Test Reviews of Lightweight Wood Frame Multi-Dwelling Buildings

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Two multi-unit buildings in the final stages of construction were tested under a variety of airborne and impact sound isolation conditions. The buildings, an apartment-style dorm and a luxury apartment building, were both constructed using lightweight wood framing. Testing was done in accordance with the sound transmission class (STC) standard ASTM E336-14 and the impact insulation class (IIC) standard ASTM E1007-13b. This article summarizes and discusses the results of these tests. Conclusions are drawn regarding sound isolation variances between outlet treatments in wood-stud walls, impact isolation variances with resiliently backed vinyl tiles, and how different treatments can affect whether heavy impacts are or are not mitigated.

In recent years it has become increasingly popular to build multi-unit dwellings using lightweight wood framing construction in lieu of heavier concrete and steel framing. While this construction typically takes less time to construct and is less expensive than its heavier alternatives, it does not provide a similar level of sound isolation. The sound isolation of multi-unit dwellings is measured using ASTM standards. The airborne sound isolation of floor and wall constructions is evaluated in terms of sound transmission class (STC) ratings and defined in ASTM E336-14;[1] the impact sound isolation of floor constructions in terms in impact isolation class (IIC) and defined in ASTM E1007-13b.[2]

International Building Code (IBC)[3] requires that multi-unit buildings meet STC-50 and IIC-50 between units (STC-45 and IIC-45 if field tested). While these represent the minimum sound isolation level, additional addendums have been provided by the International Code Council (ICC)[4] that recommends higher ratings (STC-55, IIC-55, and higher) for occupant satisfaction. Lightweight wood construction can attain these levels but often requires a combination of additional materials and specialty products added to the construction assemblies solely for acoustic purposes.

This study looks at and tests a number of different supplemental treatments that can be useful for remediation situations in lightweight wood framing construction. Depending on the base construction, these secondary treatments can vary in their effectiveness.

Background

Two multi-unit buildings were in the final stages of construction and supplemental remediation sound isolation treatments were being considered. One building was an apartment-style dorm, and the other building was a luxury apartment. Both buildings were constructed using lightweight wood construction methods. Testing was conducted in these buildings to measure the airborne and impact sound isolation in a variety of secondary acoustic treatments with the same core assemblies.

Stud-Wall Outlet Treatments. Wood-stud walls can meet the IBC required STC-50 rating but typically need additional treatments to do so. These treatments may include additional layers of drywall, resilient clips and increased levels of sound batt. In addition to the treatments, care needs to be taken to treat outlets so that the presence of holes in a wall does not mitigate the increased sound isolation of a wall. Outlet treatments can vary, but they commonly include some combination of the following: backing the outlet box with a resilient putty pad, caulking the edges of the outlet box to the wall, or applying a neoprene outlet cover behind the outlet cover. The field performance of these different treatments is not well documented. Furthermore, it is unclear if there is a benefit in combining these treatments to the base condition of having staggered stud outlets backed with putty pads.

Impact Isolation Variances – Standard IIC and Heavy Impact Sources. Isolating floor impact noise is important for comfort in multi-unit dwellings. In addition to the overall construction of the floor ceiling assembly, the floor finish will have a significant impact on an assembly's IIC rating. Hard surface flooring, such as tile, vinyl, or hardwood, typically has lower impact isolation ratings and allow more impact noise transmission. Because of this, there are many resiliently backed hard surface products and underlayments that have been designed to treat impact noise transmission with the specific aim of improving IIC ratings.

While IIC ratings provide a good measure of how well an assembly may resist impact noise transmission and medium and high frequencies such as those associated with heal clicks or lightweight objects being dropped, it does not distinguish how well an assembly isolates impact noise below 100 Hz, such as a child jumping or an adult walking barefoot. Because of this, additional efforts and standards have been made to test the effects of heavy impacts. It is unclear, however, how traditional methods and treatments to improve IIC ratings will affect heavy impact isolation.

Methodology

To measure airborne sound isolation, the procedures defined in ASTM E336-14 were used. First, a 30-second L_{eq} measurement was made in the receiver room to determine background noise. Then a pink-noise source was activated in the source room, and 30-second L_{eq} measurements were made in the source and receiver rooms to determine signal source and receiver levels. These measurements were used in combination with measured reverberation times to calculate the apparent transmission loss (ATL) of the assembly. The ATL is then graphed alongside the STC curve as defined in ASTM E336-14 to determine the apparent sound transmission class (ASTC).

To measure the impact noise isolation of floor/ceiling assemblies, the procedures defined in ASTM E1007-13b were used. First, a 30-second L_{eq} measurement was made in the receiver room to determine background noise. Then a tapping machine was activated on the floor of the source room, and 30-second L_{eq} measurement was made in the receiving room to determine receiver levels. This measurement was repeated with the tapping machine relocated to four set positions per requirements of the ASTM E1007-13b. These measurements were used, in combination with measured reverberation times to calculate the absorption-normalized impact sound pressure level (ANISPL) of the assembly. The ANISPL is then graphed alongside the IIC curve as defined in ASTM E1007-13b to determine the apparent impact insulation class (AIIC).

