Lightweight Partition Design for Residential and Commercial Buildings

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Guidelines are presented for the design and proper installation of high-performance, lightweight partitions in residential and commercial buildings that meet desired acoustical ratings. Typical wall and floor/ceiling systems with associated STC ratings are presented. Good construction practices to minimize flanking paths and maximize in-field performance are covered as well.

Today's residential and commercial property owners are concerned about the comfort and safety of the interior environment. Unwanted sound, or noise, is one factor that can influence these conditions. Lightweight partition constructions are used extensively in North America to control airborne and structure-borne sound transmission through walls and floor-ceiling assemblies. However, the benefits of high-performance acoustical systems can be lost because of improper installation or poor construction details.

Commonly specified, standardized test methods and sound control practices developed by the American Society for Testing and Materials (ASTM) should be used to determine the acoustical performance of lightweight partition constructions and can help ensure acoustical success on a project. Sound flanking paths, sound leaks, and structural short circuits that decrease the effectiveness of sound insulating systems are discussed and solutions are presented.[1]

Sound Paths

Sound waves can travel through any media, which includes air, water, wood, masonry or metal. The type of media through which sound travels determines whether the sound is either airborne or structure borne. Airborne sound is directly transmitted from a source into the air. All sound that reaches your ear is airborne. Some examples of airborne sound are passing traffic, music or voices from an adjacent room, or the noise from machinery and aircraft.

Structure-borne sound travels through solid materials either from direct contact with the sound source or from an impact on the material. All structure-borne sound must eventually become airborne sound for people to hear it; otherwise, the disturbance is felt as vibration. Examples of structure-borne noise are footsteps, door slams, plumbing vibrations, mechanical vibrations, and rain impact.

Most noise control situations require that both airborne and structure-borne sound be considered. Effective sound control addresses both sound paths by controlling or reducing noise at the source, reducing paths or blocking noise along its path, or shielding the receiver from the noise.

Practical and economical solutions to sound-related problems exist for architects, engineers, contractors, building owners and homeowners. ASTM has developed several standard test methods that determine the acoustical performance of lightweight partition constructions.[2]

Airborne Sound Transmission – ASTM E 90 and E 413

Building partitions and elements are evaluated for their ability to reduce airborne sound transmission through the assembly. The sound insulation property of a material indicates the ability of the system to reduce the loudness of a noise created in one room, or enclosure, and measured in another separated by a partition of the material (see Figure 1). Sound transmission loss of building systems, like walls, floor-ceiling assemblies, roofs, doors, windows, operable partitions, and other space-dividing elements, is measured in a laboratory using the standard test method ASTM E 90,[2] "Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements." Measurements are performed in one-third octave bands, with center frequencies of 125 to 4000 Hz.

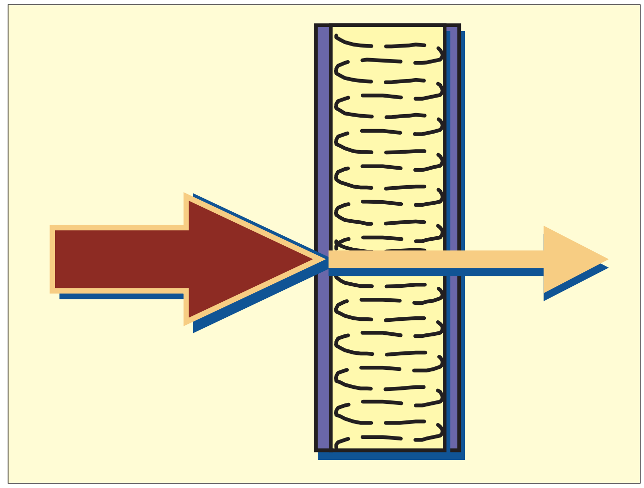

Figure 1. Airborne sound transmission.

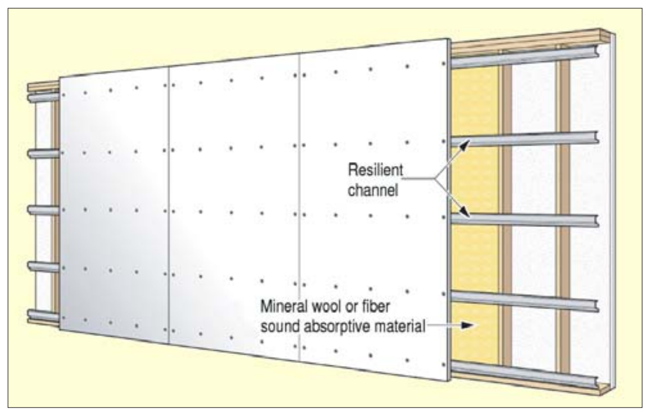

Figure 2. Acoustically treated wood stud wall, Wood 3 – STC 46.

Building assemblies are rated using the sound transmission class, or STC. Values are determined using normalized airborne sound transmission loss data from ASTM E 90 and calculated with ASTM E 413,[2] "Classification for Rating Sound Insulation." Results from ASTM E 90 are compared with a reference contour curve to calculate the STC value. The reference data in general correlates with subjective impressions of sound transmission for speech. Once the calculation criteria are met, the STC value is the sound transmission loss value in decibels at 500 Hz on the reference contour curve. All sound transmission loss testing evaluates the entire system, unlike sound absorption, which is material specific.

