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A Comparative Study of Sound Transmission Loss Provided by Glass, Acrylic and Polycarbonate

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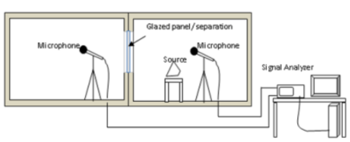
Graphical abstract



Abstract

This article presents an assessment for the airborne sound insulation provided by single glazed panels. The glazed panels were glass, acrylic and polycarbonate with a thickness of 4 mm. The experiments were conducted in a transmission loss facility consisting of semi anechoic and reverberation chambers. The panels were subjected to airborne sound and the data collected. Glass, acrylic and polycarbonate panel absorb noise most effectively above 500 Hz with the absorption peaks at 1000 Hz. The single number sound reduction index (R_W) for glass, polycarbonate and acrylic were 41 dB, 38 dB and 37 dB, respectively. This could be attributed mainly to the material density which is higher for the glass.

Keywords: Sound transmission loss; glazing; insulation; weighted index

1.0 INTRODUCTION

Lighter weight panels are widely used in various engineering applications, ranging from building construction to cars, shipbuilding and aerospace industries. Extensive researches have been conducted to study the capability of these construction elements for acoustic insulation or for protecting people against extraneous airborne. Glass façades for commercial and even government complexes are of common trend as compared to other non-transparent material. Window and glazed façade is often the main noise path for exterior disturbing noise towards the interior. As buildings with this type of façade are often located near noisy plants and crowded area, noise treatment is of interest. The two main types of passive means for improving the Sound Transmission Loss (STL) presently utilized are laminated glass technology and double glazing [1].

The transmission of airborne sound energy through a single separation element depends on several variables, such as the frequency of sound incident on the element, the physical properties of the panel (mass, internal damping, modulus of elasticity, Poisson's ratio, the connections with the surrounding structure and the vibration eigenmodes of the element [2]. The sound transmission for a given material is controlled by different mechanisms in different frequency ranges. Range I is the stiffness and damping control section, range II is the mass control section and range III is the coincidence effect section [3].

The aim of this study is to compare the sound insulation capacity of the glass, acrylic and polycarbonate. The sound insulation quality was measured at the Acoustic Laboratory in the Universiti Kebangsaan Malaysia. The facility mainly consists of a reverberation room and a semi anechoic room.

2.0 EXPERIMENTAL SET-UP

The transmission loss experiments were conducted in a suite consisting of two rooms. The set-up is shown schematically in Figure 1. The sending room is a reverberation room and the receiving room is a semi anechoic room. The volume of the reverberation room is 171m3 with wall absorption coefficient of 0.06 or less from 250 Hz and upwards. The room acts as a source for random sound absorption coefficient, machinery sound power assessment and sound transmission loss. The volume of the semi anechoic room is 121m3 with 0.9 or better sound absorption from 125 Hz and above. The room acts as a source for machinery directivity measurements and as a reception for sound transmission loss measurements. The opening between the two rooms, in which the panel is installed, is 930 mm × 930 mm, however the glazed area of a panel is 860 mm × 860 mm due to the area required for holding and other accessories. The glazed panels used are glass, acrylic and polycarbonate with a thickness of 4mm. The panels were mounted in a wooden frame. All the joints between the panel and the cavities have been sealed by rubber and silicone sealant to prevent acoustic leakage.

The measuring system comprises a dual channel Symphonie (01dB model) real time acquisition unit that transfers the data in real-time to a computer, a speaker, an amplifier of ACLAN GDB95 model, and two microphones of models 40AE-121 and 40AP-121. A dbBATI32 software was used as data analyzer. Before starting the experiments the microphones were calibrated using the BAC21 Calibrator. The single glazed sample was mounted on panel. The sound pressure level was measured using a third octave band real time analyzer. Figure 2 shows the set up for a single panel.

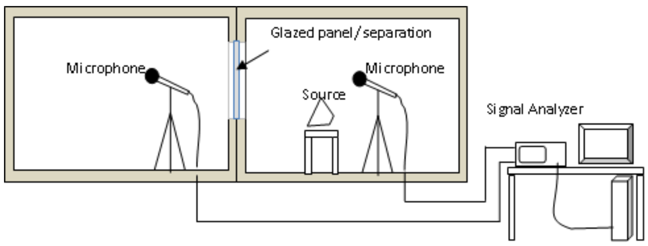


Figure 1 Schematic of experimental set-up

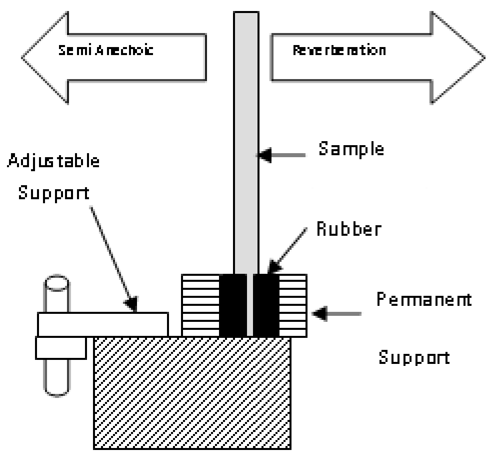


Figure 2 Experimental set-up of single glazed panels

The background noise in the reverberation and the semi anechoic rooms was recorded as shown in Figure 3. The sound pressure level was measured in the source and the receiving rooms with the microphones each located at a distance of 1 m from the panel and 1 m above the floor. The sound source generator was accordingly located in three different positions. The reverberation time and the decay were measured three times at each location.

