Glass Lamination for Acoustical Performance

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Introduction

Windows give us a view of the outside world, providing a visual escape from the confines of four walls by letting the outside view in. There are some aspects of the outside world, however, that we don't necessarily want invading our interior space.

One of these is noise. For anyone who has been exposed to the hustle and bustle of congested urban or suburban life─from traffic to construction to airport noise to all manner of human activity─there is a need to keep loud noises outside of one's working or living area.

With a typical building, there are many ways that noise can enter: walls, doors, vents, air conditioning systems, chimneys, floor systems, roof soffits, etc.

Windows are a primary way through which noise can enter a building. Thus, the acoustical performance of windows is becoming a more important architectural consideration. Designers, architects, and engineers are looking at ways to develop window systems with better acoustic performance through noise attenuation.

The following is a discussion of the basic concepts of acoustics, the methods of measuring noise attenuation in windows, and the use of lamination as one way to improve noise attenuation in window design.

Sound Propagation

Many people use the terms "sound" and "noise" interchangeably. For others, "sound" refers to anything that can be heard, while "noise" is an unpleasant or loud sound. For the purposes of this article, we will be defining sound as the vibrations in the air that can be detected by the human ear.

Sound travels through air through the propagation of variations in air pressure when something vibrates. This can happen when a person speaks, when one object strikes another, or when an object such as a car moves along the ground.

There are two important components of sound. Sound has a frequency, the number of wavelength cycles per second, and an amplitude, which is related to its loudness. The frequency is measured in Hertz (Hz), while the amplitude is represented by its Sound Pressure Level (SPL), measured in decibels (dB). The frequency is what gives a sound its pitch, with high pitched sounds such as a whistle having a high frequency and short wavelength, and low pitched sounds such as a fog horn having a low frequency and long wavelength.

The average human ear can detect sounds in a frequency range of 20 to 20,000 Hz. For the Sound Pressure Levels (SPL), the human ear is sensitive to a range of between 0 and 130 dB, from the threshold of audibility to the threshold of pain.

The SPL follows a logarithmic scale, so an increase of 10 dB would be approximately double the loudness, while a decrease of 20 dB would be about one quarter of the loudness. Table 1 shows some typical sounds and their corresponding SPL rating.

Table 1. Relationship Between Typical Sounds and Their Sound Pressure Level

Typical Sound	**SPL (dB)**
Thunder Clap	120
Nearby Riveter	110
Loud Street Noise	90
Noisy Office	80
Average Street Noise	70
Average Office	60
Restaurant Chatter	50
Private Office	40
Quiet Private Room	30
Whisper	20
Normal Breathing	10
Audibility Threshold	0

Another consideration for sound is the response of the human ear to different frequencies. The human ear has more sensitivity to higher frequencies than it does to lower frequencies. For this reason, sound level measurements will incorporate an "A-weighting" correction factor that mimics the perception of the human ear. This is described in ANSI S1-4. The A-weighted sound pressure level will be a single number, in dBA. This should not be confused with the sound pressure level in dB.

Testing for Sound Transmission

In a laboratory, sound transmission is measured with two chambers separated by a filler wall, into which the test specimen is placed. The first chamber is the source room, where the test sounds are generated, and the second chamber is the receiving room, where the sound is measured. For testing sound transmission through a building component such as a window, the test chambers must be designed to acoustically isolate the given test specimen. This assures that one is mainly measuring the transmission through the window, and not through the surrounding wall, floor, ceiling, or other building component.

Sound transmission through a path other than the test window is referred to as "flanking." In a laboratory setup in the ASTM E 90 or ISO 140 Part 3 test methods, flanking is minimized, and one is required to determine the sound transmission loss through the filler wall surrounding the test specimen. Generally, the filler wall is designed to have a much higher sound transmission loss than the test specimen, so the vast majority of sound transmission measured will be through the test specimen. The ASTM sound transmission loss (TL) or ISO sound reduction index (R) is calculated as:

$TL = L1 - L2 + 10 \log S/A$
$R = L1 - L2 + 10 \log S/A$

Where:
L1 = the average sound pressure level in the source room (dB)
L2 = the average sound pressure level in the receiving room (dB)
S = the area of the test specimen (ft^2 or m^2)
A = absorption of the receiving room

When comparing different components, the building materials with better acoustical performance are those that have less noise transmitted through them.