Figures 2 and 3 illustrate an acoustically treated wood stud wall system identified as Wood 3 with an STC of 46. The cavity was filled with 3-1/2 in. (90 mm) thick fiberglass insulation. One layer of 1/2 in. (13 mm) gypsum board was mounted to resilient channel spaced 24 in. (610 mm) on center, and the perimeter edge was sealed. Figure 4 compares the airborne sound transmission results of Wood 3 with two other systems that have the same wood stud and gypsum board configuration

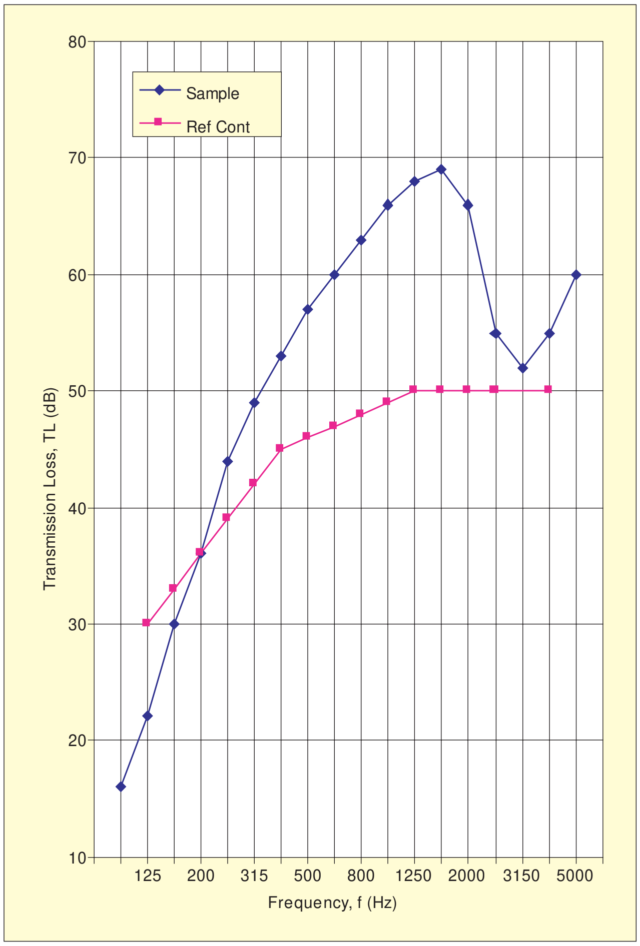

Figure 3. Sound transmission class (STC) using ASTM classification E 413; Wood stud wall, Wood 3 – STC 46 @ 500 Hz.

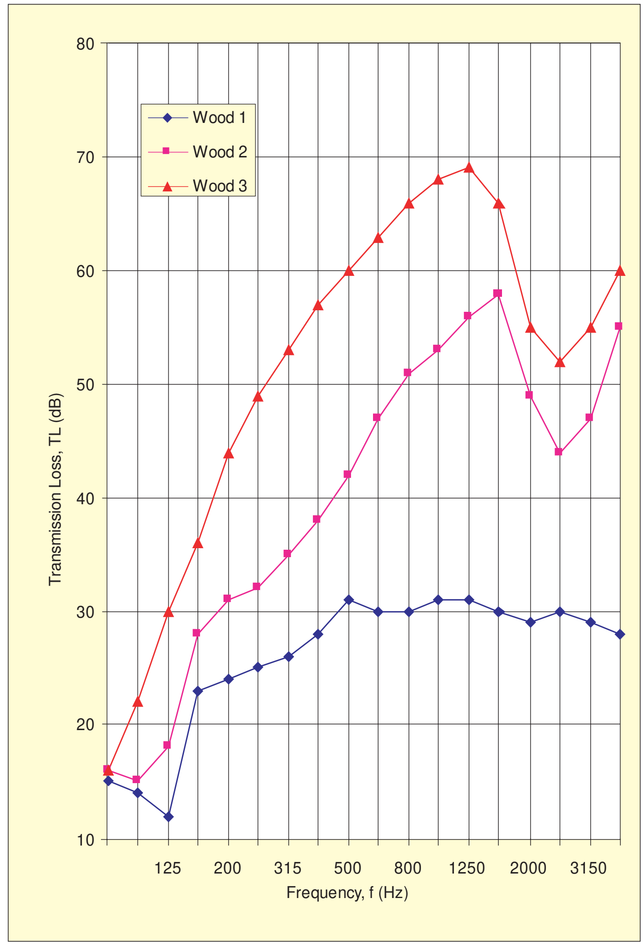

Figure 4. Airborne sound transmission data comparison of wood stud walls, Wood 1, 2, and 3 (STC 29, 39, 46).

with varying degrees of acoustical treatment.[3] Wood 1 (STC 29) has no cavity insulation, resilient channel, or perimeter air seal, and the 1/2 in. (13 mm) gypsum board was fastened directly to the wood stud frame. Wood 2 (STC 39) has 3-1/2 in. (90 mm) thick fiberglass insulation in the cavity and the gypsum board perimeter was air sealed.

Air sealing the gypsum board perimeter and adding lightweight, absorptive, fiberglass insulation to the cavity increased the wood stud wall system STC value 10 points from the Wood 1 system. By additionally breaking the structural tie between the gypsum board surface and the wood studs with resilient channel, the Wood 1 system increased the STC by 17 points.

Figure 5 illustrates a 25-gage, 3-1/2 in. (90 mm), steel stud wall assembly, with studs spaced 24 in. (610 mm) on center, no cavity insulation, and a balanced, double 5/8 in. (16 mm), Type X gypsum board finished wall surface. The gypsum board perimeter was air sealed. The wall is identified as Steel 3 with an STC of 50.[4]

Two 25-gage, 3-1/2 in. (90 mm), steel stud wall systems, with studs spaced 24 in. (610 mm) on center and 5/8 in. (16 mm), Type X gypsum board with and without 3-1/2 in. (90 mm) fiberglass insulation in the cavity, identified as Steel 1 and Steel 2 are compared with Steel 3 in Figure 6.[5] Both systems were air sealed at the gypsum board perimeter.

