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Sound Transmission Loss Analysis on Building Materials

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ABSTRACT

This study is mainly to determine the sound transmission loss (STL) performance of the four selected building materials using the impedance tube. The four building materials are; autoclaved aerated concrete (AAC), laminated glass, expanded polystyrene and rockwool. Transmission loss occurs when a sound goes through a partition or barrier. The specimens are prepared in two thicknesses, which are 10 mm and 20 mm. The STL of the specimen was determined and analysed. It is observed that the STL results for all the tested materials are having a similar trend, which is a thicker specimen gives higher STL. In general, all the materials deliver high STL at the frequency range of 3000 – 5500 Hz. In overall, the result shows that the expanded polystyrene scores the highest STL among the four building materials in this study. Six combinations of different material also were tested, and AAC & expanded polystyrene combination shows the highest STL value among the six combinations. The outcomes of this study can be referred by noise control engineer on the selection of the sound insulation material for the building noise insulation treatment.

Keywords: Sound transmission loss (STL); building materials.

INTRODUCTION

Acoustic knowledge on the building material is important when it comes for construction. It is important to know what the desired requirement of the wall is and which materials suitable for it [1]. People often made a mistake in choosing the noise insulation material for the buildings and resulted in too much echo during the speech in the hall or etcetera [2-3]. The basic knowledge on the acoustic is the sound transmission loss (STL) and sound absorption. These two terms may sound like the same, but it is not. The STL occurs when a sound goes through a partition or barrier [4]. When airborne sound impinges on a wall, some of the sound energy is reflected, some energy is absorbed within the wall structure, and some energy is transmitted through the wall [5]. Whereas the sound absorption is the act of turning acoustical energy into some other form of energy, usually is heat. The sound insulation performance of the noise insulation materials depends on the thickness, density, and others [6].

Normally, the parts of a building, such as roof, wall, door and window are required specific acoustic property to achieve sound insulation purposes, for instance, insulate the traffic noise, construction noise, and machining noise which the noise source nearby with the residential area [7]. The target materials for this study are wall materials, which are Autoclaved Aerated Concrete (AAC), laminated glass, expanded polystyrene and rockwool as normally these materials are used for the building wall or partitioning of the rooms. For example, AAC widely to be used for wall building as it is cost-effective [8], good sound insulation [9-10], and lightweight [11].

In general, heavy and impervious materials are shown better in blocking or attenuating sound energy compare to light and porous materials. The empirical mass law deduced from real-world measurements showed that the transmission loss is directly proportional to the surface density of the barrier [4]. Thus, different types of wall materials are selected and analysed to determine the STL performance in this study.

METHODOLOGY

Two-load Method

The two-load method is one of the methods to determine the sound pressures and from the sound pressures calculate the sound transmission loss (STL). Figure 1 shows the sketch of the two-load method STL impedance tube measurement. For the STL impedance tube measurement, there are four sound waves transmitted from the sound source, passing through the specimen, and sound waves reflected by the specimen and rigid end of the impedance tube [12]. The sound pressure at microphone 1, 2, 3, and 4 can be expressed as Eq. (1) to (4) respectively.

$$P_1 = Ae^{j(\omega t-kx_1)} + Be^{j(\omega t-kx_1)} \tag{1}$$

$$P_2 = Ae^{j(\omega t-kx_2)} + Be^{j(\omega t-kx_2)} \tag{2}$$

$$P_3 = Ce^{j(\omega t-kx_3)} + De^{j(\omega t-kx_3)} \tag{3}$$

$$P_4 = Ce^{j(\omega t-kx_4)} + De^{j(\omega t-kx_4)} \tag{4}$$

where A to D are amplitudes of the sound waves and k is the wave number. x_1 to x_4 are the distance between the specimen with the respected microphone 1 to 4 as shown in Figure 1.

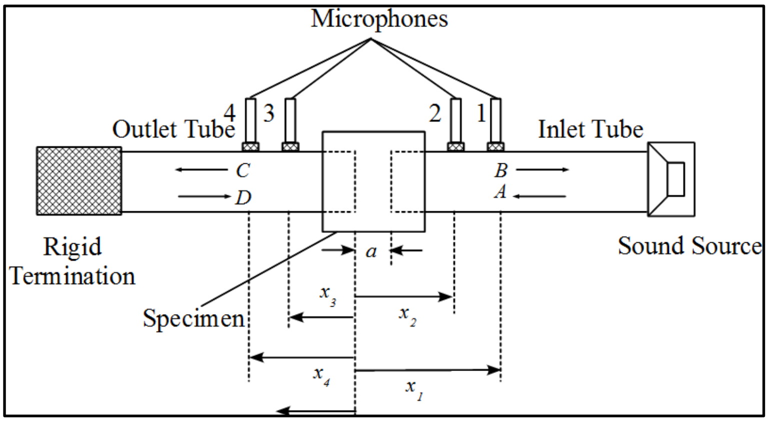


Figure 1. Two-load method of STL measurement.

