Improved Sound Reduction with Laminated Glass

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3 = sound reduction 4 = laminated safety glass

Abstract

Growing concern over detrimental noise in densely populated areas has called for improvements in the sound insulation of our building spaces. While laminated safety glass has been optimized for safety and security and offers effective screening of UV-radiation as an additional benefit, its acoustic performance – although superior to monolithic glass – has not been given full consideration in the past. Now, newly developed PVB-films with enhanced vibration damping behavior have become available, providing an alternative to poured resins for glazing systems designed to meet high sound attenuation requirements.

Moreover, in addition to the use of acoustic PVB for architectural applications it has become evident that this new type of PVB can also contribute to further reduce noise levels experienced in cars. Using an appropriate interlayer actually present the only way to impart enhanced damping properties to windshield and sidelites since non-transparent damping materials, being very successful in damping body vibrations of a car, can naturally not be applied to glass surfaces.

The human ear

As compared to the sense of vision, where the human eye perceives electromagnetic radiation in the narrow range of 400 – 800 nm, a much broader band of about 20 – 20000 Hz is accessible to the ear, encompassing 3 powers of ten. Its dynamic range is even more impressing realizing that in terms of received sound pressure level 7 powers of ten are covered. It is important to notice, however, that the ear responds to different pitches in a non-linear manner, being generally less sensitive to lower frequencies and more sensitive to high frequency sound with a maximum response between 2000 and 5000 Hz.

Damping

The underlying principle for sound attenuation by partitions is described by the "mass law of acoustics" which basically states that doubling the weight (i.e. doubling thickness or density) or doubling the frequency results in an increase of 6 dB in the sound attenuation. Plotting the sound transmission loss of a given partition as a function of frequency thus results in curves displaying a slope of 6 dB per octave. In practice, however, strong deviations from this idealized curve shape are typically observed which hamper the acoustic performance. These negative deviations are caused by resonance phenomena, the most universally observed being "wave coincidence" which arises from a coupling of non-vertically impinging sound waves with surface waves that

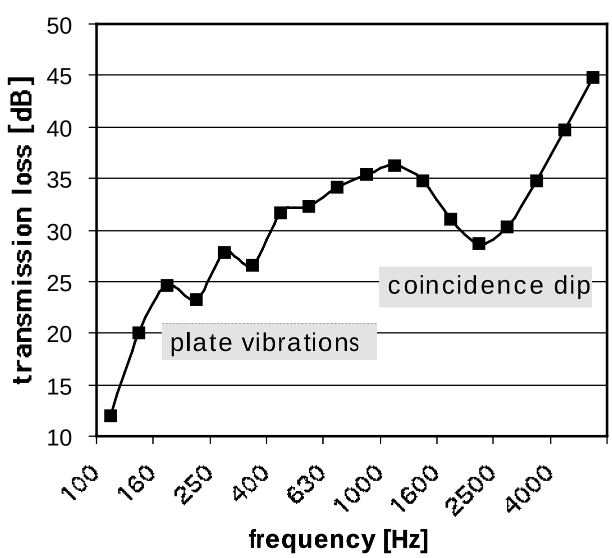
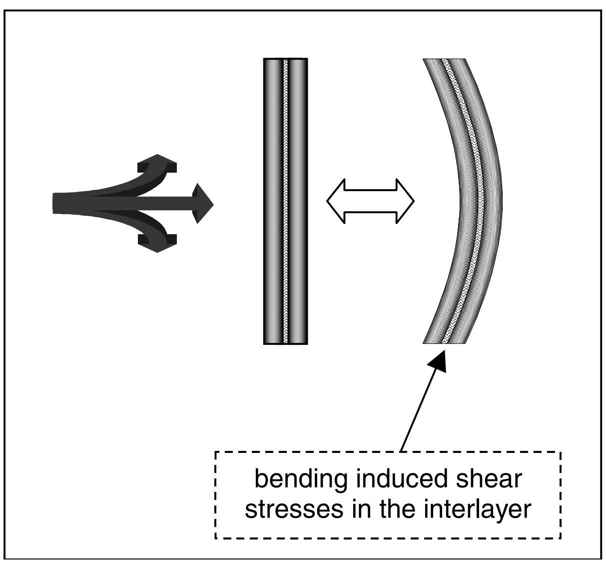


Figure 1: Schematic representation of a typical sound transmission curve for monolithic glass.

can build up on the partition. Being in resonance, the partition, in our example a glass pane, becomes virtually transparent to sound of a narrow frequency band comprised in the noise spectrum (figure 1).