Light-gage steel studs are generally considered to be acoustically resilient. The STC value for the system increases from 38, Steel 1, to 50, Steel 2 and 3, by adding lightweight fiberglass insulation to the cavity or doubling of gypsum board mass.

Impact Sound Transmission – ASTM E 492 and E 989

Floor-ceiling assemblies are evaluated for the ability to reduce impact sound transmission, like footsteps or dropped objects on the floor surface, through the system to the space below (see Figure 7). The test specimen is the primary sound transmission path. Impact sound transmission loss of floor-ceiling assemblies is measured in a laboratory using the standard test method ASTM E 492,[2] "Laboratory Measurement of Impact Sound Transmission Through Assemblies Using a Tapping Machine." Measurements are performed in one-third octave bands, with center frequencies ranging from 100 to 3150 Hz. Impact noise is generated using a tapping machine, which drops five hammers in rapid succession at equal intervals on the surface of the test specimen.

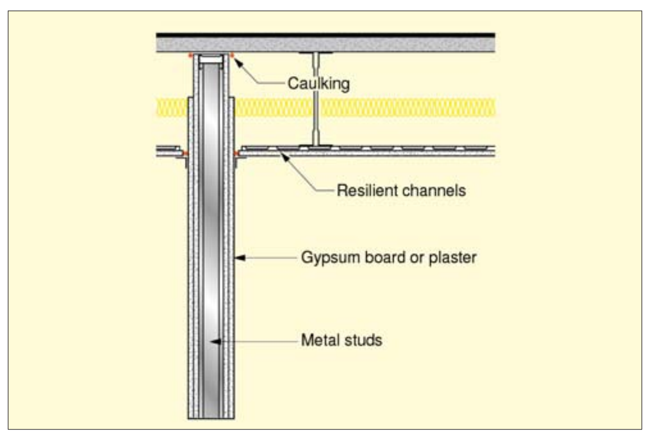

Figure 5. Steel stud wall, Steel 3 – STC 50.

Floor-ceiling assemblies are rated using an impact insulation class, or IIC. Values are determined using normalized impact sound transmission loss data from ASTM E 492 and calculated with ASTM E 989,[2] "Classification for Determination of Impact Insulation Class." Impact sound pressure levels measured in the receiving room below the test specimen during ASTM E 492

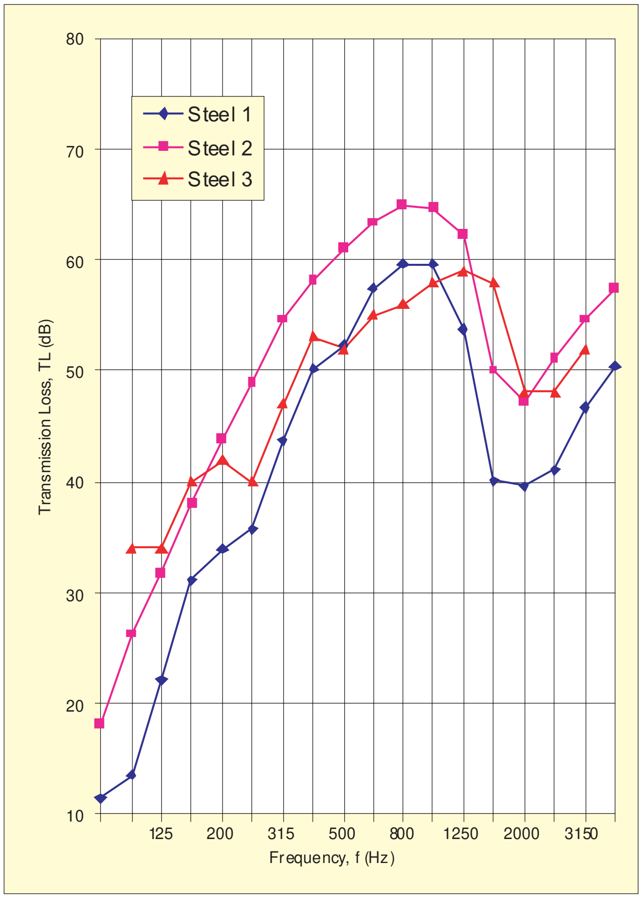

Figure 6. Airborne sound transmission data comparison of steel stud walls, Steel 1, 2, and 3 (STC 38, 50, 50).

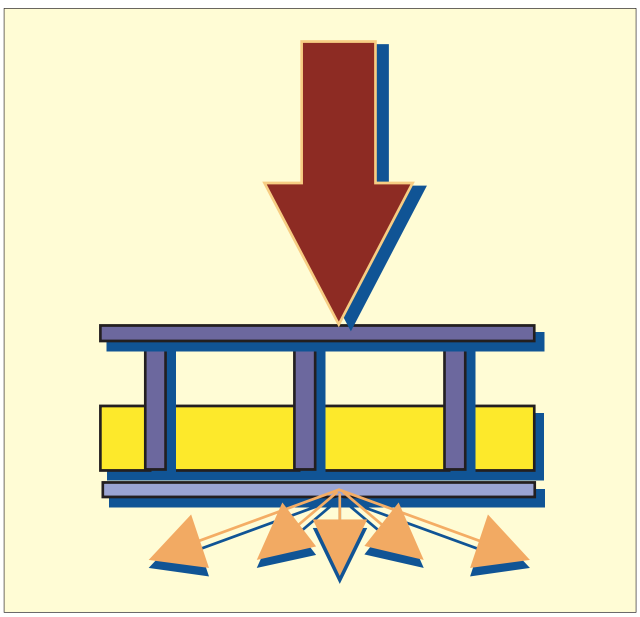

Figure 7. Impact sound transmission.