To more effectively compare different building materials, single number rating systems were developed incorporating the sound reduction characteristics across a given sound spectrum. In North America, a rating system was introduced in 1970 under ASTM E 413 "Classification for Rating Sound Insulation." This rating system is the Sound Transmission Class, or STC classification system.

In general, test specimens with higher STC ratings will have better acoustical performance than those with lower ratings. This is based on a "standard household noise" spectrum. The spectrum emphasizes the mid or high frequency sound energy levels found with such noises as live speech, radio and television noise, vacuum cleaners and appliances, and other household noise. It is less appropriate for lower frequency noises such as car traffic, airport noise, trains, and industrial processes.

The STC rating will usually be quite similar to the classification outlined in ISO 717-1, the Weighted Sound Reduction Index (Rw). The procedures for the two classification systems have slightly different measurement frequency ranges, and slightly different calculation procedures. The ASTM frequency range is from 125 to 4000 Hz, while the ISO frequency range is 100 to 3150 Hz. The STC rating is calculated with a slightly different procedure than the Rw rating, and these procedures are described in detail in the referenced ASTM and ISO classification standards. Still, for most test specimens, the Rw and STC ratings will be nearly the same, only differing by at most 1 or 2 points.

Both the STC and Rw rating systems emphasize medium and higher frequency sounds as opposed to lower frequency sounds, so both are less appropriate for determining performance near highways, airports, or industrial sites.

The "Outdoor-Indoor Transmission Class" (OITC) rating system was developed in ASTM E 1332. This was developed in the late 1980s to respond to the perceived need for a more robust classification system that would address more of the low frequency incident sounds. While the STC rating system is fairly well entrenched in the literature, codes, and government regulations, the OITC rating system is now becoming more visible. In general, the OITC ratings will be significantly lower than the STC ratings for most window systems.

Reduction of Noise Transmission through Windows

There are several ways that one can reduce the sound transmission through a window.

For a single lite system, an increase in glass thickness will reduce the sound transmission and increase the STC value for the window, based on the Mass Law:

$$TL = 20 \log(m_S \times f) - 47$$

Where:
TL = transmission loss across the barrier (dB)
m_S= mass per unit area of the barrier
f = frequency of the incident sound wave

Therefore, if the mass per unit area is doubled, the Mass Law states that the difference between the transmission loss for a fixed frequency will be 6 dB.

In real life, however, the Mass Law is not always followed exactly. In some cases, doubling the glass thickness will only yield a 3-5 improvement in the STC rating. One reason for this is the "coincidence effect." This occurs because glass will resonate or vibrate at a particular frequency. When this frequency matches that of an incoming sound wave, the sound will not be blocked significantly by the material.

In a graph of sound transmission loss versus frequency for regular annealed glass, this effect can be seen in a significant "coincidence dip" towards the higher frequency region. The "coincidence dip" will move to lower frequency as the glass thickness is increased, more towards the region where the human ear will have increased perception. This becomes a serious problem when trying to improve the acoustical performance of the window, especially since the STC or Rw ratings are calculated to correlate with the human ear's perception.

The other drawback to increasing glass mass is the obvious increase in weight and thickness for a window. One would not want to have to use a 1" thick piece of glass for a simple window to achieve a desired STC rating, especially if the thicker glass means that the window now weighs hundreds of pounds! For this reason, increasing glass mass is not seen as the most effective way to improve the acoustical performance.

For insulated glass units, sound transmission reduction can be improved by increasing the air space. One obvious drawback of this approach is that there may not be enough room to accommodate the increased space.

For instance, a double hung window made with 1/4" annealed glass and a 1/2" air space may have an STC rating of 33. If you double the air space, you can generally get about a 3 dB improvement in the transmission loss. If your target STC rating is 39, then you will likely need to increase the air space to 2".

