.

Sound-Deadening Board vs. Double Drywall



Which is the better buy? Based on decibels per dollar, the double drywall with fiberglass batts beats out sound board. Sound-deadening board has a modest effect on wood studs, but almost no effect on metal studs, since they already are resilient.

In side-by-side townhouse units, the problem can be solved in the design phase. Design the framing to act as two separate structures (see drawing) and maintain a clear space of at least one inch extending from the foundation to the roof peak. (We have measured sound isolation of STC 60 between adjacent townhouses constructed in this manner with separate studs, cavity insulation, and two layers of drywall on each side.)

Flanking Transmission

Sound, like water, will leak out of its container through any convenient path. These so-called flanking paths can undermine your best soundproofing efforts. An ungasketed door can reduce the sound isolation of an STC 50 wall to STC 30.

Typical flanking paths include electrical outlets and heating ducts, cracks where partitions meet floors and ceilings, and spaces over drop ceilings. Electrical outlets or recessed medicine cabinets placed back-to-back also are a problem: Single-pane glass is a good sound transmitter, as are hollow-core doors. If you ignore these weak links in your soundproofing scheme, your work will be wasted.

Single-Family Homes

Sound transmission rarely is a problem in single-family homes. In fact, many people make use of sound transmission to call the family to dinner, check on the children, and so on. Occasionally, though, better sound isolation between rooms is called for. Possible examples include master bedroom to children's rooms, a music room, or a home office.

Before considering partitions and floors, one should consider doors and other openings, which are often the major leakage point. First, add sound gaskets (for example, a large-section, neoprene weatherstripping) on the doors at the perimeter and threshold. Next, consider increasing the door's density by going to a solid-core door.

The sound isolation of the door should be within 10 STC points of the wall. For higher performance, upgrade to a tandem-door set; that is, two doors back-to-back in the same frame.

Once leaks are treated, the next logical upgrade is to fill the wall or ceiling cavity with sound-absorbing material. For noncritical applications, a 1½-inch-thick fiberglass batt probably is the most cost-effective material. (A full-thickness batt is only slightly better.)

After cavity absorption, the next upgrade would be to decouple one surface from the other by using resilient channels or double studs. This is especially important in wood-frame construction since wood is extremely stiff and transmits low-frequency sounds readily.

Plumbing Noise

Plumbing noises can be substantially reduced by modest measures.

Regardless of whether the noise is generated by a valve or a pipe fitting, most of the water-flow noise we hear is radiated by floor and wall surfaces rather than by the pipes themselves. The key to minimizing plumbing noise is to avoid rigid contact between pipes and materials in floors, walls, and ceilings.

Where horizontal pipe runs are clamped to the floor joists, use an oversized clamp with sponge neoprene to isolate the pipe from the clamp and the joist. Where pipes penetrate the floor, make sure the pipe does not touch the edge of the penetration. Where pipes penetrate the surface of a partition, make sure the pipe does not touch the edge of the drywall, and use non-hardening caulk to form a resilient gasket between the pipe and the drywall.

It also is helpful to use fibrous insulation in stud cavities where pipes run. Plastic waste pipes will radiate more noise than cast iron. Enclose plastic waste lines in two layers of gypsum board with fiber insulation inside the cavity.

Sound-Control Materials

Acoustical sealant. Acoustical sealant is used to block leakage paths, and to make resilient connections between materials. Although some caulks are marketed as "acoustical sealant," any non-hardening sealant will do. Most butyl caulks and silicone caulks are effective.

The proper location for acoustical sealant is between the floor and the first layer of drywall on each side of the stud. Ideally, the sealant bead should be in continuous contact with the floor surface, the vertical face of the stud, and the bottom edge of the drywall. Where partitions are to be sealed against the underside of the structure above, the sealant should be applied similarly at the ceiling.

Where partitions join gypsum-board ceilings, acoustical sealant is not needed since the tape and joint compound are usually adequate. Acoustical sealant is not necessary for partitions having an STC rating of less than 35.