In addition to testing the AIIC, attempts were made to measure low-frequency impact isolation using a modified procedure defined in Annex A of ISO 10140-3:2010.[5] First, a 30-second L_{eq} measurement was made in the receiver room to determine background noise. Then a six-pound medicine ball was dropped at four different locations in the source room from a height of one meter. At each dropping location, an L_{max} measurement was taken in four different locations in the receiver room. These measurements are then combined to determine the normalized low-frequency impact sound pressure level (NLFISPL). This differentiates from the ISO standard, because the impact source used was a standard medicine ball instead of the "heavy/soft impact source" as defined in the ISO standard. Measurements made may be used to compare to each other using the same source but not any other measurements.

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Description of Tested Conditions

Stud Wall Outlet Treatments. Testing was completed to measure and evaluate sound isolation of a wood-stud wall between bedroom units in the dorm building according to the standard ASTM E336-14. ASTC ratings were measured for varying combinations of outlet treatments on four different walls in the dorm building. All receiver and source rooms in the testing configurations were identical: being unoccupied with a volume 1280 ft^3 and a shared partition of 108 ft^2. The bedroom wall has a laboratory STC rating of 61 (RAL-TL02-35).[6] This is a full-height wall consisting of the following:

- 5/8-inch-thick Type X gypsum wallboard
- Neoprene clips (24-inch OC vertical, 48-inch OC horizontal)
- 7/8-inch-thick hat channel (25 gauge, 24-inch OC vertical)
- 2 × 4-inch wood studs 16” O.C.
- 3.5-inch-thick unfaced fiberglass sound batts in stud cavity
- Two layers of 5/8-inch-thick Type X gypsum wallboard

In addition to this wall construction, the outlets in this wall are installed in separate stud cavities to avoid back-to-back configurations and are backed with putty pads. In addition to the putty pads, the sound isolation of the walls was tested with the following outlet treatments: caulking the outlet box to the surface of the wall and applying a rubber outlet cover between the box and the typical outlet cover box.

Each tested wall construction and assembly was identical to each other, except the noted outlet treatments and the floor on which the wall was located. There was one wall tested on the fourth floor, two walls on the third floor, and one wall on the second floor. Because of the construction sequence, each wall was tested with multiple outlet treatment combinations but not necessarily all of the following combinations: putty pad only; putty pad and caulked outlet boxes; putty pad and outlet cover pads; and putty pad, caulked outlet boxes and outlet cover pads all combined.

Impact Isolation Variances – Standard IIC and Heavy Impact Sources. Testing was completed to measure and evaluate the impact insulation of a lightweight wood floor/ceiling assembly between vertically stacked kitchen/living room areas in the apartment building. These measurements were made according to the standard ASTM E1007-13b and a modified version of Annex A of ISO 10140-3:2010. In addition to the currently installed vinyl-flooring tile, a number of resiliently backed vinyl tiles and underlayment products were tested in addition to the base floor assembly. The source and receiver rooms in the testing configurations were identical: being unoccupied with a volume of 3711 ft^3 and a shared partition of 407 ft^2. The base floor assembly between residence units consisting of:

- Glued vinyl tile flooring
- 1-inch-thick cementitious topping
- 1/4-inch-thick recycled rubber resilient underlayment
- 3/4-inch-thick tongue-and-groove OSB sheathing
- 16-inch wood chord truss (16-inch OC, 27-foot1-inch span)
- 3-inch-thick fiberglass batts in joist cavity
- Half-inch-thick resilient channel (24-inch OC)
- 5/8-inch-thick Type C gypsum wallboard

The receiving and source rooms were both divided into two sections: Living room and kitchen, with each taking up about half of the room, but with their volumes open to one another. The kitchen portion of the room had the floor assembly defined above. The living room portion of the room had carpet and pad over the cementitious topping instead of vinyl in the floor assembly defined above. Testing configurations involved placing resiliently backed vinyl tiles and underlayment samples on top of the vinyl base assembly and remeasuring the impact isolation.

The tile samples did not cover the entire vinyl portion of the room; instead, the samples were moved to accommodate the tapping machine’s different positions. Because of this, the testing results do not reflect the impacts of damping that may occur when the flooring material covers the entire area. Further, the results are not official and should only be used for comparison among this data set. The different tile and underlayment tested are defined in Table 1.

The construction sequencing did not allow for a testing setup that would have replaced the vinyl tile flooring with resiliently backed tiles or tiles with underlayment. Additionally, impact insulation was measured for the carpeted portion of this room for comparative purposes. The floor assembly for the carpeted portion was identical to the vinyl portion, except that instead of vinyl flooring tile, there was 16-ounce, closed-loop carpet installed on an 8-ounce carpet pad.

Field Measurements and Results

Measurements were completed in both buildings to determine apparent sound transmission class (ASTC) for wall assemblies and both apparent impact insulation class (AIIC) and ASTC for floor-ceiling assemblies. Additionally, low-frequency impact testing was measured on the floor-ceiling assemblies.