If your system only allows 1 3/4" total window thickness, you would not be able to achieve this STC rating by increasing the air space alone. Doubling the mass of glass may also be impractical. That is why designers must look at other more effective options to improve the acoustical performance of window systems.

Laminated Glass for Sound Control

Glass lamination consists of bonding two or more lites of glass together with one or more layers of plastic material. The plastic interlayer between the glass can provide improved safety and security performance by holding the glass together and keeping glass shards in place after breakage.

In addition, the plastic interlayer can provide acoustical performance benefits. As mentioned before, glass will vibrate at a particular frequency, allowing sound waves to penetrate through the window without significant attenuation. The presence of a plastic interlayer between the two lites of laminated glass has a damping effect that reduces this vibration, thus reducing sound transmission. Sound waves can be absorbed by the plastic interlayer so they are not transmitted to the second lite of glass, and therefore not transmitted to the receiving room.

In this way the two lites of glass have been "decoupled," so that you have the acoustical benefits of the additional mass of glass, but not the drawbacks caused by the shift in the "coincidence dip" towards the lower frequency sound waves.

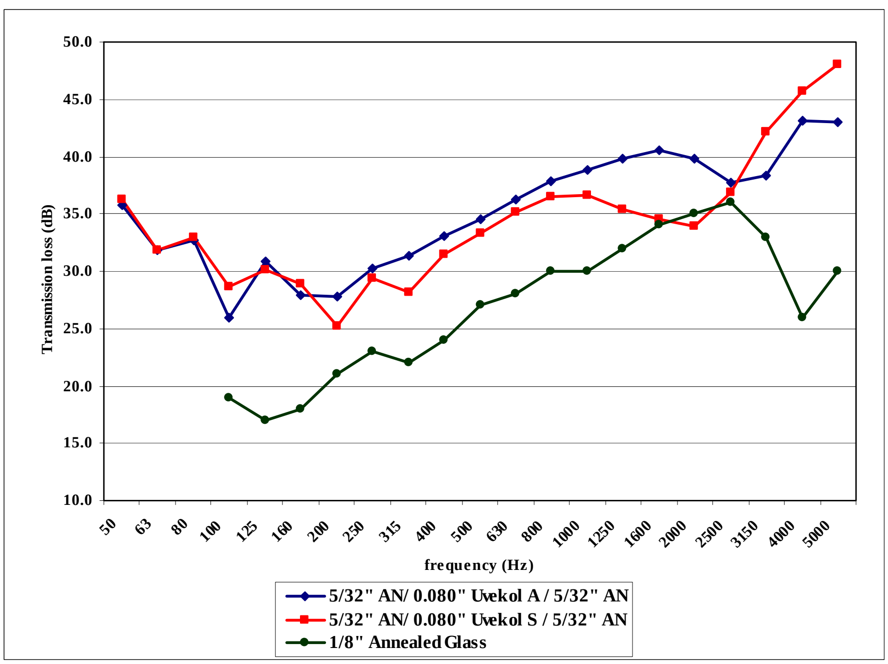
The Effect of Laminate Interlayer Type on Acoustical Performance

As one would expect, different types of laminate interlayers can have different acoustical performance. In general, a softer, more pliable interlayer will have better performance than a stiffer interlayer because it can more effectively dampen sound vibrations.

This can be seen when we compare the acoustic performance of two types of UV curable interlayers. One, UVEKOL® S, is designed for safety and security performance; it is a more rigid material. The other, UVEKOL® A, is a more pliable interlayer designed specifically for acoustic applications.

Both materials are supplied in liquid form and pumped between two lites of glass. They are then cured under UV black lights for the same period of time to form a solid plastic interlayer. Figure 1 shows the sound transmission loss for the two different types of interlayers, in comparison to 1/8" annealed glass.

Figure 1. Transmission loss (dB) vs. Frequency for Laminated and Annealed Glass



STC Ratings

5/32" AN/ 0.080" UVEKOL® A / 5/32" AN	**38**
5/32" AN/ 0.080" UVEKOL® S / 5/32" AN	**35**
1/8" Annealed Glass	**30**

One can see that the UVEKOL® S laminate made with 5/32" annealed glass has a much higher STC rating than the single lite of 1/8" annealed glass. This is due to both the increased mass and the presence of the plastic laminate interlayer.

