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LABORATORY MEASUREMENT OF TRANSMISSION LOSS OF WALL JOINTS USING SOUND INTENSITY TO PREDICT SOUND ISOLATION OF WALLS

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ABSTRACT[*]

It is well known that the sound isolation of a wall can be degraded due to sound leaks at the top or bottom of the wall. A method for quantitatively measuring the acoustical effect of such joints would not only allow comparison of sealing methods and products, but also evaluation of the effect of sound leaks and other errors in installation. One method is ISO 10140-1 Annex J, which describes building small cassettes which hold only the joint and measuring the transmission loss per unit length of joint. However, previous research by the authors indicates that this method has poor dynamic range and therefore limited usefulness for this purpose. The authors have been developing a modified method using sound intensity to measure the transmission loss of the joint, which provides increased sensitivity and precision. This data can be used to calculate the composite isolation of the wall/joint system and the effect of deficiencies in the joint. The calculations are compared to full size testing to evaluate the accuracy of the method.

Keywords: *sound transmission loss, slits, sealant, sound intensity*

1. INTRODUCTION

It is well known that air leaks at the top of walls where they intersect with the structure can significantly degrade the airborne noise isolation. It is conventionally considered best practice to establish an airtight seal at the top-of-wall joint using resilient caulking. Various products exist that can take the place of a caulked joint from a fire safety perspective. However, in North America there is no standardized or broadly accepted method for evaluating the acoustical effect of these products, top-of-wall joint design, or any similar narrow element.

It may seem obvious that one could simply construct a wall in the lab with the proposed top-of-wall joint and compare this to a standard test of the same wall with the top fully sealed. This could show equivalence to the traditional method of caulking or simply evaluate the wall's acoustical insulation. However, this method is impractical due to uncertainty in the measurement procedure. It is common for different accredited laboratories to report differences in transmission loss on the same wall assembly that exceed 10 dB at the relevant mid- and high-frequency bands. (For example, the ASTM reference assembly, despite being designed to minimize variation in construction, has a reproducibility standard deviation of 3 dB or more at the upper frequencies. [1]) These uncertainties make it impossible to use traditional acoustical test methods to determine by comparison whether the differences are due to the top-of-wall joint or to variability in the measurement.

1.1 Evaluating Construction Errors

Development of a robust methodology would have additional benefit beyond evaluating products. While holes or cracks observed in separating construction rightly raises the suspicion of possible sound leaks, these do not necessarily have a significant effect on the airborne sound isolation. Such leaks and other workmanship issues are often blamed, when in practice equal or greater attention should be placed on other possible causes such as flanking sound transmission. [2, p. 501] The authors have previously

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documented how acoustical experts tend to automatically blame installation errors for lower than expected sound ratings of walls with resilient channels, when the actual problem was insufficient consideration of statistical variation of wall performance. [3] Similarly, top-of-wall leaks are often blamed reflexively, even when (in hindsight) it is rather unlikely that they were the primary issue or the potential cause of the actual performance limitation. Often, the “solutions” are wholesale modifications of a variety of components of construction rather than focusing on the actual limitations of the assembly. These failures are due to a lack of understanding of the limitations of the existing data and test methods.

It is therefore valuable to develop a method for reliably and quantitatively evaluating the acoustical performance of top-of-wall joints. This would give a means to investigate the effect of errors in construction.

1.2 Composite Transmission Loss

On the other hand, manufacturers have been using simplistic calculations of composite STC rating to claim that a product or method is suitable for a particular situation. Using such calculations when one of the components has much less area than the other is entirely unhelpful considering the uncertainties involved.

For example, a manufacturer measures a typical wall with and without a small element installed. The sound reduction attributed to the element is calculated by

$$\mathrm{R_E} = -10\log\left(\frac{S_C 10^{-\frac{R_C}{10}} - S_{Wall}10^{-\frac{R_{Wall}}{10}}}{S_E}\right) \quad (1)$$

where *R* is the sound reduction index, *S* is the area, and the subscripts are *C* for composite (wall and element), *wall* for the wall (without the element) and *E* for the element. This is a common calculation that assumes that the radiated sound power depends only on the area, which has not been demonstrated to be a useful calculation for slit-type elements.