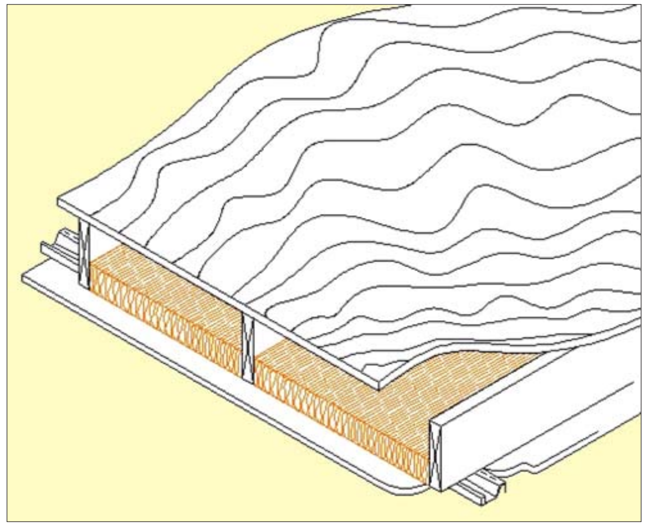

Figure 8. Wood joist floor-ceiling system, Floor 4 – STC 52, IIC 46.

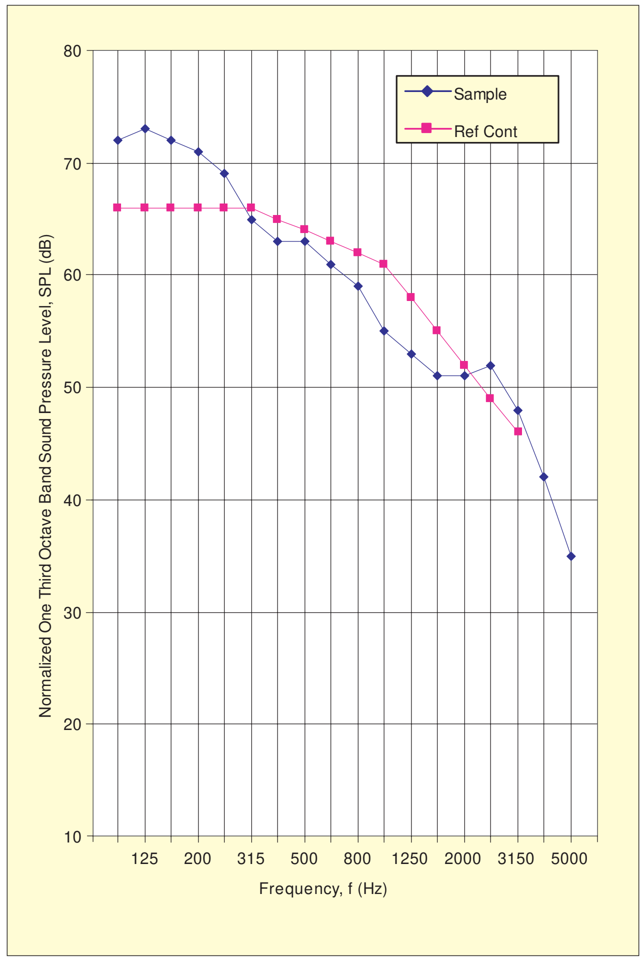

Figure 9. Impact insulation class (IIC) using ASTM classification E 989; Wood joist floor, Floor 4 – IIC 46 @ 500 Hz.

are compared with the IIC reference contour curve to calculate the IIC value. The reference data in general correlate with subjective impressions of sound transmission for speech. Once the calculation criteria are met, the IIC value is the sound transmission loss value in decibels at 500 Hz on the reference contour curve subtracted from 110 dB.

Figures 8 and 9 illustrate and provide graphical results for an acoustically treated wood joist floor-ceiling system identified as Floor 4. The assembly is comprised of a 5/8 in. (15 mm) oriented–strand-board (OSB) floor fastened to a 9-1/4 in. (235-mm) wood joist frame spaced 16 in. (406 mm) on center. The cavity has been filled with 6 in. (152 mm) fiberglass insulation, placed on top of a 1/2 in. (13-mm) resilient channel-mounted, 5/8 in. (16 mm), Type X gypsum board ceiling. Resilient channels were placed perpendicularly against the wood joists, spaced 24 in. (610 mm) on center, and the perimeter edge was sealed. The IIC value for the system was 46.