In single-family homes, acoustical sealant would be used only where extra sound isolation is specified. For high-STC partitions (45 and above), acoustical sealant also should be used to fill any gaps between electrical boxes and the drywall cutouts.

Resilient channels. Resilient channels are essential to achieve STC ratings of greater than 45 with a single-wood-stud wall. Builders often ask how to treat a corner joint where one or both surfaces are attached with resilient channels. In most cases, a standard tape-and-compound joint is fine because the sound energy transmitted via the edge connection is minimal.

In critical locations, double studs usually are used, anyway. An alternative edge treatment for critical work is to leave a 3/16-inch gap, fill it with acoustical sealant, and hide the joint with a wood molding nailed to only one surface.

Misused Acoustical Materials

For every acoustics problem, there seem to be several "experts" who think that it can be solved using lead, cork, Homasote, or some other special material. In fact, most acoustics problems are best solved using standard building materials such as concrete, gypsum board, fiberglass insulation, and caulk. Following is a list of the most commonly misused acoustical materials.

Homasote. Homasote makes a fine tack board, but a sound absorber it is not. Many people are convinced that Homasote applied to the wall surfaces of a room will control reverberation. Certainly, it is more absorptive than gypsum board or plaster. I have not seen any published test data on the absorption characteristics of Homasote, and this lack of information is revealing. I would estimate that Homasote is three to four times less effective than typical acoustical ceiling panels.

Vermiculite. Vermiculite is a pelletized thermal insulation that can be poured. When people realize they should have used acoustical batts in the stud cavity of a wall, they often try pouring Vermiculite into the cavity since it is easier to do this than dismande the drywall. Unfortunately, the results usually are disappointing since vermiculite is not very efficient at absorbing sound.

When cavity insulation is called for, money is better spent blowing in chopped fiberglass or cellulose insulation. Don't be overly concerned about filling 100 percent of the wall cavity. Fifty percent fill in each stud bay will be 80 to 90 percent as effective as 100 percent fill. (One desperate builder tried filling a stud cavity with sand. This would have been very effective if the wall had not burst.)

Polystyrene. Since polystyrene has a higher R-value per inch than fiberglass blanket, it must have better acoustical performance. Right? Wrong. Foam insulation has almost no useful acoustical properties. Its mass is negligible, as is its ability to absorb sound.

Lead. Lead is an extremely effective sound barrier, but at what cost? The advantage of lead is its high density. In most cases, concrete or gypsum board can provide the same surface mass as lead (about two pounds per square foot) at a lower cost and without introducing a new trade on the project.

Half-inch gypsum wallboard provides approximately the same transmission loss as 1/32-inch lead sheet. Lead is useful where dimensions do not allow thick multiple layers of gypsum board, or in tight work areas where the lead is easier to cut and patch.

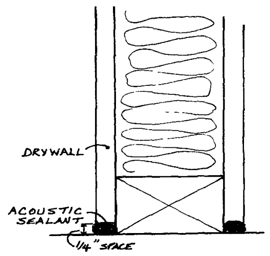
Acoustical tile. When faced with an acoustics problem, too many people see acoustical tile as the answer. Acoustical tile stapled to the ceiling of the downstairs apartment might provide two or three decibels of relief, but you will be in for a disappointment if you expect it to completely silence the sound of children running across the wood floor upstairs.

Sound board. Sound board—made of pressed wood fiber—is popular because it is easy to install, not because it is effective. Sound board provides three important properties—absorption, resilience, and mass—but none of them in sufficient quantity to be very useful.

If you want sound absorption in your wall cavity, use fiberglass blankets. If you want extra mass in your wall construction, use more layers of gypsum board. If you want resilience between the gypsum-board surface and the stud, use resilient channels or, better yet, staggered studs.