Stud-Wall Outlet Treatments. Testing was completed in the dorm building to measure the apparent sound transmission class of four similarly constructed walls with varying outlet configurations. Table 2 is a summary of the tests. Detailed transmission loss levels used to determine ASTC levels for each test are presented in Figures 2-11.

In each tested wall, the presence of adding outlet treatments in combination with the original putty pad either changes the measured STC by one point or does not change the measured STC at all. Other than showing minimal change in sound isolation ratings, there does not appear to be a consistent pattern between adding outlet treatments in addition to a putty pad and the measured STC rating.

Impact Isolation Variances – Standard IIC and Heavy Impact Sources. Testing was completed in the apartment building to measure the apparent impact insulation class of a single floor assembly with different variations of resiliently backed vinyl tiles and underlayment. Table 3 summarizes these tests. Detailed absorption normalized impact sound pressure levels used to determine AIIC levels and the normalized low frequency impact sound pressure levels are presented in Figures 12-22.

The base floor assembly had a field tested AIIC of 45. This just meets the IBC standard for field-tested impact insulation. In each tested floor condition, additional floor coverings and underlayment increase the tested AIIC of the base assembly by 2-6 IIC points. The low-frequency impact was measured for the above conditions, and the calculated normalized low-frequency impact sound pressure levels for these tests are presented in Figure 1.

Table 1. Configurations tested for impact insulation.

Test Number	Flooring Surface	Details	Underlayment	Details
12	Base assembly	–	Base assembly	–
13	Locking vinyl tile	4-mm thick tile	Base assembly	–
14			1.5 mm-thick rubber underlayment	59 lbs/ft^3 laydown mat
15			1/2”-thick, medium-density fiber board	20-30 lbs/ft^3 rigid cellulous
16	Locking vinyl tile	7-mm thick tile	Base assembly	–
17			1.5 mm-thick rubber underlayment	59 lbs/ft^3 laydown mat
18			1/2”-thick, medium-density fiber board	20-30 lbs/ft^3 rigid cellulous
19	Resiliently backed	3-mm thick tile	Base assembly	–
20	Vinyl tile	backed 3-mm thick rubber underlayment	1.5 mm-thick rubber underlayment	59 lbs/ft^3 laydown mat
21			1/2”-thick, medium-density fiber board	20-30 lbs/ft^3 rigid cellulous

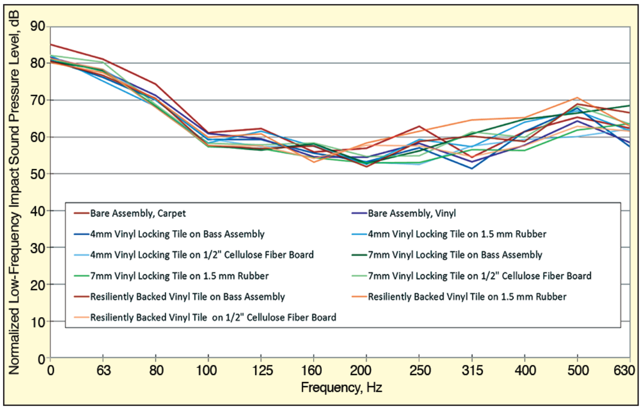

Figure 1. Normalized low-frequency impact sound pressure levels.

The calculated NLFISPL levels for the different resiliently backed vinyl tiles and underlayment are generally similar to each other, particularly at and below 100 Hz. There is some variance at the higher frequencies, but there is not a pattern correlated between the different vinyl treatments. Observationally, implementing different treatments didn't make a noticeable improvement in the severity of the low-frequency impacts or their ability to rattle other building elements. The carpeted portion of the room did have NLFISPL levels around 2-5 points higher than the vinyl treatments at the lower frequencies.

Conclusions

This study examines and tests a number of different supplemental treatments that can be useful for remediation situations in lightweight wood framing construction. Not all supplemental treatments will increase the composite sound isolation of lightweight wood framing construction. Secondary treatments need to be evaluated in the context of the base assembly in which they will be applied before installation.

Stud-Wall Outlet Treatments. Walls form the basis for horizontal sound isolation in lightweight wooden construction of multi-unit dwellings. Standard wall constructions typically require additional

Table 2. Results of ASTC testing of varying outlet treatments in wall assemblies in dorm.

Test No.	Wall	Condition	ASTC
1	Fourth floor	Putty pads/caulked outlet boxes	47
2	Fourth floor	Putty pads/caulked outlet boxes/ outlet cover pads	48
3	Third floor A	Putty pads/caulked outlet boxes	48
4	Third floor A	Putty pads/caulked outlet boxes outlet cover pads	48
5	Third floor B	Putty pads only	49
6	Third floor B	Putty pads/caulked outlet boxes	48
7	Second floor	Putty pads only	49
8	Second floor	Putty pads/caulked outlet boxes	50
9	Second floor	Putty pads/outlet cover pads	50
10	Second floor	Putty pads/caulked outlet boxes/ outlet cover pads	50

Table 3. Results of AIIC testing of varying resiliently backed vinyl tiles and underlayments in addition of base floor assembly in apartment building.