The main contribution of acoustically effective interlayers to reducing sound transmission resides in their capability to drastically reduce the amplitude of vibration the partition is excited to under resonance. This effect roots in the microscopic shear motion the interlayer is subjected each time a fraction of the glass laminate is displaced from its equilibrium position as it vibrates (see figure 2). While the whole laminate starts vibrating under the influence of the impinging sound waves, bending waves build up, consequently introducing a slight curvature in the whole structure. An analysis of the relative motion of the glass panels and interlayer reveals that upon bending, the interlayer is subject to shear stresses. As the shear modulus of the interlayer comprises a significant non elastic component, quantifiable by the loss modulus, any shear deformation will lead to a dissipation of mechanical energy into heat. It is this process that accounts for the damping action of the interlayer inside the laminate. Depending mainly on the magnitude of the loss modulus at service temperature, large differences can exist from one interlayer type to another. TROSIFOL Sound Control, for example, is a PVB interlayer, formulated to exhibit a high loss modulus at service temperature.



The vibration damping effect of an acoustic PVB is easily visualized in an relatively simple experiment: A laminated bar carrying a small accelerometer is excited with a short strike to freely vibrate on two foam supports. The difference in terms of the decay of the amplitudes between a standard PVB and an acoustic PVB is obvious (see figure 3).

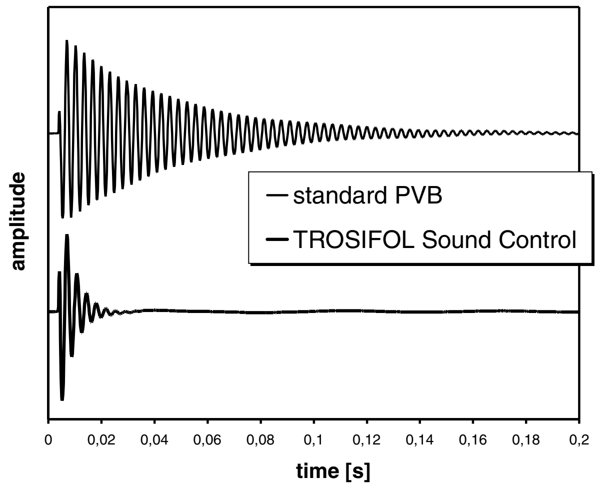


Figure 3: Decay of free vibration observed on laminated glass bars of 10 x 30 cm with 2.1 mm glass.

Measuring noise reduction

How does one judge on the acoustic quality of one glazing as compared to another ? Since the human organ of hearing is as subjective as any other sense, laboratory measurements are required for an objective ranking of acoustical glazings. In view of the fact that in acoustics, even small perturbations can seriously interfere with the signal to be measured, the standardized laboratory procedures for data acquisition and evaluation must be followed closely in order to arrive at meaningful data. To this end, the international standards such as ISO 140 (defined sample size, signal acquisition, laboratory configuration among others) and ISO 717 (data evaluation) were recently introduced. In practice, the glazing unit to be tested is mounted in an opening integrated in an otherwise highly insulating wall. This wall separates the source room, equipped with a loudspeaker, from the receiver room, equipped with a sensitive microphone. While the loudspeaker produces noise across a range of pitches, the sound pressure level in the receiving room is integrated within third octave bands centered around frequencies from 50 up to 5000 Hz and compared to the sound pressure level close to the source. For each individual third octave band, the difference in sound pressures is converted to a transmission loss, carrying the unit decibel [dB]. Plotted as a function of frequency, one obtains sound transmission curves that allow a detailed analysis and assessment of the acoustical performance of each glazing. Figure 4 presents the result obtained with laminated glass (2 x 2.1 mm glass plus 0.76 mm interlayer) and float glass of 3.9 mm. Although the transmission curve for the latter is shifted to lower values owing to its slightly smaller mass if compared to the laminated samples, one clearly notes firstly the different performance in the coincidence region, the acoustic PVB being by far the most efficient in terms of suppression of coincidence and secondly reduced plate vibrations at frequencies below 800 Hz.