It would be especially foolish to use sound board with a metal-stud partition since metal studs naturally flex and provide resilience comparable to the effect of sound board. Test-data examples on sound board show that a 3 5/8-inch stud with sound board on both sides and 5/8-inch drywall on both sides yields an STC of 47. The same stud with a two-inch fiber blanket and two layers of 5/8-inch gypsum board on each side gives an STC rating of 55. ■

Proper Use of Acoustical Sealant



Acoustical sealants are used to seal up sound leaks at partition tops and bottoms electrical outlets, and other penetrations. Any flexible, non-hardening sealant will do.

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The ABCs of STC Ratings

Sound intensity is typically measured in decibels, and the ability of materials to block sound is rated by Sound Transmission Class (STC). Since these are based on a logarithmic scale, an increase of 10 decibels indicates a tenfold increase in sound pressure (although this sounds like only a doubling to the human ear). Similarly, a wall with an STC rating of 40 would reduce a 60-decibel noise to 20 decibels across the wall.

STC is measured in a laboratory using two large, reverberant rooms separated by a very thick concrete wall. The concrete wall has a large framed opening in which the test specimen is constructed.

The actual performance of a partition in the field depends on many variables, not the least of which is construction quality. At higher STC ratings, partitions are more likely to be compromised by flanking through the structure or through leaks due to inadequate sealing.

In general, we recommend using a 5 dB safety factor to allow for less-than-perfect construction techniques, as well as variations in room finishes. So if you need STC 45 isolation, it is best to use a partition having a lab-test rating of STC 50.

The STC rating was developed to describe in a single number a partition's ability to isolate speech sounds. Sounds with significant low-frequency energy, such as mechanical equipment or full-range music, will not be as well isolated as the STC number would suggest unless the two sides of the wall are decoupled, as with a double-stud system. This decoupling principle also is useful in isolating structure-borne and impact sounds.

Another common pitfall in acoustical design is the failure to consider the level of background noise in the space. Background noise in the receiving room will tend to increase the sense of acoustical privacy.

For example, a partition that is adequate to isolate voices between offices in a large office building with moderately noisy mechanical systems will not be adequate to isolate the same speech sounds in a very quiet office environment. Beyond some point, of course, the background noise itself becomes disturbing. Intrusive noise such as a dripping faucet, whining lights, or a neighbor's speech will seem annoying at lower levels than continuous background noise from a fan or air conditioner.

The most widespread cause of unsatisfactory sound isolation is the process called *value engineering* in which the minimum-cost partition is selected to meet the minimum standard of sound isolation. The choice is often based on an exhaustive review of test reports to find the highest published STC rating for a given partition type, ignoring tests showing lower values for the same construction.

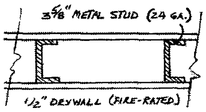
The best example of this is the popular "unbalanced" partition consisting of 2½-inch metal studs with insulation blanket in the cavities, two layers of gypsum board on one side, and one layer of gypsum board on the other. Various test reports rate this assembly as high as STC 51, thus meeting the usual benchmark of STC 50. Our field tests usually rate this wall STC 42 to 46, and residents generally are dissatisfied with the poor acoustical privacy.

By using minimum STC criteria, the contractor leaves no margin for less-than-perfect execution, lower-than-normal background noise, or louder-than-normal residents. ■

—Timothy Foulkes

Correction Factors for STC Rating

Starting with a 3⅝-inch, steel-stud wall, this chart shows how various changes raise or lower its STC rating. The more correction factors you use, however, the less accurate the results will be.



Base Case

Change in Construction	Change in Decibels (dB)
¼" to ⅝" drywall	+1 dB
16" o.c. to 24" o.c.	+1 dB
Add fiberglass batt	+5 dB
Metal stud to wood stud	-5 dB
Add resilient channel to wood stud	+6 dB
Add resilient channel to 24-gauge metal stud	0 dB
Add resilient channel to 16-gauge stud	+2 dB
Add one layer of drywall	+2 dB
Add two layers of drywall	+3 dB
Stagger the studs	+5 dB
3⅝" stud to 6" stud	+3 dB
Fire-rated to non-fire-rated drywall	-2 dB