Impacts of Amplified Sound in Commercial Spaces Below Residences

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High-density, mixed-use buildings often result in residential units directly above commercial spaces, such as restaurants and bars. The increased use of sound systems with subwoofers in commercial spaces presents low-frequency impacts that are not sufficiently addressed by code and are often difficult to predict because of a lack of transmission loss test data below 50 Hz for common assemblies. While building and local codes aim to protect residences by broadly regulating transmitted noise levels, the codes and the metrics often fall short and overlook issues of audibility, disturbance, and annoyance. Measurement metrics referenced by codes are typically A-weighted and long-term time averages (L_{Aeq} or L_{dn}), which do not adequately account for low-frequency content or fluctuating sound levels that may be associated with amplified sound. Due to the inadequacy of these metrics, a building may comply with the code requirements yet still result in aggravation for residents.

Building and local codes typically define baseline requirements for the sound isolation performance of partitions or allowable levels of transmitted sound for residential spaces. Compliance with these code minimum requirements does not often align with occupant satisfaction. In other words, even if the code minimum is met, residents may still lodge complaints. The use of amplified music with subwoofers in commercial spaces presents additional challenges for sound isolation because the transmission loss for most partitions is reduced at lower frequencies.

This research topic arose from a project where a mixed-use building owner hired Mei Wu Acoustics to evaluate the existing demising floor/ceiling assembly between a vacant commercial space and occupied apartments above. Given the existing architectural conditions, the owner wanted to know which types of commercial uses would comply with code requirements for interior residential noise levels, and they wanted to understand the degree of disturbance or annoyance that commercial uses could present even if the code requirements were met.

The prior tenant in the commercial space was a buffet-style restaurant that had operated for many years, and as we understood it, the residents did not have noise concerns during typical restaurant operations. Only when the restaurant had special events with amplified music did the tenants hear transmitted noise. This anecdotal information was useful in correlating the residents' experience with our calculations and analysis of sound transmission between the commercial and residential spaces.

Code Requirements

Code requirements regarding the architectural sound isolation and transmitted interior noise levels of residences are often determined in the United States by the building code and the local authorities, such as in a municipal code or general plan. The International Building Code (IBC) is in use or adopted in 50 states, the District of Columbia, and a number of U.S. territories.[1] IBC, Chapter 12, Section 1207. requires residential floor/ceiling assemblies separating dwelling units from each other and from public spaces to achieve a minimum rating of STC-50 (or STC-45 when field tested).[2]

The California Building Code (CBC) is comparable with the IBC and has an STC-50 (FSTC-45) requirement for demising partitions; however, the CBC goes further by establishing a maximum allowable interior noise level in residences of 45 dBA L_{dn} due to exterior sources.[3] Housing and Urban Development (HUD) projects are also subject to the same interior noise level requirements of 45 L_{dn}.[4] These interior noise level requirements are typically intended to protect residents from environmental noise sources like vehicular traffic and are used to guide the building façade design.

L_{dn} (also sometimes referred to as DNL or day-night sound level) is a single-number average of measured sound pressure levels over a 24-hour period. This metric applies a 10-dB penalty to sound levels measured between the hours of 10 p.m. and 7 a.m. to account for nighttime decreases in ambient levels in residential communities. Many local authorities will cite 45 L_{dn} or 45 dBA as the baseline requirement for interior residential sound levels due to transmitted noise generated outside the occupant's space. For example, the city of Long Beach, California, sets interior noise limits for residences at 45 dBA during daytime hours, and 35 dBA during nighttime hours, which is roughly equivalent to 45 L_{dn}. The Long Beach code also imposes a penalty if the sound sources are tonal, impulsive, or contain speech or music, reducing the standard by an additional 5 dBA.

Local authorities may also establish criteria in terms of maximum sound levels. The city of Palo Alto, California, defines "noise level" as "the maximum continuous sound level or repetitive peak sound level produced by a source or group of sources" and sets the interior transmitted sound level limit of multi-family residential spaces at no more than "6 dB above the local ambient three feet from any wall, floor, or ceiling inside any dwelling unit on the same property, when the windows and doors of the dwelling unit are closed, except within the dwelling unit in which the noise source or sources may be located." The "local ambient" is defined as "the lowest sound level repeating itself during a six-minute period" and "in no case shall the local ambient be considered or determined to be less than 30 dBA" for residential interior noise levels.

As evidenced by the Palo Alto code definitions, municipal codes can be plagued by ambiguities that require significant interpretation. These ambiguities can yield dramatically different end results depending on how and when the measurements are executed or how the measurement data are evaluated. Further, the use of single-number metrics, such as dBA or STC, can oversimplify nuanced problems, This will be demonstrated and discussed. While these codes can provide a baseline for noise control, they are not well enough defined to predict issues of annoyance, disturbance, or audibility.