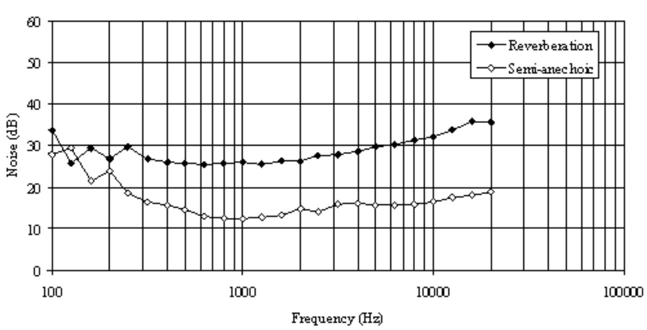


Figure 3 Background noise for reverberation and anechoic chamber

3.0 RESULTS AND DISCUSSION

The results of the experiment of the single glazed panels are shown in Figure 4. The figure shows transmission loss for glass, acrylic and polycarbonate panels. It can be observed that the sound transmission loss of the three panels increases with the frequency up to 1000 Hz and then decreases regardless of the type of the panel.

The first resonance frequency (f_1) is given by [3]:

$$f_1 = \frac{Bh}{2\pi ab}\sqrt{\frac{E}{\rho\ 1-\nu^2}} \tag{1}$$

where h, a, b, ρ, ν, E are the thickness, length, width, density, Poission ratio and the elastic modulus of specimen, respectively, and B = 10.4. When the frequency is lower than f_1 the sound transmission is mainly controlled by the stiffness. In this frequency range, the response of the wall when facing sound pressure is similar to a spring, the sound transmission is proportional to the stiffness of the wall, i.e. the stiffer the material the better the transmission loss.

From Table 1 all the first resonance frequencies of the samples are lower than 100 Hz, so there is no stiffness control section in Figure 4. As the frequency increased, the transmission loss curve enters a region where the transmission loss is controlled by the various resonant frequencies of the wall. Transmission loss in this region is limited by the damping of the wall. At frequencies above the resonant frequencies, the transmission loss is controlled by the mass of the wall [4]. In this region the transmission loss is given by the Mass Law as follows:

$$TL = 20 \log (m.f) - 47 \tag{2}$$

where f = frequency
m = is the surface density (kg/m^2)

In this section the sound transmission loss climbs straightly when the frequency increases and the theoretical slope coefficient is 6 dB/Octave. The slopes obtained experimentally for the glass, acrylic and polycarbonate are 4, 4.2 and 4 dB/Octave, respectively, which is logical as the actual increase is less than that predicted by the Mass Law [5]. Tadeu and Mateus [6] reported that as the mass of the element increases, so does insulation, as a result of increasing forces of inertia. When the frequency of sound incident on an element that maintains the same mass is increases, the vibration power of the element decreases and greater dissipation of sound energy is observed, leading to the rise in acoustic insulation.

Above the mass-controlled region lies the coincidence-controlled region. The coincidence effect arises from the fact that for all frequencies above the critical frequency f_c, there is a certain angle of incidence, at which a plane wave may excite the wall such that the sound wave will be transmitted through it with a reduced loss. This is possible in that above the critical frequency, the wavelength of the bending wave in the wall may become equal to the projection of the wavelength in air upon the wall. The coincidence effect is normally exhibited by a dip in insulation. From Figure 4 it is obvious that the dip for the acrylic and polycarbonate occurs at around 3000 Hz. According to Tadeu *et al*. [7], the transmission loss dip for glass occurred 3000Hz. However in that experiment the size of the panel is different and a double glazing with an air gap was used. Moreover, in Malaysia the humidity is high compared with other countries.

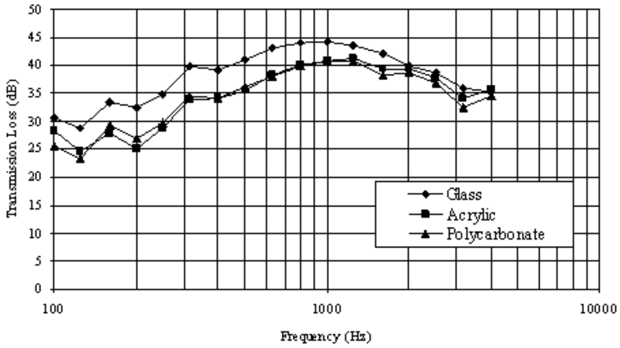


Figure 4 Sound transmission loss (dB) for glass acrylic and polycarbonate

The weighted sound reduction index (R_W) is obtained in accordance to the international evaluation criterion of sound insulation material, to compare the performance of the glass, acrylic and polycarbonate. The R_W is a single-number quantity for airborne sound insulation rating. The value, in decibels, is specified from the reference curve at 500 Hz after shifting it according to the ISO 717/1[8].