Test No.	Condition	AIIC
11	Base assembly – carpet	66
12	Base assembly – vinyl	45
13	4-mm vinyl locking tile on base assembly	47
14	4-mm vinyl locking tile on 1.5-mm rubber underlayment	50
15	4-mm vinyl locking tile on 1/2" cellulose fiber board	52
16	7-mm vinyl locking tile on base assembly	48
17	7-mm vinyl locking tile on 1.5-mm rubber underlayment	49
18	7-mm vinyl locking tile on 1/2" cellulose fiber board	52
19	Resiliently backed vinyl tile on base assembly	50
20	Resiliently backed vinyl tile on 1.5-mm rubber underlayment	51
21	Resiliently backed vinyl tile on 1/2" cellulose fiber board	51

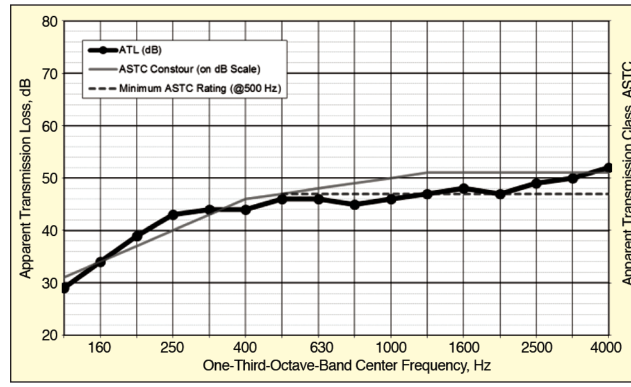

Figure 2. ASTC 47; fourth floor – putty pad and caulked outlet box; Test 1.

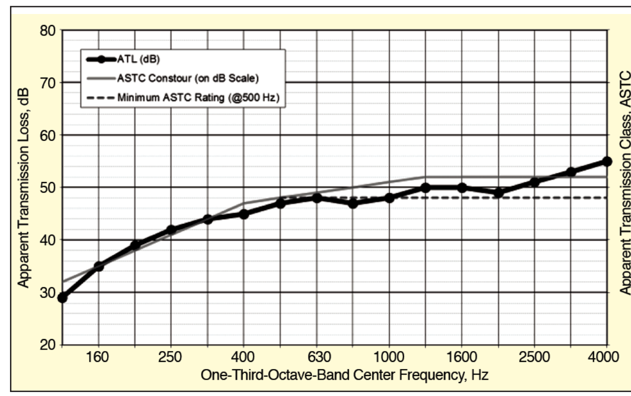

Figure 3. ASTC 48; fourth floor – putty pad and caulked outlet box & outlet cover pad; Test 2.

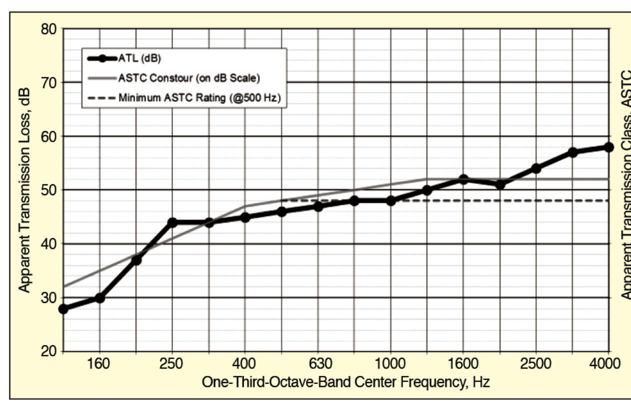

Figure 4. ASTC 48; third floor Wall A – putty pad and caulked outlet box; Test 3.

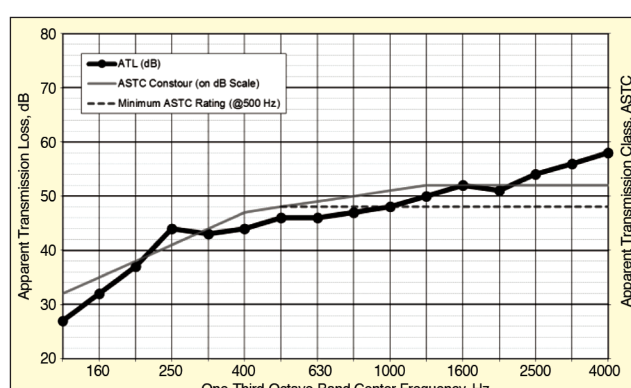

Figure 5. ASTC 48; third floor Wall A – putty pad and caulked outlet box and outlet cover pad; Test 4.