Several solid-wood-joist floor systems with varying degrees of acoustical treatment are compared for airborne and impact sound transmission in Figures 10 and 11, respectively.[6] The five wood joist floor systems are identified as Floor 1 through 5. The systems have increasing STC values of 33, 34, 43, 52, and 54, and increasing IIC values of 28, 30, 37, 46, and 49. The

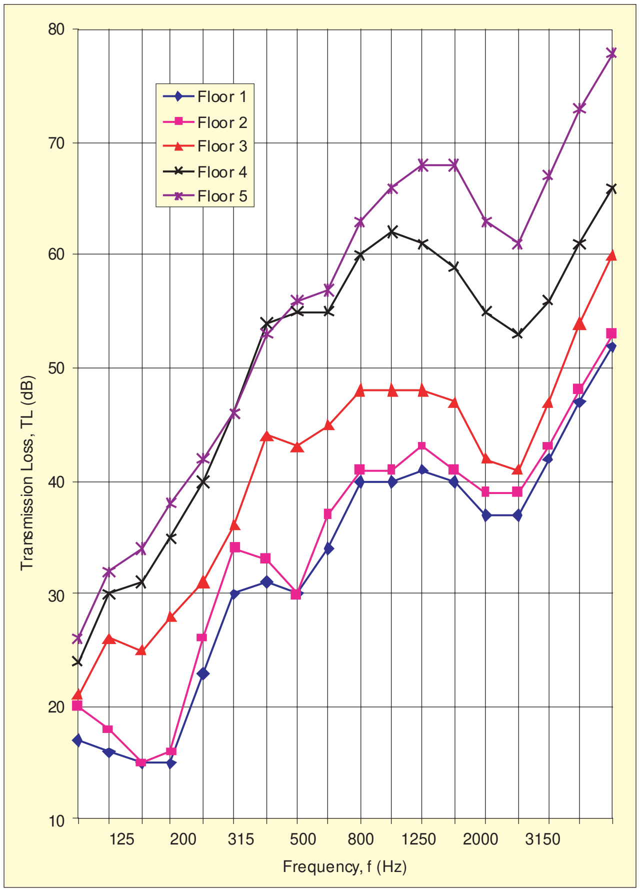

Figure 10. Airborne sound transmission data comparison of wood joist floors; Floors 1-5 (STC 33, 34, 43, 52, 54).

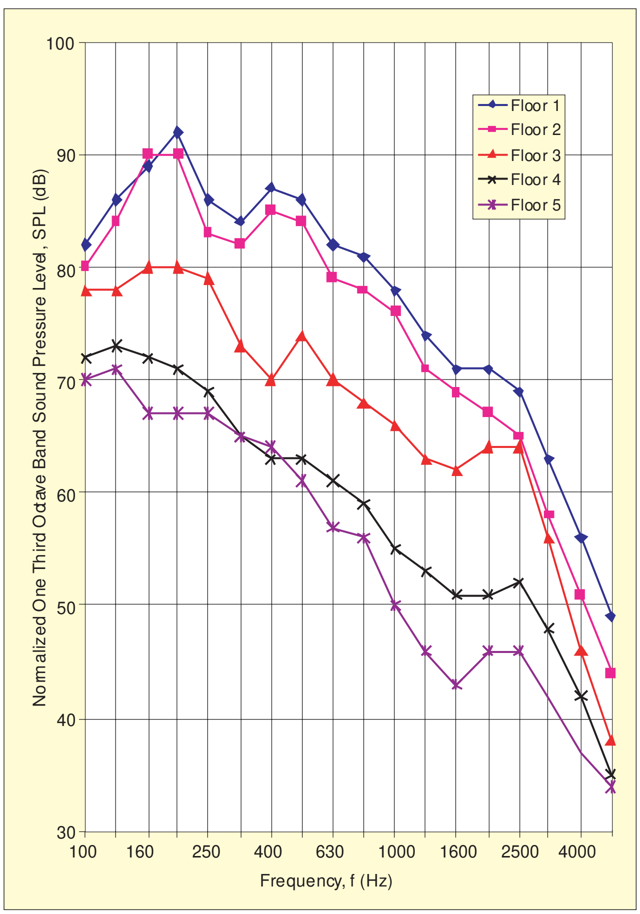

Figure 11. Impact sound transmission data comparison of wood joist floors; Floors 1-5 (IIC 28, 30, 37, 46, 49).