Figures 5, 6 and 7 show the sound transmission loss and the reference curve for the determination of the R_W for the glass, acrylic and polycarbonate, respectively. It was found that the glass has 41 dB which is higher compared to 38 dB and 37 dB for polycarbonate and acrylic, respectively (Figure 8). This could be attributed to the density and hence the mass/surface area ratio which is higher for the glass. The R_W values for the acrylic and the polycarbonate reflect no variation and this could be attributed to the closeness in their densities. The densities of the glass, acrylic and polycarbonate are shown in Table 1.

Table 1 Properties of the used materials

Material	**Density (kg/m^3)**	**Modulus of Elasticity (GPa)**	**Poisson Ratio**	***f_1* (Hz)**	**Thickness (mm)**
Glass	2440	72.00	0.22	49.85	4
Acrylic	1160	2.65	0.41	14.83	4
Polycarbonate	1200	2.20	0.37	13.05	4

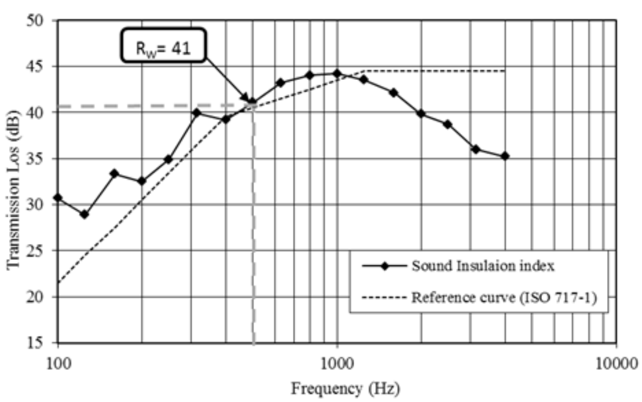


Figure 5 ISO 717/1 Sound transmission loss (dB) for glass

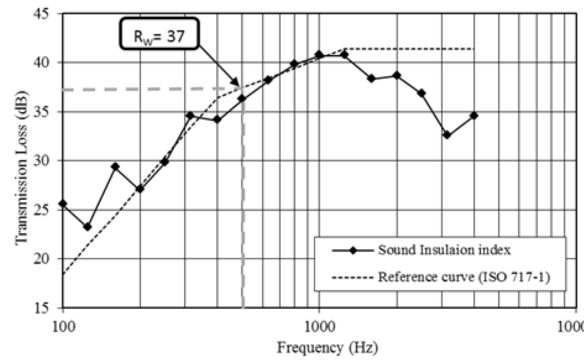


Figure 6 ISO 717/1 Sound transmission loss (dB) for acrylic

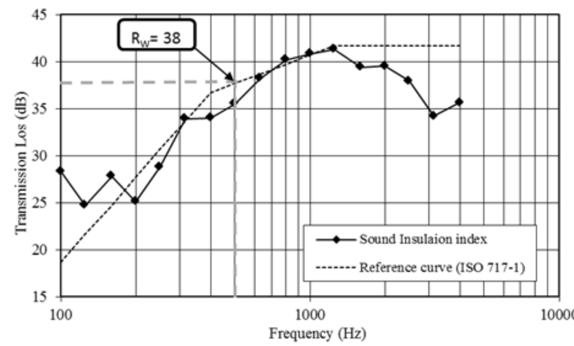


Figure 7 ISO 717/1 Sound transmission loss (dB) for polycarbonate

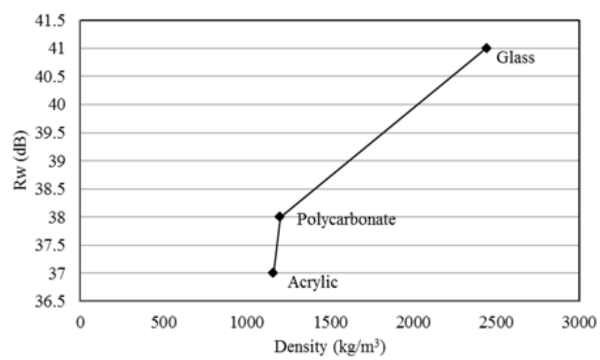


Figure 8 Weighted sound transmission loss (dB) versus density for glass acrylic and polycarbonate

4.0 CONCLUSIONS

In this work the sound transmission through single glazing panels of glass, acrylic and polycarbonate has been demonstrated. Glass significantly shows that it is the preferred solution for transparent windows and façade in the sense that it is able to have the highest noise transmission loss as compared to polycarbonate and acrylic. The experiments display that the weighted sound reduction index increases with the density of the panel. The STL of the materials can be further improved by increasing the thickness using double glazing configuration.

Acknowledgement

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