If a wall (2.4 x 2.4 m) is tested with a small element (100 x 100 mm), the element area is just 0.25 percent of the total area. This makes the calculated value for R_E strongly dependent on the value for the wall in such a way that this calculation is entirely unsuitable. E.g., assume R_C is 65 dB. If R_{wall} is 65 dB then R_E is also 65 dB, but if R_{wall} is 65.2 dB the R_E is only 52.4 dB. The measurement method does not have anywhere near the precision to reliably perform this calculation.

Further, the calculation is often done with single number ratings such as STC instead of in third-octave bands. This is clearly unsuitable since the effect of the joints is primarily above 500 Hz while the calculated rating is often controlled by lower-frequency bands.

Calculating composite transmission loss for elements of this type requires further study to determine its limitations. This study attempts to develop a method to measure the sound reduction of slits and elements without requiring the calculation method of Eq. (1).

2. REVERBERATION ROOM METHOD

2.1 Previous Results

In a previous study [4], the authors developed a test method based on ISO 10140-1 Annex J. [5] The standard states that this is applicable to “acoustic sealing of slits (with or without fillers)” as well as gaskets and door or window seals. The test method is the same as typical measurement of sound reduction index, except calculated by length (per meter of the joint) rather than by area (per square meter of the wall).

Testing was performed as described in ASTM E90 [6], except that Eq. (5) in that document is modified to

$$R(f) = L_S(f) - L_R(f) + 10\log\frac{l_0 l}{A_R(f)} \quad (2)$$

where *R* is sound reduction index or transmission loss; *L* is the average sound pressure level and *A* is the acoustic absorption (in m^2) in the source (S) and receive (R) chambers, indicated by subscripts; l is the length of the specimen in meters, and l_0 is the reference length of 1 m. We refer to this as the reverberation room method.

Testing was performed at Western Electro-Acoustic Laboratory in Santa Clarita, California. WEAL is NVLAP-accredited for ASTM E90, which defines airborne noise insulation measurements analogous to ISO 10140-2. The dimensions of the receiving chamber were 6.3 x 4.5 x 5.2 m. The opening between the chambers is nearly the entire common wall; a filler wall is built in the opening to reduce the size of the test opening. The filler wall is constructed of double wood studs, 150 mm and 200 mm deep (6 inch and 8 inch, nominal, respectively), with a 50 mm gap between the studs, glass fiber batt insulation in the stud cavities, four layers of 16 mm (5/8-inch) type X gypsum wall board on the source side and three layers on the receive side. The measured insulation of the filler wall is STC 73 and R_w (C; C_{tr}) = 72 (-1; -4).

The cassettes were much thinner than the filler wall between the test chambers. The cassette was mounted flush with the filler wall on the source room side and sloped in the vertical direction on the receive side to avoid a deep tunnel or niche. This was accomplished by cutting the studs at an angle in a manner that did not bridge the stud rows; this is shown in Figure 1.

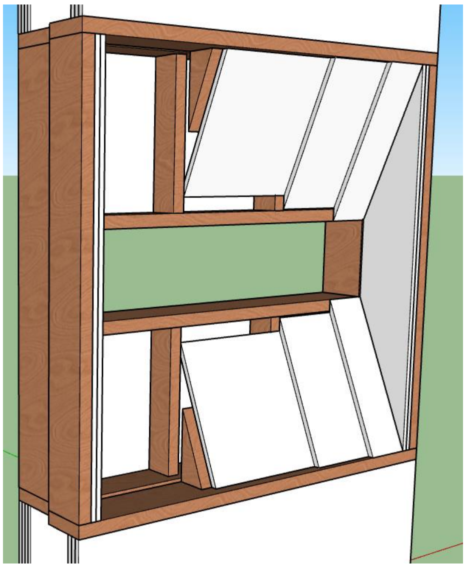

Figure 1: Rendering showing frame for measuring cassettes in the filler wall.

2.2 Previous results

Here we summarize key findings from the previous study.

- The frequency range of the method was limited to frequencies above 500 Hz.
- The dynamic range of the method appeared to be insufficient to accurately measure the joints under test. The measured isolation of the joints in that study differed from the maximum TL by just 6 dB. The situation was not improved even when the length of the joint was doubled, which should have increased the signal to noise ratio.
- The method was largely independent of the length of the joint, as desired.
- Full-scale testing of a wall with the joint under test was performed and compared with the cassette test of the joint. The TL of the cassette data was significantly lower than the full-scale wall, and using the cassette data would significantly underpredict the actual performance of the wall in this case.