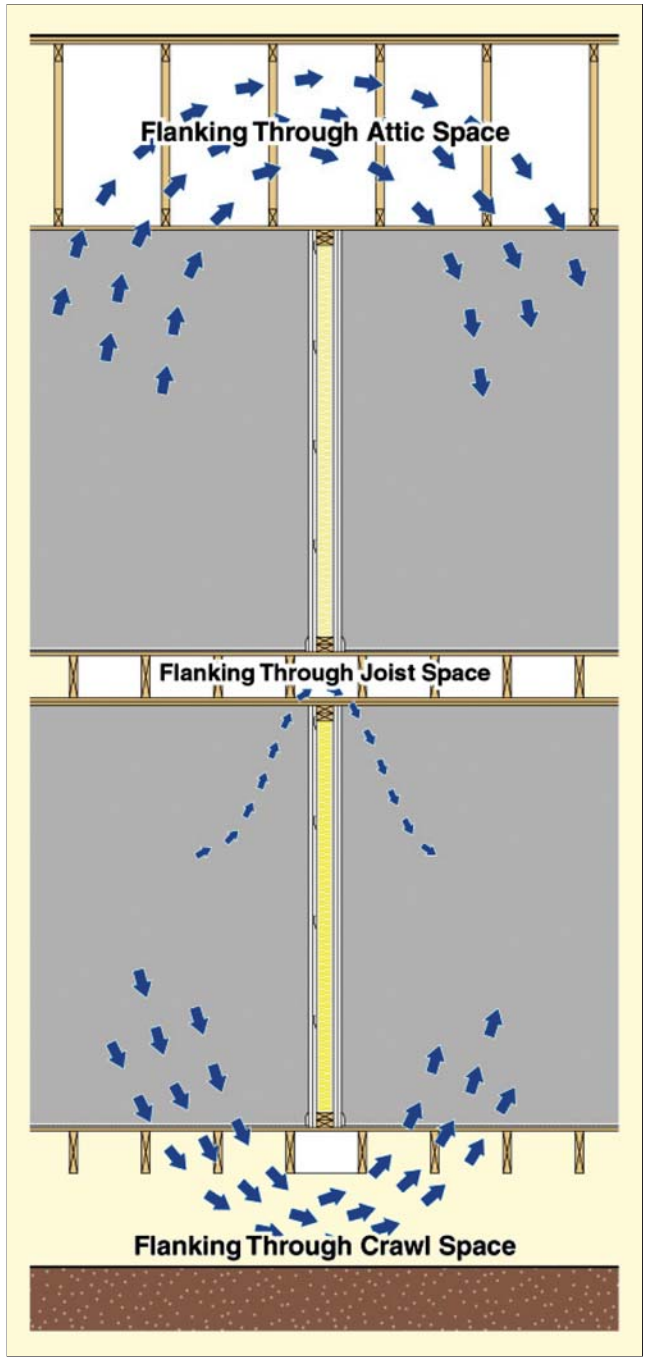

Figure 12. Sound flanking paths.

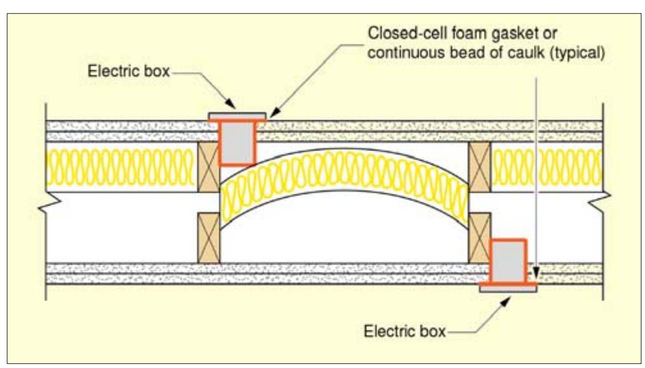

Figure 13. Air leakage paths.

systems were air sealed at the perimeter of all exposed surfaces.

Floor 1 represents a standard floor-ceiling assembly with a 5/8 in. (15 mm) OSB surface, 9-1/4 in. (235-mm) wood joists spaced 16 in. (406 mm) on center, and a 5/8 in. (16 mm), Type

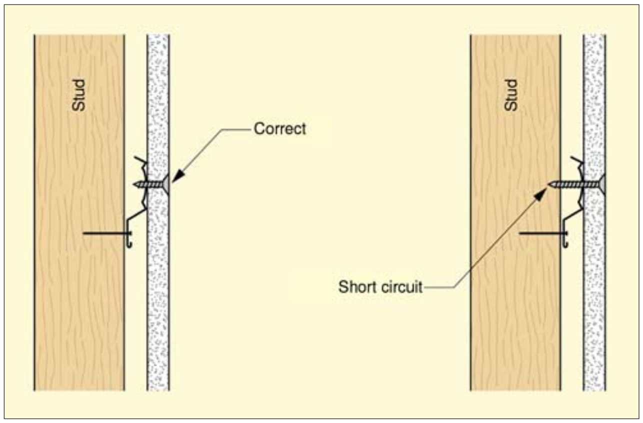

Figure 14. Fastener short circuits.

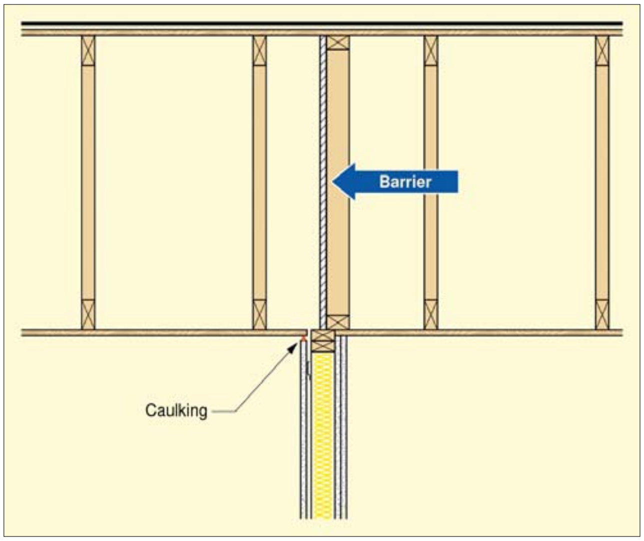

Figure 15. Gypsum board blocking.

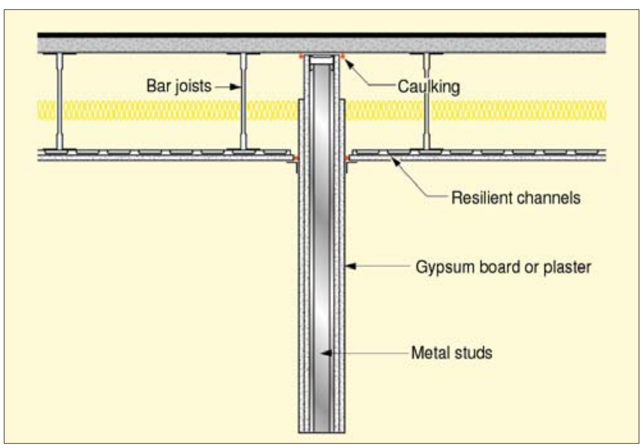

Figure 16. Partition wall height extension.