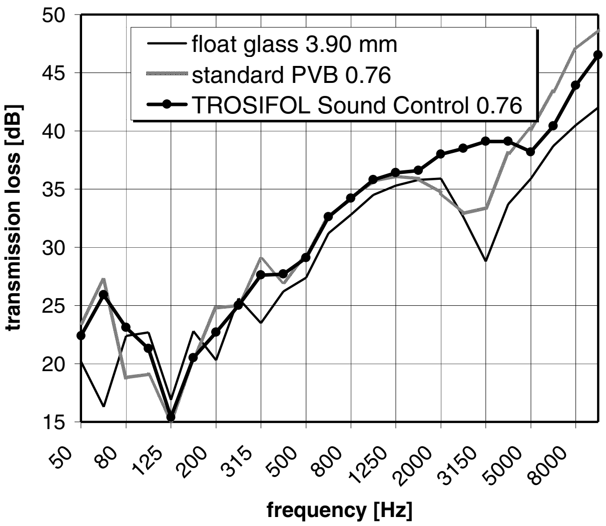


Figure 4: Acoustic behavior of laminates and float glass as a function of interlayer performance.

Automotive applications

In the case of automotive applications, an ever increasing proportion of glass is incorporated in the car surface for esthetic, i.e. enhanced luminosity, as well as safety reasons, i.e. 360° visibility. Since the car glazing is the only part, where transmitted sound – airborne or structural – cannot be suppressed applying the common non transparent damping compounds or suspensions, it is not easy to target for example structural vibrations, which can build up on a large glass surfaces such as the windscreen and become audible as booming sound, when the engine produces low frequent vibrations capable to excite a fundamental vibration of the lite. While standard PVB does not contribute significantly to damp low frequency vibrations, the acoustic PVB does. At a service temperature of 20 °C and approximately 280 Hz the first does not even approach 2 % damping, while the latter provides a huge 33 %.

Insulating glass

Due to the need for thermal insulation in exterior glazing applications the natural choice normally is insulating glass. It is well known however that owing to resonant coupling between the two plies, sound transmission can actually be more significant as with a single glazing unit of equivalent total thickness. Whereas an insulating glazing unit comprising one or two laminates with standard PVB reduces resonant dips to a rather small extent in the sound transmission curve, an acoustic PVB efficiently damps the resonant vibrations, thus leading to a better acoustic comfort inside building spaces.

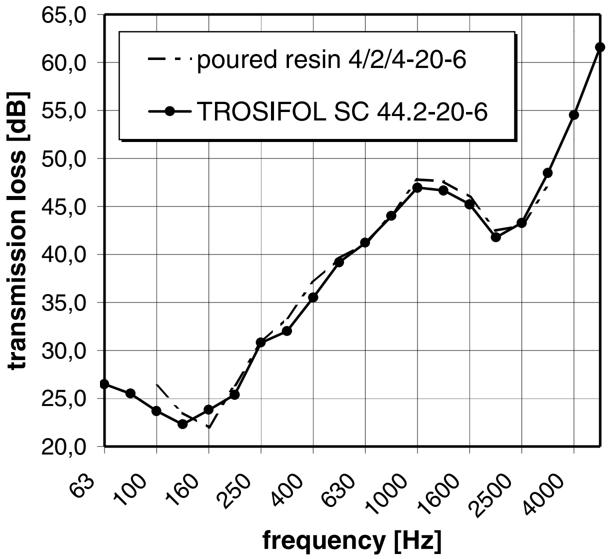


Figure 5: Comparison of insulating glazing with make up 4/X/ 4 – 20 argon – 6 float (mm).

Comparison of acoustic PVB with poured resins

While in the past, weighted sound reductions of 40 dB or more could only be realized employing poured resins in connection with a double glazing, PVB-interlayers with similar damping characteristics (see figure 5) have become available to the glass laminating industry now. The disadvantages of poured resins, namely the tedious fabrication process item by item, the poor optical quality of the laminates caused by thickness variations of the interlayer and the inadequate safety characteristics can be avoided by the use of acoustic PVB which imparts the laminate not only the acoustic quality but also the safety features known from standard PVB.