One can also see, however, the presence of the “coincidence dip” in the transmission loss curve between frequencies of 1000 and 3000 Hz. For the laminate made with the softer UVEKOL® A interlayer, the transmission loss is mostly higher than that of the stiffer laminate, and the “coincidence dip” has shifted up to 1600 to 4000 Hz. The dip is closer to that of the single 1/8" lite, but is less pronounced. This results in a higher STC rating of 38 for the UVEKOL® A laminate, compared to the STC rating of 35 for the same type of laminate made with UVEKOL® S.

Performance of UVEKOL® A in Different Window Systems

Table 2 shows the STC ratings for UVEKOL® A in different laminate systems, and gives a general guideline on how much improvement can be obtained with each type of change to the system.

Table 2. STC Ratings for UVEKOL® A Laminate Configurations*

Configuration – mm	**STC**
Monolithic:	
6 mm	31
12 mm	35
Laminated:	
3/ 0.8 UvA / 3 – 6.8 mm total	36
3/ 1.1 UvA / 3 – 7.1 mm total	36
6/ 0.8 UvA / 3 – 9.8 mm total	37
6 / 0.8 UvA / 6 – 12.8 mm total	39
6/ 1.1 UvA / 6 – 13.1 mm total	39
10/ 0.8 UvA / 6 – 16.8 mm total	41
Double Glazing Laminated:	
3/ 0.8 UvA / 3 / 13 Air Sp. / 6 – 25.8 mm total	40
3/ 0.8 UvA/ 3 / 102 Air Sp. / 5 – 113.8 mm total	50

* Testing performed at Riverbank Acoustical Laboratories, Geneva, IL

One can see the increase in STC rating with the use of laminated glass versus monolithic glass, and the improvement with increased glass thickness for laminates. One can also see the improvement with increasing the air space in an insulated double glazing. It is up to the window designer to determine how best to achieve the desired acoustical performance, whether it is by increasing glass thickness, using laminated glass, and/or using an insulated unit with an increased air space.

Other design considerations, including the type of edge sealing, gasketing, insulated glass (IG) spacer systems, and the type of gas used to fill the insulated glass (IG), will also play a role in determining how much noise attenuation can be achieved.

The use of laminated glass, however, has several advantages that make it an attractive option for noise reduction:

- Reduced space requirement
- Reduced weight
- Additional benefits from lamination: safety performance, security performance
- Reduction in the “coincidence dip”
- Maintaining of clear visibility

For these reasons, the incorporation of laminated glass in window systems for good acoustical performance is often seen as not just an option, but as a requirement.

Summary and Conclusions

As we have discussed, sound is vibration in air that can be detected by the human ear. There are many ways that sound can be transmitted from outside a building to inside, and windows are one of those possible paths.

A special test setup can isolate specific building components, such as windows, and allow for measurement of the sound transmission through them. Several different standardized rating systems have been developed by ASTM and ISO, including STC (Sound Transmission Class), Rw (Weighted Sound Reduction Index), and OITC (Outdoor-Indoor Sound Transmission Class). These ratings are single numbers that allow someone to compare one system to another, and to determine whether or not a design change has improved the ability of a building component to reduce sound transmission.

The sound transmission of windows can be reduced in several different ways, including increasing glass mass, increasing the air space of an insulated glass (IG) unit, or adding laminated glass.

Laminated glass can be an effective way to reduce sound transmission, while using less space and weight. In addition, laminated glass can provide other benefits, such as improved safety and security.

One type of interlayer used to prepare laminated glass is UVEKOL® A. This is a UV curable interlayer that has been designed specifically for acoustical performance. STC ratings that were measured for different window systems show the benefits of using UVEKOL® A to reduce sound transmission. Incorporating laminated glass in a window system is an important tool in window design for improving acoustical performance, and is quite commonly used for these applications.

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