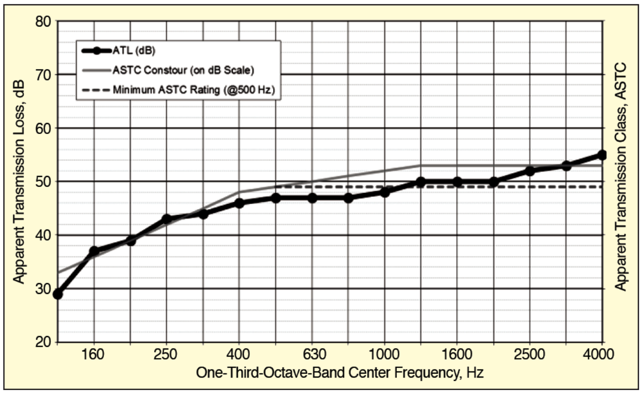

Figure 6. ASTC 49; third floor Wall B – putty pad only; Test 5.

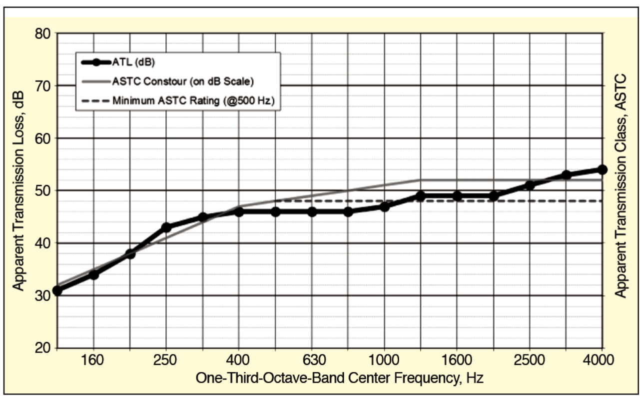

Figure 7. ASTC 48; third floor Wall B – putty pad and caulked outlet box; Test 6.

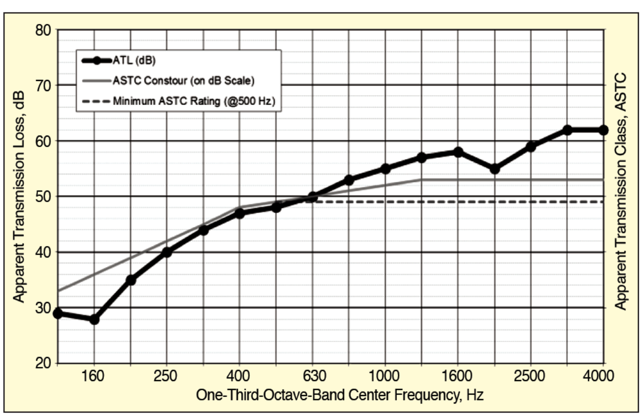

Figure 8. ASTC 49; second floor – putty pad only; Test 7.

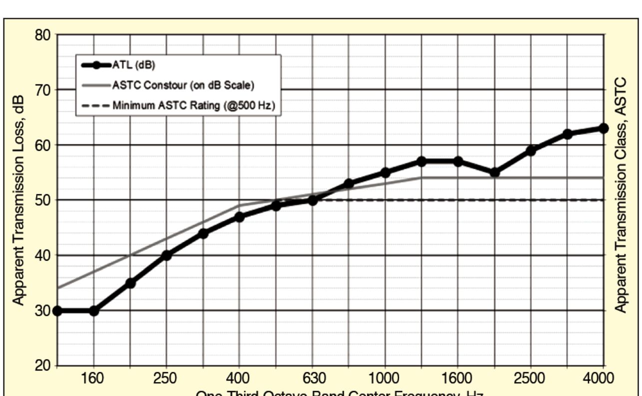

Figure 9. ASTC 50; second floor – putty pad and caulked outlet box; Test 8.

treatment to meet IBC standards. Changing the overall design of the wall to increase its sound isolation capabilities is not enough to achieve appropriate sound isolation by itself. It is important to acoustically treat outlets in walls where sound isolation is a

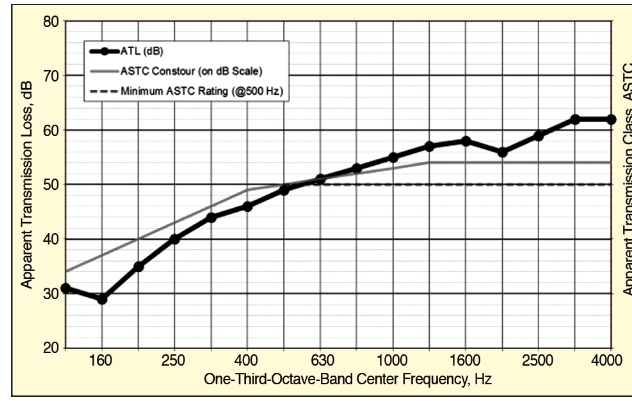

Figure 10. ASTC 50; second floor – putty pad and outlet cover pad; Test 9.