3. SOUND INTENSITY METHOD

3.1 Measurement Method

It seemed that the reverberation room method had insufficient sensitivity to accurately measure the joints under test, and we suspected that this was due to flanking noise through the filler wall assembly, or the complexities of the coupling of a small source to a large reverberation room. Because sound intensity can directly measure the radiated sound power and can reject sound radiated from flanking paths, it had the potential to be a better measurement method.

The filler wall and cassettes were constructed in the same manner as in the reverberation room method. The transmission loss was measured using a sound intensity probe following the procedure in ASTM E2249 [7]. Acoustical absorption was temporarily added to the receiving chamber on carts to create a sufficiently absorptive receiving room. This allowed for rapid switching between reverberation room and sound intensity measurements without disturbing the specimen. See Figure 2.

Figure 2: Carts containing absorptive materials to quickly change the sound absorption in the receiving room

3.2 Measurements

The cassettes were 1.25 m x 0.25 m high x 216 mm deep. A very short double stud wall was constructed in the cassettes, consisting of two sets of 64 mm (2.5 inch) steel studs with a 25 mm air gap and insulation and two layers of 16 mm (5/8-inch) type X gypsum board on each side. The gypsum board was cut to provide a defined gap at the top of the wall.

Several top-of-wall joint products were tested, including traditional caulk, with different sized gaps. For each configuration of product and gap size, the cassette was installed and both measurement methods were performed without disturbing or reinstalling the cassette.

3.3 Results

Some representative results are shown in the following figures. Figure 3 shows the reverberation room method and Figure 4 shows the intensity method of the same products. The black and grey lines are the traditional caulk, the light blue and light red lines are two products under evaluation, and the dark red line shows the gap with no product or sealant. (Note that this is not a clear gap because of the presence of the solid top stud track.)

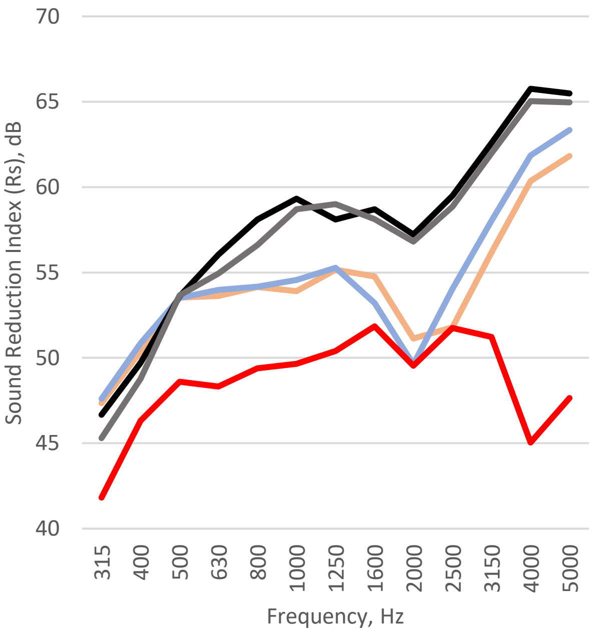

Figure 3: Measurement using reverberation room method. See text for legend.

As before, there were only significant differences observed above 500 Hz, and most strongly between 1000 and 4000 Hz.

The reverberation room and intensity methods gave broadly consistent results. However, the reverberation room method showed limited dynamic range, similar to the previous results, with only about 6 dB between the tested assemblies. The intensity method resulted in much higher transmission loss values for the caulked joints, especially above 1000 Hz. The difference between the intensity method and the reverberation room method increased with the performance of the joint. This suggests that the reverberation room method is being controlled by flanking or other paths, and that the intensity method is successfully excluding these paths. With the intensity method, differences between the tested joints can be observed over a wider range of performance. For example, the difference between the orange and blue curves is apparent in both Figure 3 and Figure 4, but the difference between the black and grey curves, with about 10 dB better insulation, can only be seen in Figure 4 using the sound intensity method.

