



## **Identifying impacts of amplified sound in commercial spaces below residences in mixed-use buildings**

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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 (LAeq or Ldn), 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. This study will identify the key sound insulation issues for residences above commercial spaces with amplified sound, present test results, and evaluate magnitudes of impact according to the types of commercial uses and common types of floor/ceiling assemblies.**

### **1 INTRODUCTION**

Building and local codes typically define baseline requirements for the sound isolation performance of partitions or the 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 in commercial spaces, and particularly systems with

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subwoofers, presents additional challenges for sound isolation because the transmission loss for most partitions is reduced at lower frequencies and more difficult to control.

The present research topic arose from a project where a mixed-use building owner hired Mei Wu Acoustics to evaluate the existing demising 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 resident's experience with our calculations and analysis of sound transmission between the commercial and residential spaces.

## **2 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 the 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 US territories<sup>1</sup>. 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)<sup>2</sup>.

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 Ldn due to exterior sources<sup>3</sup>. Housing and Urban Development (HUD) projects are also subject to the same interior noise level requirements of 45 Ldn<sup>4</sup>. These interior noise level requirements are typically intended to protect residents from environmental noise sources such as vehicular traffic and are used to guide the building façade design.

Ldn (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 10pm-7am to account for nighttime decreases in ambient levels in residential communities. Many local authorities will cite 45 Ldn 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, 35 dBA during nighttime hours, which is roughly equivalent to 45 Ldn. 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 “six 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 upon how the measurements are executed or how the measurement data is evaluated. Further, the use of single number metrics, such as dBA or STC can over simplify nuanced problems, as 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.

### **3 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 which has been measured in 1/3 octave bands in the frequency range of 100Hz to 5000Hz, as defined in 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-range such as people talking or small television speakers. STC ratings are not useful when the noise sources have low frequency content below 100Hz, 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 amplitude of the source and its transmission through the partition in 1/3<sup>rd</sup> octave bands. Laboratories are typically unable to accurately test transmission loss below 50 Hz and more commonly measure only to 100Hz. This lack of data presents challenges when attempting to calculate sound transmission due to audio systems with subwoofers, which operate below 100 Hz.

### **4 EVALUATING IMPACTS**

In order 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 and subwoofers. The demising floor/ceiling assembly between the commercial space and the residence will be 6-inch concrete (2446 kg/m<sup>3</sup> 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 (7am-10pm), 35 dBA nighttime (10pm-7am), to achieve 45 Ldn.

Fig. 1 below provides the results of the sample calculations showing the sound source 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 would should be considered for greater accuracy. With residential above commercial it is common for plumbing, gas, and electrical services to be routed through the commercial space and serve the residences above. These penetrations, particularly if improperly sealed, can result in a reduction of transmission loss performance of the demising assembly.

The source sound spectrum in the commercial space indicated in Fig. 1 is based upon 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 L1% percentile. The transmitted levels are plotted against a typical ambient background noise spectrum of 35 dBA, which would be due to mechanical or HVAC systems in the residence, the transmitted environmental noise levels (such as from traffic); and various other transmitted sounds from other spaces in the building.