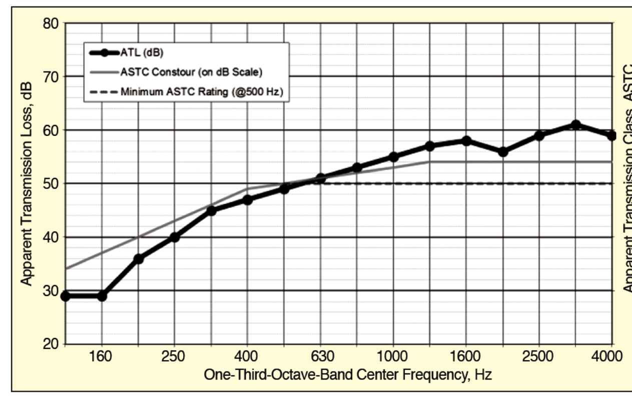

Figure 11. ASTC 50; second floor – putty pad and caulked outlet box and outlet cover pad; Test 10.

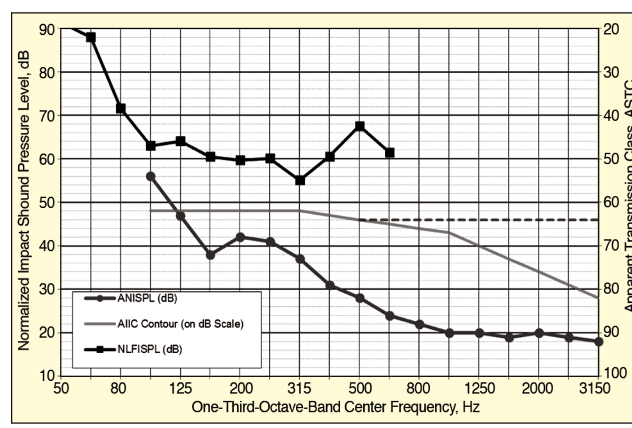

Figure 12. AIIC 66; base assembly – carpet; Test 11.

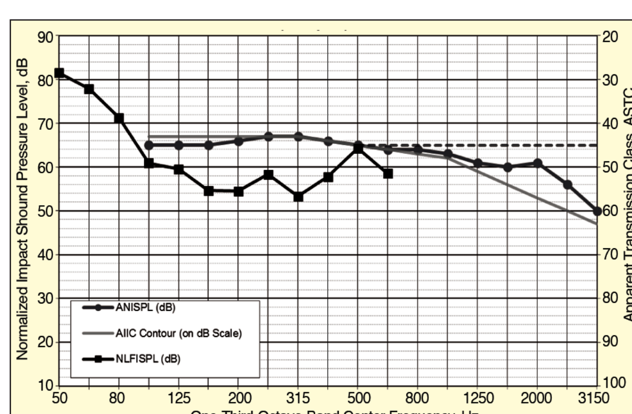

Figure 13. AIIC 45; base assembly – vinyl; Test 12.

concern. Otherwise, the presence of untreated electrical outlets will degrade the sound isolation provided by the wall

Generally, the presence of the secondary outlet treatments that

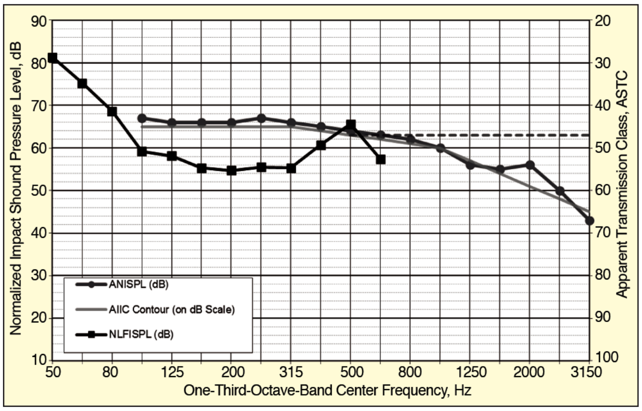

Figure 14. AIIC 47; 4-mm vinyl locking tile on base assembly; Test 13.

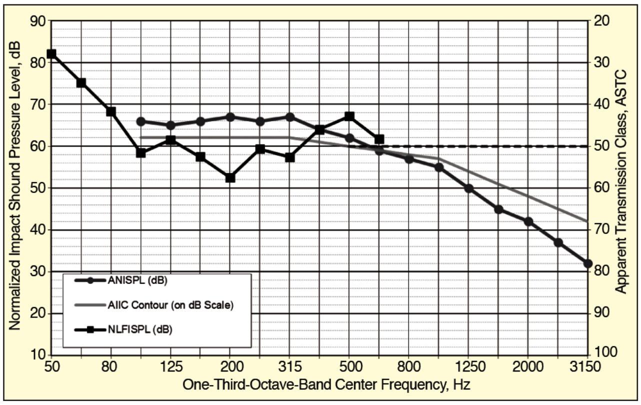

Figure 15. AIIC 50; 4-mm vinyl locking tile on 1.5-mm rubber underlayment; Test 14.