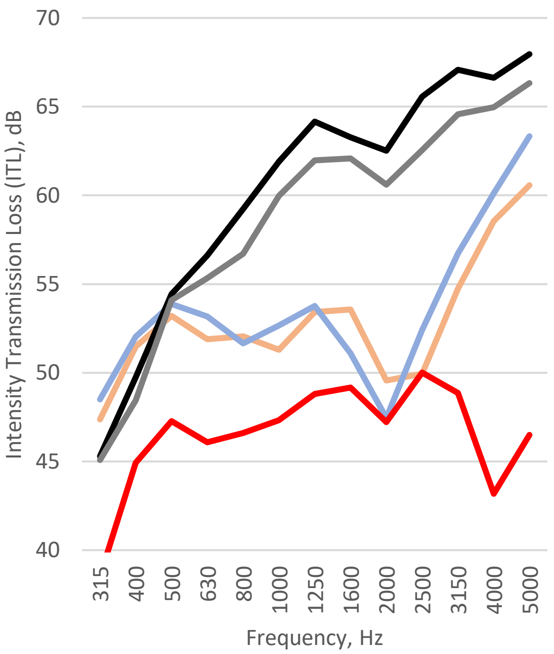

Figure 4: Measurement using sound intensity method. See text for legend.

3.4 Comparison of Methods

The difference between sound intensity and traditional reverberation room methods has been studied previously, and we can define it as $K = R - R_I$, where R is the sound reduction (a.k.a. transmission loss) and R_I is the sound reduction measured with sound intensity. ASTM E2249 includes results from a study [8] of this difference K, while a different value is given in ISO 15186-1. [9] These are plotted along with the measured differences in our study in Figure 5.

The lower-performing assemblies in this study have a $K \approx 2$ and without strong frequency dependence. This is somewhat higher than the previously reported differences. Further investigation will be required to determine whether this is inherent in the cassette-type measurement method or due to other causes.

For the higher performing (fully caulked) assemblies, K is large and negative. This is a clear indication that the reverberation room method is controlled by flanking paths, while the sound intensity method is successfully excluding those paths from the measurement.

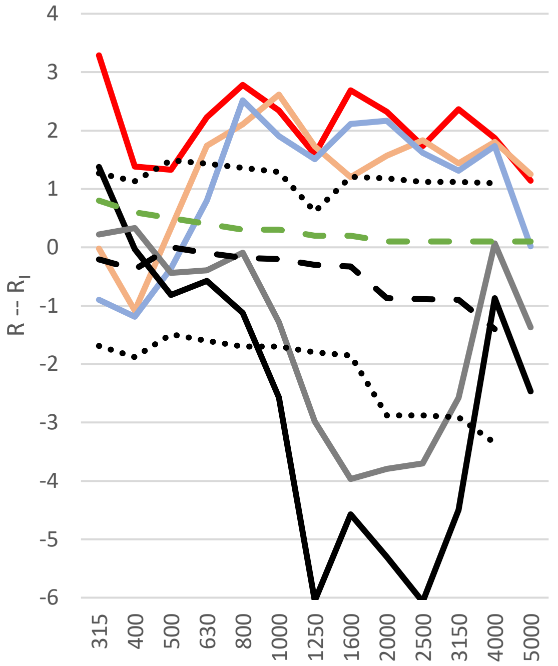

Figure 5: Comparison of sound intensity and reverberation room methods. Black and green dashed curves are the differences reported in ASTM E2249 and ISO 15186-1, respectively. Remaining colors are from the study and the same assemblies as in Figure 3 and Figure 4.

4. SUMMARY

A method of quantifying the effects of joints is needed to compare products and methods, evaluate the effect of sound leaks on the overall isolation, and estimate the associated risks. A small-scale cassette method has been developed.

The difference between joint types is observed above 500 Hz. Using sound intensity to measure the transmission loss gives greater dynamic range compared to the reverberation room method, which is limited by flanking through the structure supporting the cassette.

Using the cassette mounting method and measuring the transmission loss with sound intensity is a promising method for measuring and comparing the performance of joints. Because sound intensity is easily performed in the field as well as the laboratory, this method may also be suitable for in situ measurements. Further investigation will determine whether the performance of full-scale walls with various top-of-wall joints can be predicted using this method.

5. ACKNOWLEDGMENTS

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