X gypsum board ceiling fastened directly to the floor frame. Adding 6 in. (152 mm) fiberglass insulation to the cavity, identified as Floor 2, only increases the STC and IIC values 1 point. Absorptive cavity insulation is less effective in floor-ceiling assemblies due to the increased cavity depth and strong structural ties between the floor and ceiling surfaces.

Mounting the gypsum board ceiling to 1/2 in. (13-mm) resilient channel, placed perpendicular to the joists, and spaced 24 in. (610 mm) on center without cavity insulation, Floor 3, increases the STC and IIC values by 10 and 9 points, respectively. The addition of 6 in. (152 mm) fiberglass insulation, Floor 4, increases the STC and IIC values an additional 9 points. The combination of breaking the structural ties between floor and ceiling systems along with lightweight absorptive fiberglass insulation provides the greatest increase in acoustical performance.

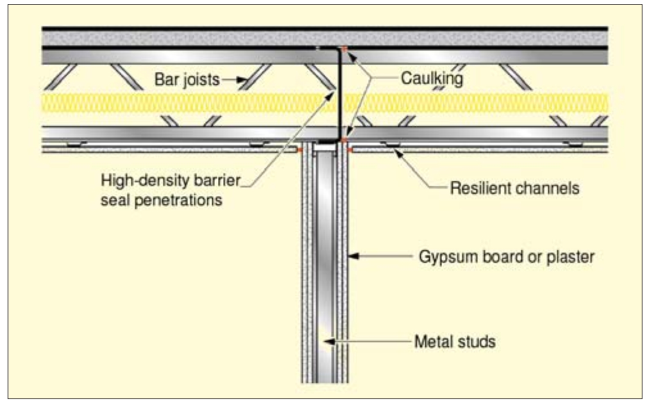

Figure 17. Sheet metal blocking.

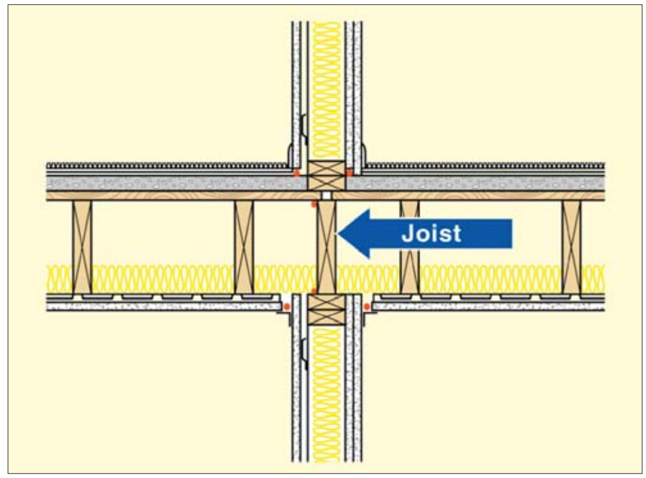

Figure 18. Between-floor blocking.

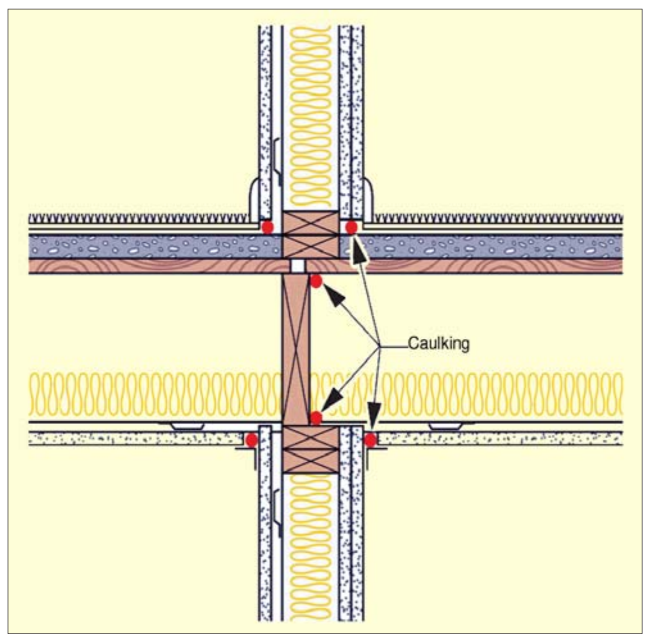

Figure 19. Between-floor caulking.

The STC and IIC values increase an additional 2 and 3 points, respectively, by removing the resilient channel and mounting the gypsum board ceiling to a 1-1/2 in. (40 mm), C-channel, 1 in. (25 mm), U-channel steel grid system with members symmetrically spaced 24 in. (610 mm) on center and suspended from 12-gage wires attached to the underside of the OSB floor, Floor 5.

In general, impact sound transmission test results are ap-

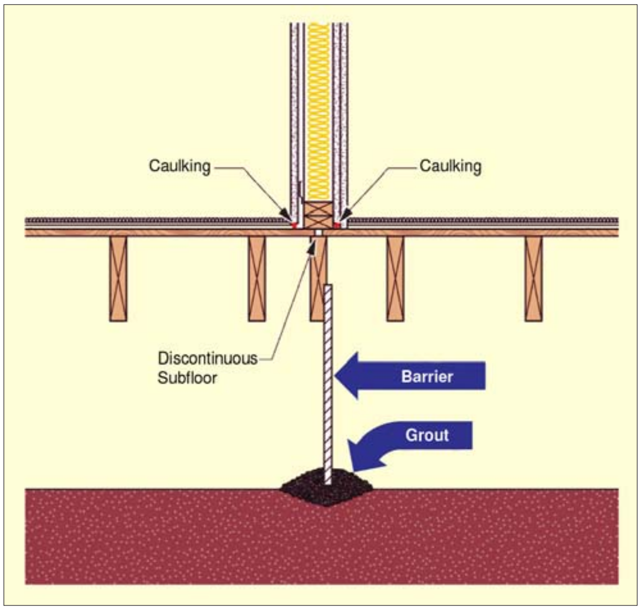

Figure 20. Under-floor blocking.