The amplitudes of a sound wave can be expressed in terms of the sound pressures – P_1, P_2, P_3, and P_4 for the 4 microphones and shown as Eq. (5) to (8). The STL coefficient, α can be determined using the Eq. (9).

$$A=\frac{j\left(P_1 e^{jkx_2}-P_2 e^{jkx_1}\right)}{2\sin k(x_1-x_2)} \tag{5}$$

$$B=\frac{j\left(P_2 e^{-jkx_1}-P_1 e^{-jkx_2}\right)}{2\sin k(x_1-x_2)} \tag{6}$$

$$C=\frac{j\left(P_3 e^{jkx_4}-P_4 e^{jkx_3}\right)}{2\sin k(x_3-x_4)} \tag{7}$$

$$D=\frac{j\left(P_4 e^{-jkx_3}-P_3 e^{-jkx_4}\right)}{2\sin k(x_3-x_4)} \tag{8}$$

$$\begin{Bmatrix} A \\ B \end{Bmatrix} = \begin{bmatrix} \alpha & \beta \\ \gamma & \delta \end{bmatrix} \begin{Bmatrix} C \\ D \end{Bmatrix} \tag{9}$$

For the two-load method, two different conditions of the test were conducted, which are rigid cap terminating and open terminating [13]. Solved the equations together and the sound transmission loss coefficient, α is

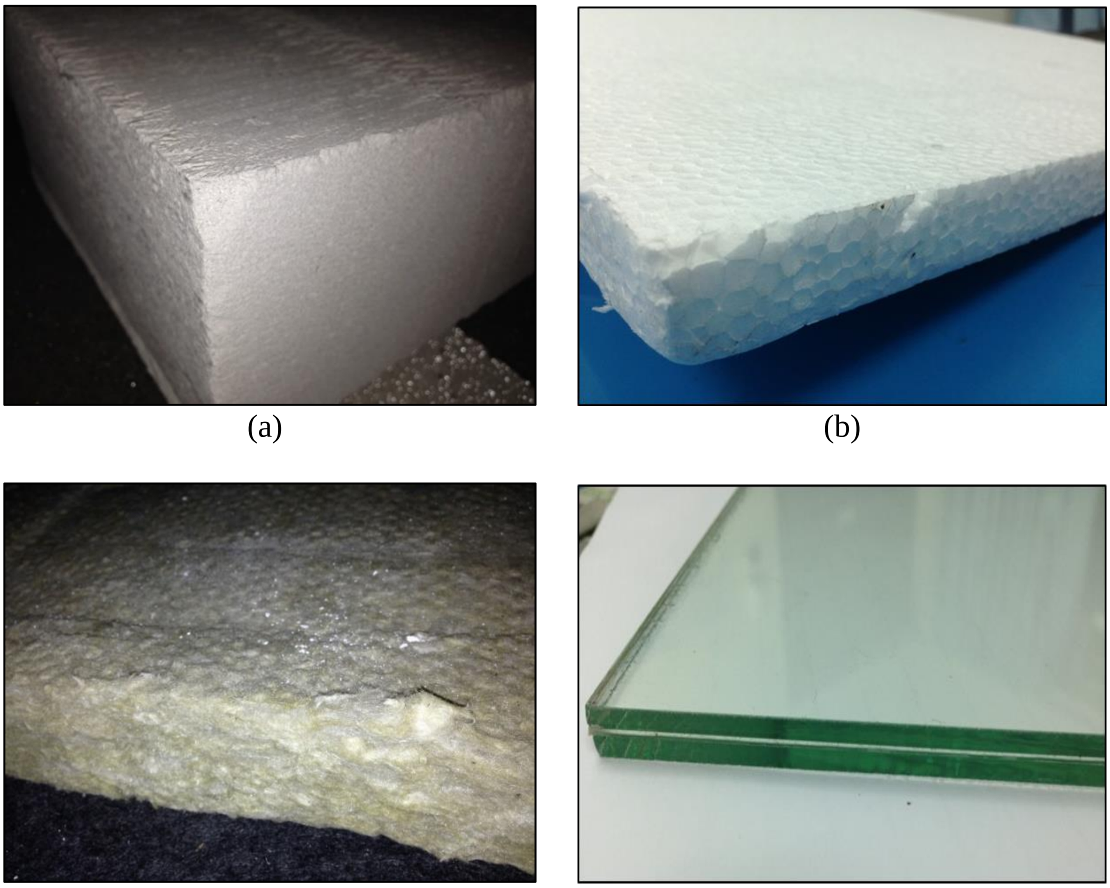
$$\alpha=\frac{A_1D_2-A_2D_1}{C_1D_2-C_2D_1} \tag{10}$$