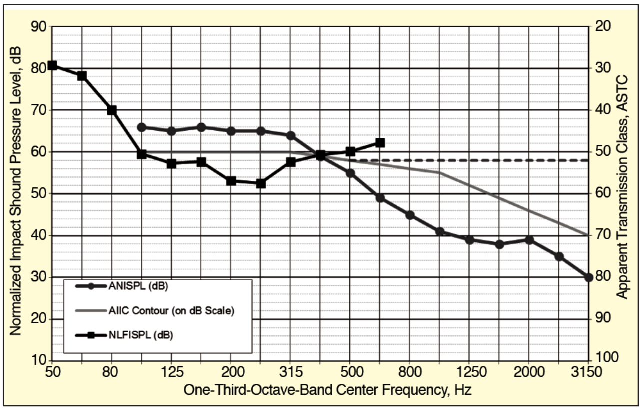

Figure 16. AIIC 52; 4-mm vinyl locking tile on 1/2-inch cellulose fiber board; Test 15.

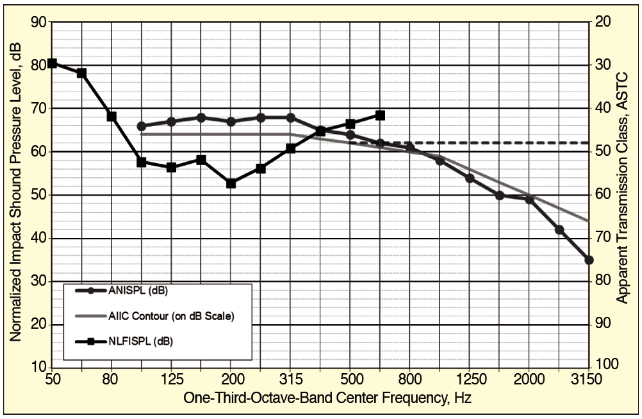

Figure 17. AIIC 48; 7-mm vinyl locking tile on base assembly; Test 16.

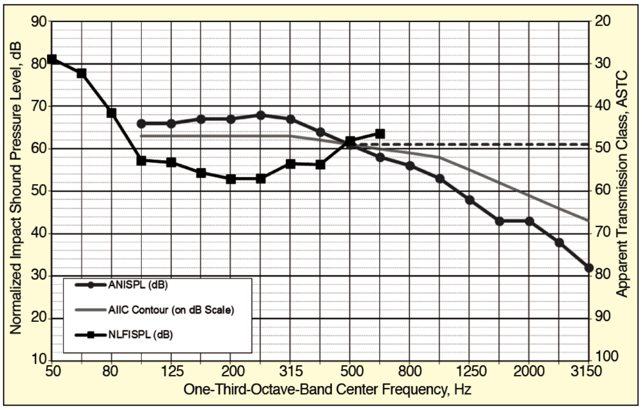

Figure 18. AIIC 49; 7-mm vinyl locking tile on 1.5-mm rubber underlayment; Test 17.

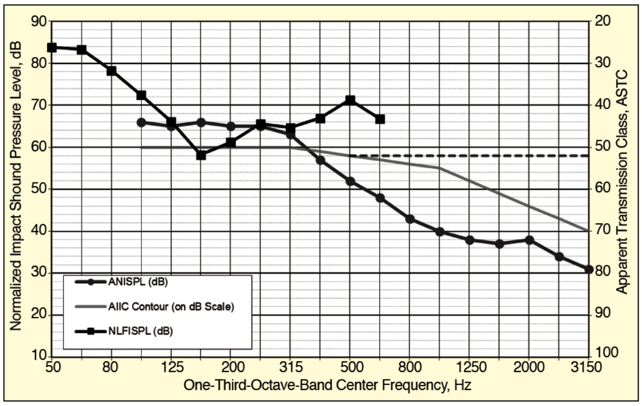

Figure 19. AIIC 52; 7-mm vinyl locking tile on 1/2-inch cellulose fiberboard; Test 18.

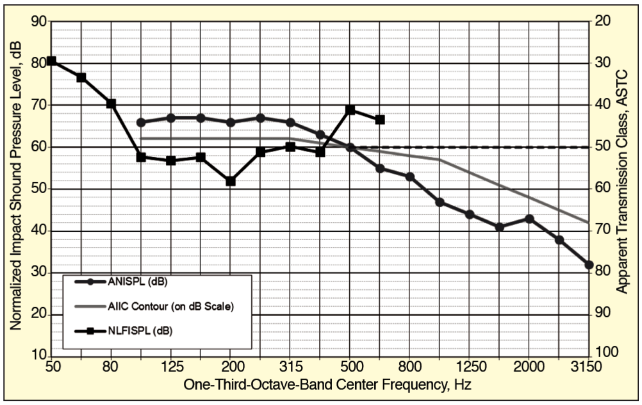

Figure 20. AIIC 50; resiliently backed vinyl tile on base assembly; Test 19.