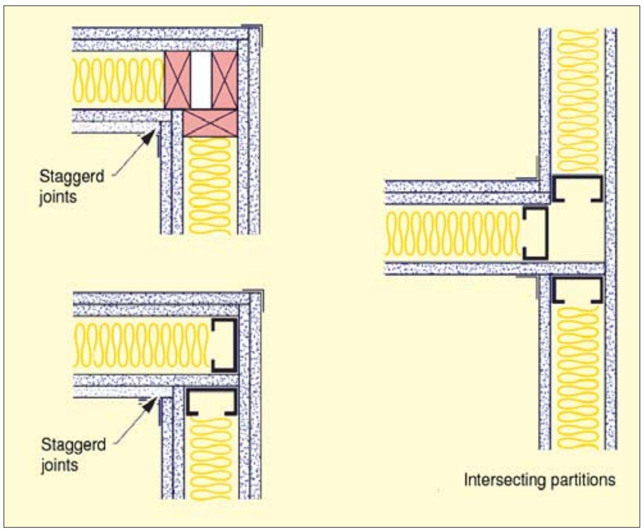

Figure 21. Wall corner structural breaks.

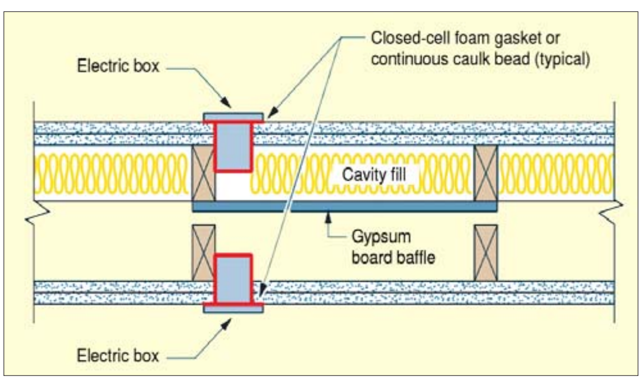

Figure 22. Electrical penetration treatment.

proximately 4 to 6 points lower than airborne sound transmission test results due to the strong influence of the structural connection between the OSB floor surface, the wood joist framing, and the finished gypsum board ceiling surface. Resilient floor coverings, like a carpet and pad or isolated, suspended ceilings combined with sound absorptive material like fiberglass insulation, will increase the system's performance with respect to impact sound transmission. However, the only way to effectively compare systems is to examine the corresponding system-specific IIC test results.

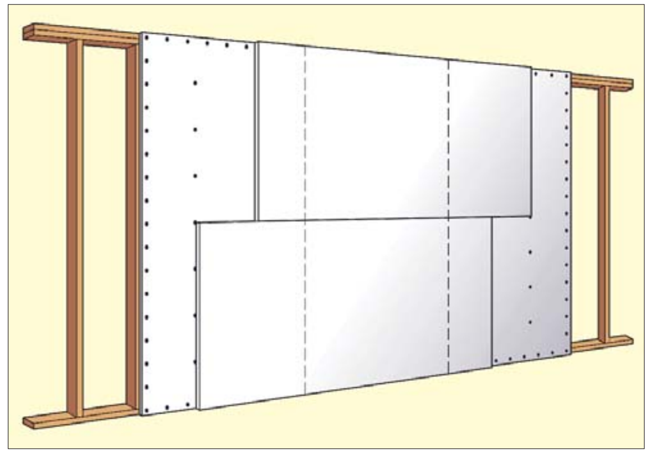

Figure 23. Overlap gypsum board seams.

Interior Lightweight Partition Concerns – ASTM E 497

Most of the benefits of using acoustical insulation are realized in the construction of lightweight partition walls. However, the benefits of systems with high STC ratings can be lost because of improper installation or poor construction details. Sound flanking paths, sound leaks, and structural short circuits due to fasteners are a few conditions that decrease the effectiveness of sound insulating systems, as illustrated in Figures 12 to 14.

The ASTM standard practice, E 497,[2] "Installing Sound-Isolating Lightweight Partitions," provides recommendations for preventing situations or conditions that will detract from the acoustical performance of various types of partitions, such as wood and steel stud walls, floor-ceiling assemblies, and roof-ceiling systems. Combinations of dense sound barrier materials, like gypsum board, sheet metal, or wood framing, and acoustical caulk can block many above ceiling, between floor-ceiling, and below floor sound flanking paths, as illustrated Figures 15 to 20.

Systems must be airtight, since sound will always take the path of least resistance no matter how small the opening. All penetrations and perimeter joints should be sealed with combinations of gaskets and acoustical caulk. Framing members, fastening systems, plumbing, and electrical conduits should be vibration isolated when possible to minimize the structure-borne transfer of sound energy through the assembly, as illustrated in Figures 21 through 23.

Integrating sound control techniques and products into the design process are the best ways to ensure success. Lightweight partition constructions can be optimized through the combination of structural breaks and absorptive cavity insulation. Noise problems that exist after a building is occupied are sometimes difficult to solve, and usually are much more expensive than if addressed during design.

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