and the equation for STL in dB is

$$STL = -20\log(\|\alpha\|) \tag{11}$$

Materials Selection

In this study, there are four different building materials chosen, which are autoclaved aerated concrete (AAC) [14-15], expanded polystyrene [16-17], rockwool [18-20], and laminated glass [21-23]. In general, the four materials that choose in this study are normally applied for buildings or constructions. For example, AAC is used to build the structure of building [24-25]; laminated glass is used for the window [26]. These four materials are shown in Figure 2(a) – 2(d). All of the materials are cut into a cylinder shape with the diameter of 30 mm and the thickness of 10 mm and 20 mm.



(a) (b) (c) (d)

Figure 2. Building materials (a) autoclaved aerated concrete (AAC); (b) expanded polystyrene; (c) rockwool; (d) laminated glass.

Experiment Setup

In this study, two-load method impedance tube was used for the sound transmission loss (STL) measurement for the building materials. Figure 3 shows the experimental setup in the laboratory. The two-load method impedance tube setup was built according to ASTM E1050 [27]. There are two pairs of microphones before and after the specimen is mounted on the main tube. The ½ inch BSWA MA211 microphones were used in this measurement. It was calibrated with CENTER 326 sound level calibrator before the STL measurement was conducted. The main tube is made of acrylic and in the shape of a cylinder, with a diameter of 30 mm and 3 mm wall thickness.

In Figure 3, one end of the main tube is connected to the sound source (speaker box) driven by the output signal generator of LMS SCADAS Mobile SCM01. The random noise containing the frequencies of 125 Hz to 5500 Hz is used for the noise source. The other end of the main tube is terminated with the rigid or anechoic termination. The signals from the four microphones are collected by the data acquisition board of LMS SCADAS Mobile SCM01 and then processed by the analyser software.