Sound Transmission through Floor/Ceiling Assemblies

STC (sound transmission class) is a single number rating to characterize the sound isolation performance of assemblies. The STC rating is calculated by fitting a pre-defined curve to a partition's transmission loss data that has been measured in 1/3-octave bands in the frequency range of 100 to 5000 Hz (defined by ASTM E413). When the curve is positioned according to the criteria set in the standard, the single-number STC rating is given by the transmission loss value at the point where the curve crosses the 500-Hz frequency line. The frequency distribution of the STC curve aligns with human speech, and as a result, STC ratings are most useful for selecting partitions where the noise sources under consideration are mid-frequency range, such as people talking or small television speakers. STC ratings are less useful when noise sources have low-frequency content below 100 Hz, such as industrial and mechanical sounds, musical instruments, or audio systems with subwoofers.

One of the most significant issues with using STC as a design criterion is that, due to the way in which STC is calculated, two partitions may achieve identical STC ratings but exhibit dramatically different transmission loss performance. Where there are critical noise impacts, it is necessary to evaluate the spectrum and

Based on a paper presented at Inter-Noise 2015, 44th International Congress on Noise Control Engineering, San Francisco, CA, August, 2015.

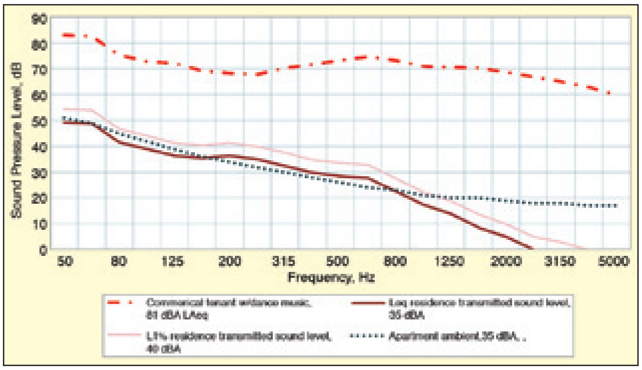

Figure 1. Sample calculation showing transmitted sound levels from amplified music in a commercial space to a residence through a 6-inch concrete floor/ceiling assembly.

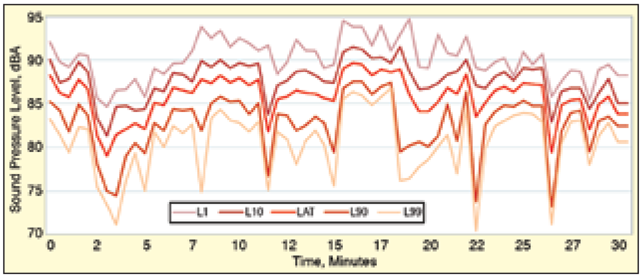

Figure 2. A-weighted, 30-second, time-average measurements for 30 minutes in a bar with amplified music.

amplitude of the source and its transmission through the partition in 1/3-octave bands. Laboratories are typically unable to accurately test transmission loss below 50 Hz, and more commonly measure only to 100 Hz. This lack of data presents challenges when attempting to calculate sound transmission due to audio systems with subwoofers, which operate below 100 Hz.

Evaluating Impacts

To identify the impacts of low-frequency sound transmission from amplified music, a single case study will be presented using the measured spectrum from a lively bar with amplified dance music with subwoofers. The demising floor/ceiling assembly between the commercial space and the residence will be 6-inch concrete (2446 kg/m^3 density), which has a laboratory tested STC rating of 53 (National Research Council of Canada Test# B-3463-1).

The objective of this exercise is to identify the allowable sound level range that the commercial tenant can operate at while complying with code but also to identify the degree to which a resident may still be impacted even though the code requirements are met. The code minimum requirement for this exercise is a transmitted sound level in the residence of no more than 45 dBA daytime (7 a.m. - 10 p.m.), 35 dBA nighttime (10 p.m. - 7 a.m.), to achieve 45 L_{dn}.

Figure 1 provides the results of the sample calculations showing the source sound spectrum in the commercial space and the transmitted sound level through the 6-inch concrete slab to the residences above. This simple exercise does not take into consideration flanking paths, leaks, or the differences between a laboratory test rating and a field test rating, which should be considered for greater accuracy. As a rule of thumb, the field STC rating is often considered to be 5 STC points lower than the laboratory test. With residential above commercial, it is common for plumbing, waste, gas, and electrical services to be routed through the commercial space and serve the residences above. These penetrations, particularly if improperly sealed, can also result in a reduction of transmission loss performance of the demising assembly.