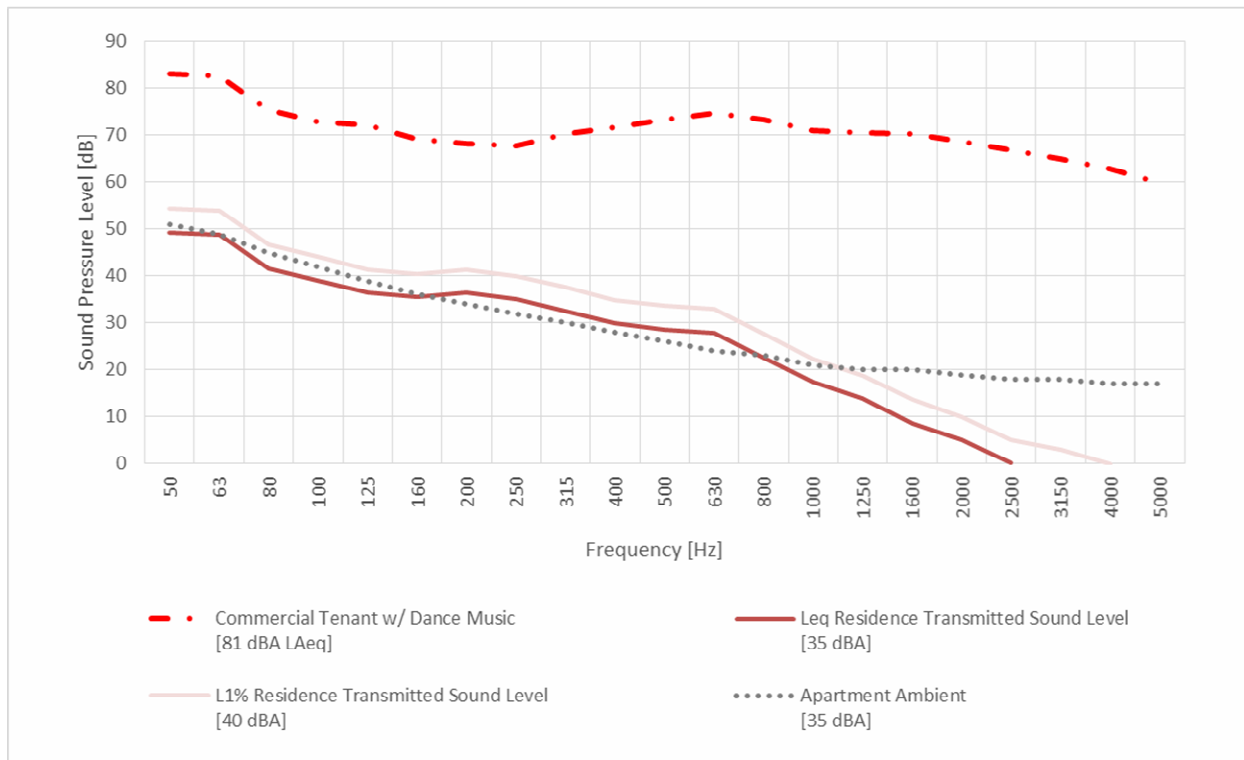


Fig. 1 – Sample calculation showing transmitted sound levels from amplified music in a commercial space to a residence through a 6-inch concrete floor/ceiling assembly

As shown in Fig. 1, the sound level in the commercial space can be around 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. 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 200Hz-800Hz and below 63 Hz are above the apartment ambient and likely to cause a disturbance. Transmission loss data is not available below 50 Hz, however based upon the trend in the measured and transmitted data, it is likely that levels from the subwoofers could exceed the apartment ambient below 50 Hz.

Background noise levels in apartments can range from 25-35 dBA at nighttime. 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. In condominiums and high-end and luxury buildings, tenants do not expect to hear music from adjacent spaces and it is often desirable to design to a more stringent criteria than the code minimum to avoid tenant complaints.

Fig. 1 also shows the transmitted L1%, which is a percentile metric that indicates the sound level that was present for 1% of the measurement period. For this exercise, we have assumed an L1% of around 5 dBA above the Leq, which has been based upon our measurements shown in Fig. 2 below, which are 30-second averages taken for a period of 30 minutes – from 0:00h to 0:30h at night – in a lively bar with amplified dance music and subwoofers. Based upon our experience, the dynamic range of amplified sound can vary significantly, resulting in an L1% levels of 5-15 dB above the Leq.

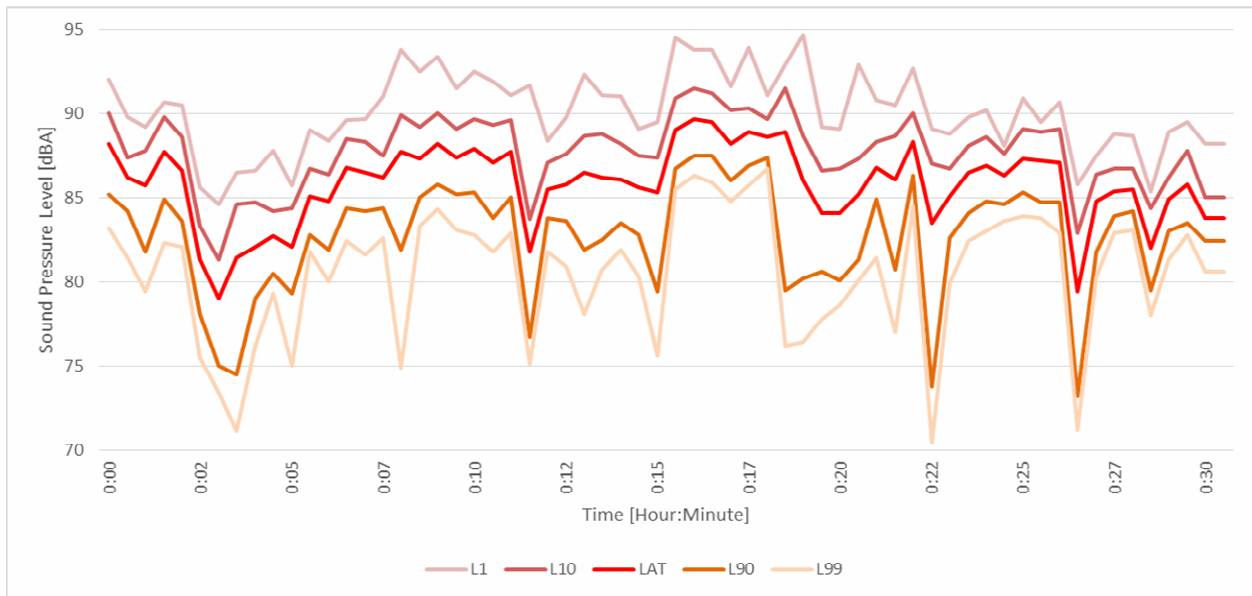


Fig. 2 – A-weighted 30-second time-average measurements for a period of 30 minutes in a bar with amplified music.

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 in order to comply with code. However, as shown in Fig. 1, at these upper limits the transmitted sound levels are likely to be audible and disturbing to the residents.

Based upon typical average sound levels for various commercial uses<sup>6</sup>, 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 only during the daytime hours (7am-10pm) such as a retail store or restaurant with amplified music. Uses such as dance clubs, live music venues, or even certain fitness spaces with loud amplified music such as spin, crossfit, or dance classes are likely to be too loud and would 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, fire sprinklers and these leaks must be factored into any analysis.

## 6 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, 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, can over simplify 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 not sufficient for addressing issues of audibility or annoyance.

## 7 REFERENCES

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