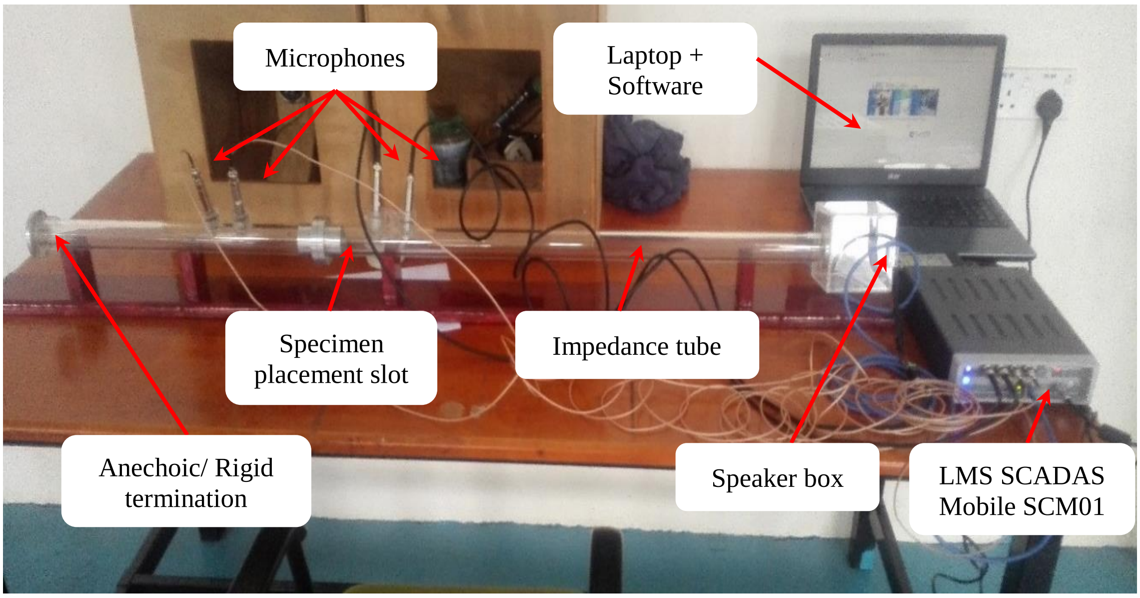


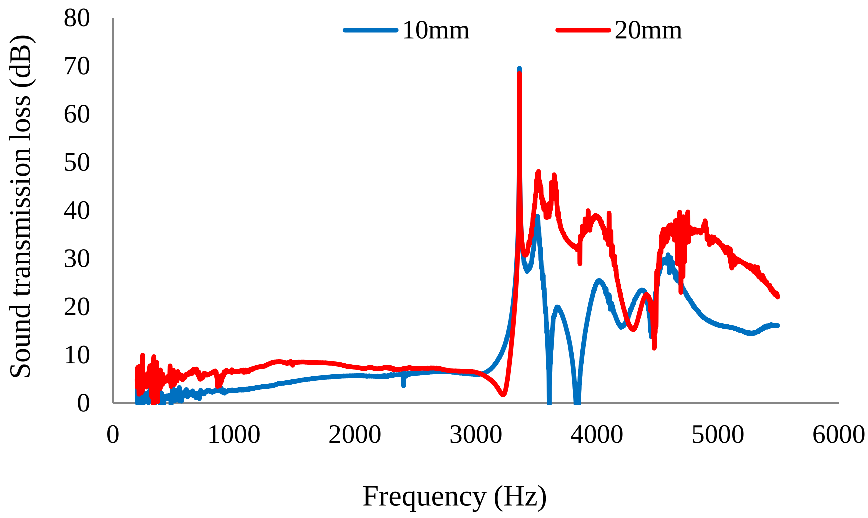
Figure 3. Two-load method impedance tube experimental setup.

RESULTS AND DISCUSSION

Sound Transmission Loss (STL) of Building Materials

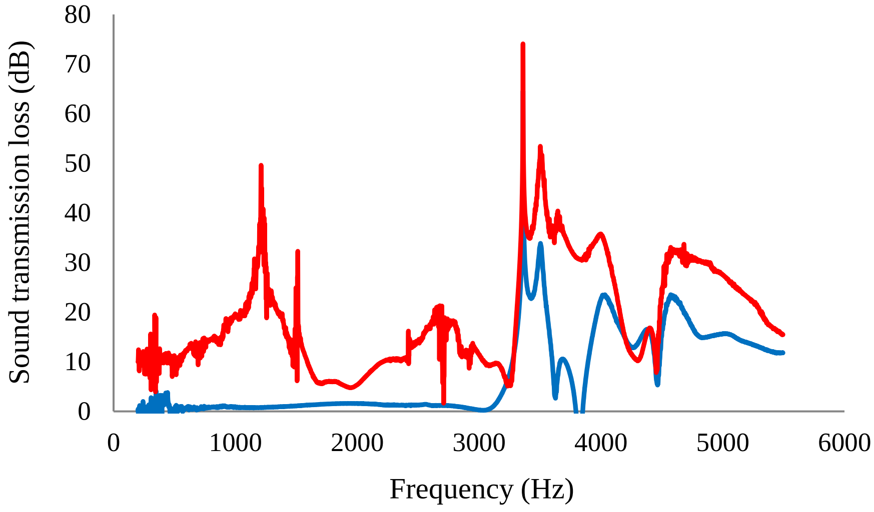
The sound transmission loss (STL) of autoclaved aerated concrete (AAC) is shown in Figure 4(a). The result indicates specimen with 20 mm thickness has higher STL compared with 10 mm thickness specimen. The STL of AAC is greatest in the frequency range of 3000 – 5000 Hz. From frequency 3000 – 5500 Hz, the STL for both 10 mm and 20 mm specimens are considered fluctuate. Frequency range from 200 - 3000 Hz, the STL of 10 mm specimen is steadily increasing to 7dB where 20 mm specimen is increased to 8dB at 1300 Hz and decreases slowly until 3000Hz. The peak value for both lines are fell in the frequency of 3360 Hz. The peak value of STL for 10 mm specimen is 69.6 dB, which is higher than 20 mm specimen with the STL peak value of 68.5 dB. The different in the peak value is less than 1 dB.

Figure 4(b) shows the STL result of expanded polystyrene. It is found that 20 mm thickness specimen also has greater STL compared to 10 mm thickness specimen, which similar trend compared with AAC. For frequency range of 200 - 3000 Hz, the 10 mm specimen is steady with a low STL, and start fluctuating in the frequency range of 3000 – 5500 Hz. Specimen with thickness 10 mm reaches the highest STL of 64.6 dB at 3360 Hz. The 20 mm thickness specimen is fluttered from 200 – 5500 Hz. It is observed that there are four STL peaks, which drop at 1210 Hz, 2630 Hz, 3360 Hz and 4540 Hz, with the STL of 49.6 dB, 20.1 dB, 74.1 dB and 31.3 dB respectively. Both of the specimens reached the highest STL at frequency 3333 Hz. By the observation as depicted in Figure 4(b), expanded polystyrene specimen has shown it could deliver much more improvement of STL compared to others selected materials in this study for the frequency below 3300 Hz, as its thickness was increased from 10 mm to 20 mm.