The source sound spectrum in the commercial space indicated in Figure 1 is based on measurements taken in a bar with amplified dance music and subwoofers. The transmitted sound level into the residence is shown as the time-average level L_{eq} along with the L_1% percentile. The transmitted levels are plotted against an ambient background noise spectrum of 35 dBA, which may be due to mechanical or HVAC systems in the residence, the transmitted environmental noise levels (such as from traffic), and various transmitted sounds from other spaces in the building.

As shown in Figure 1, the sound level in the commercial space can be roughly 81 dBA and comply with a 35 dBA nighttime transmitted sound level in the residence; 91 dBA to comply with the daytime requirement of 45 dBA in the residence. Looking at the transmitted spectrum, it is clear that even though these transmitted levels can be shown to comply with code requirements, amplitudes at frequencies between 200 - 800 Hz and at 63 Hz are above the apartment ambient and likely to cause a disturbance. Transmission loss data are not available below 50 Hz. However based on the trend in the measured and transmitted data, it is likely that levels from the subwoofers could exceed the apartment ambient below 50 Hz.

If transmitted noise levels are at or above the ambient background noise levels in the apartment, it will likely be audible and disturbing to the occupants. It should be noted that 35 dBA nighttime ambient would be at the upper limit of acceptability and compliance with a 45 L_{dn} rating for a residential interior. Depending on the intended type of use or degree of quality, such as condominiums, high-end, and luxury buildings, the background noise criteria may be significantly lower than the code minimum, and the occupants may have higher expectations for the sound isolation performance of their units.

Figure 1 also shows the transmitted L_1%, which is a percentile metric that indicates the sound level that was present for 1% of the measurement period. For the exercise, we have assumed an L_1% of roughly 5 dB above the L_{eq}, which has been based on our measurements shown in Figure 2, which are 30-second averages taken for a period of 30 minutes – from 0:00 h to 0:30 h at night in a lively bar with amplified dance music and subwoofers. Based on our experience, the dynamic range of amplified sound, particularly amplified speech and live amplified music, can vary significantly and result in an L_1% levels of 5 - 15 dB above the L_{eq}.

According to the case study calculation presented here, the commercial tenant's operating noise levels would be limited to around 91 dBA daytime and 81 dBA nighttime to comply with code. As shown in Figure 1, however, at these upper limits, the transmitted sound levels are likely to be audible and disturbing to the residents.

Based on typical average sound levels for various commercial uses,[6] the commercial tenant space is likely to be acceptable for most uses without amplified music and conditionally acceptable for certain uses with light amplified music that operate primarily during the daytime hours (7 a.m. - 10 p.m.) such as a retail store or restaurant with background music. Uses such as dance clubs, live-music venues, or even certain fitness spaces with loud amplified music and amplified speech such as spinning classes, dance fitness classes, or crossfit, are likely to be too loud and exceed the code requirements of both daytime and nighttime limits.

In the case study presented here, there may be ways to increase the transmission loss performance of the floor/ceiling assembly by using a suspended or resiliently hung ceiling in the commercial space. This may allow for an increase in the allowable operating sound levels of the commercial space. However, the effectiveness of this ceiling layer can be significantly limited by penetrations such as lighting, HVAC services, and fire sprinklers, and these potential leaks must be factored into any analysis.

Furthermore, adding a resiliently hung ceiling can pose many challenges in terms of installation as well as usability for the tenants. For example, anything within the commercial tenant that needs to be suspended from above (including building services) should ideally be located below the resilient ceiling. Attaching objects directly to the ceiling may negatively impact the loading of the isolators. Alternatively, penetrations through the ceiling to the structure above can cause short-circuits or leaks that may also compromise the isolation performance of the ceiling.

Sound levels within the commercial space may also be controlled operationally. For example by limiting hours of impact or providing tenants with the ability to monitor their own sound levels so they can proactively control their levels to an agreed-upon criterion. We have also found that using compressor/limiters on amplified speech and amplified music, particularly in the context of fitness classes, can help set a threshold for the sound system and limit the dynamic range of impacts. The use of sound system equalizers may also be helpful in reducing specific problematic frequency bands without having to reduce the entire volume of the sound system.

Conclusion

Compliance with code and satisfying occupant expectations are two separate design goals. Even if the code requirements are met, residents can still be disturbed and issue complaints. Occupant expectations can also vary considerably depending upon the type of occupancy, whether or not the occupant is a renter or owner, and the value of the property, among other factors.

The use of single-number metrics, such as time-averaged, A-weighted sound pressure levels (dBA) or STC ratings, can oversimplify nuanced noise control problems. When dealing with the transmission of amplified sound from a commercial tenant to a residence, it is important to understand not only the amplitude of the sound source but the frequency distribution and temporal characteristics of the transmitted sound. Single-number metrics, even with penalties applied for tonal, impulsive, and musical sound sources, are often not sufficient for addressing issues of audibility or annoyance.

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