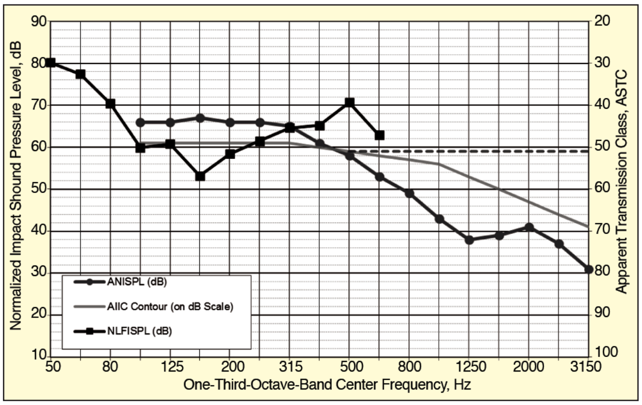

Figure 21. AIIC 51; resiliently backed vinyl tile on 1.5-mm rubber underlayment; Test 20.

were studied did not change the result of the overall ASTC values. All of these measurements had the outlets in staggered studs and backed with putty pads. In each of the four walls, the measured sound isolation never varied more than one ASTC point for each

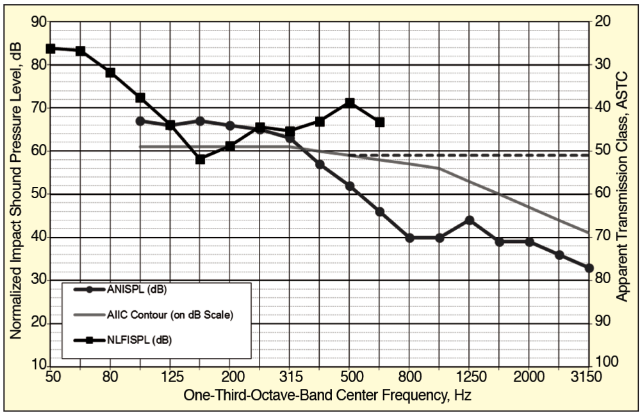

Figure 22. AIIC 51; resiliently backed vinyl tile on 1/2-inch cellulose fiberboard; Test 21.

specific wall. While the presence of more treatments generally increased the measured ASTC rating by one point, Wall B on the third floor had the opposite effect. The measured ASTC rating decreased from 49 to 48 with the addition of caulking the outlet boxes.

There are two reasons that might explain why the ASTC values do not proportionally increase with the additional outlet treatments. First, it is likely that the presence of a correctly installed putty pad effectively treats the outlet penetration. If the putty pad effectively seals the outlet penetration, then additional treatments will not improve the sound isolation. Additionally, the outlet cover pad was difficult to install in the field, since the pad did not seem to allow the standard cover to make complete contact with the wall. Second, there may be some limits on the overall sound isolation that can be achieved in these walls due to flanking noise. While efforts were made to limit flanking noise, the natural limits of lightweight wood framing construction prevent higher levels of sound isolation.

Partitions that are otherwise able to achieve higher levels of sound isolation may still benefit from supplemental treatments in addition to putty pads and staggered outlets. When treating outlet treatments in similar wood-framed constructed buildings with similar wood-stud walls, the results of these tests appear to indicate that outlet treatments in excess of a correctly installed putty pad may not be necessary.

Further research testing these outlet treatments in a laboratory setting would be interesting to determine whether flanking noise had a significant impact on the results. Also, testing these treatment variations in different walls (both higher and lower sound isolation levels) could indicate that these additional treatments might be useful at different base sound isolation capabilities.

Impact Isolation Variances – Standard IIC and Heavy Impact Sources. Impact isolation is an important goal for user satisfaction in multi-unit dwellings using lightweight wood construction. The testing configurations only used small tile and treatment samples. It is likely that a system installed throughout the entire vinyl area would increase weight on the floor and add damping to the floor that could increase the measured AIIC. The base vinyl assembly had a tested AIIC of 45. The different testing configurations were able to increase the AIIC by a small to moderate 2 to 7 points.

Generally, the thicker underlayment materials result in a higher AIIC values. The 1.5-mm-thick underlayment resulted in AIIC values between 49 and 51, while the half-inch-thick (12.7 mm) underlayment resulted in AIIC values between 51 and 52. The benefit of this thicker underlayment was mitigated when the topping vinyl tile had its own resilient backing. The resiliently backed tile had a measured AIIC rating of 51 with both underlayment options. Though both options performed one point better than the measured AIIC 50 of the resiliently backed tile on the bare assembly by itself.

When comparing the two vinyl tiles themselves, there does not appear to be a consistent benefit of having a thicker tile. Both the 4 mm and the 7 mm tiles performed similarly with each underlayment treatment. In each underlayment configuration, the vinyl tiles had measured AIIC values within one point of each other, but neither was consistently better than the other.

A variety of treatments proved useful for increasing AIIC ratings above the base vinyl AIIC 45. Upon inspection of the low-frequency impact insulation values, there does not appear to be a similar correlation for low-frequency impact insulation. The NLFISPL levels show that all of the different vinyl flooring options perform similarly to each other at and below 100 Hz. There is some variation as the frequency increases, but there is no consistent pattern at these levels. Additionally, the carpet had the highest AIIC rating, with 66, but had the highest measured NLFISPL.

While it is important to make treatments to increase impact insulation as traditionally measured with AIIC, these treatments may not increase the low-frequency impact insulation. To treat low-frequency impact noise, such as children jumping or adults walking barefoot, designers and construction professionals will need to explore additional treatments instead of relying solely on treatments that increase or meet certain IIC values as specified in the standards.

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