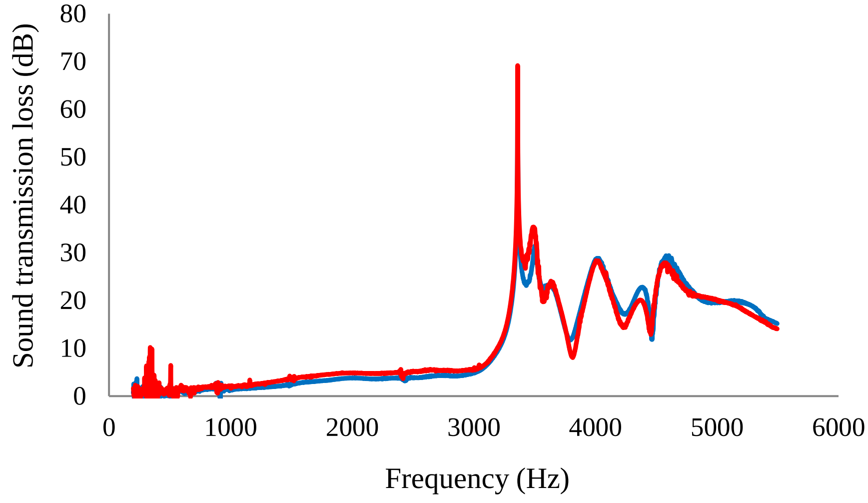
80
70
60
50
40
30
20
10
0
Sound transmission loss (dB)
10mm
20mm
0
1000
2000
3000
4000
5000
6000
Frequency (Hz)

(a)



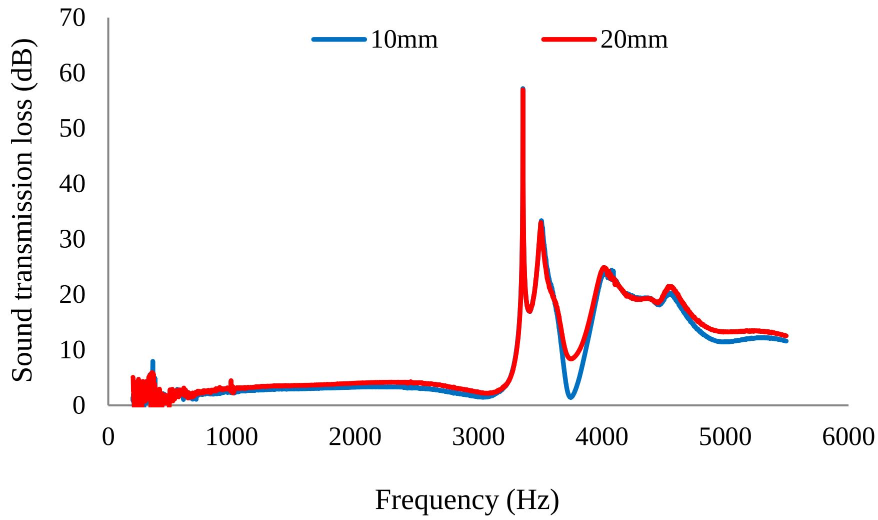
80
70
60
50
40
30
20
10
0
Sound transmission loss (dB)
0
1000
2000
3000
4000
5000
6000
Frequency (Hz)

(b)



80
70
60
50
40
30
20
10
0
Sound transmission loss (dB)
0
1000
2000
3000
4000
5000
6000
Frequency (Hz)

(c)



(d)

Figure 4. Sound transmission loss of (a) AAC (b) expanded polystyrene, (c) laminated glass and; (d) rockwool.

Figure 4(c) shows the STL of laminated glass for the specimen thickness of 10 mm and 20 mm. It is observed that the STL curve for the 10 mm and 20 mm specimens are quite close to each others. Both the specimens have the steady STL for the frequency range of 200 – 3000 Hz and fluctuate at a higher frequency range of 3000 – 5500 Hz. Both of the specimens have the STL peak at the same frequency but different value, which is 69.2 dB for 20 mm thickness specimen and 66.9 dB for the 10 mm thickness specimen. Even Figure 4(c) shows both specimens have almost similar STL, however in overall, 20 mm thickness specimen has greater STL compared to the 10 mm specimen. Based on the observation in this section, laminated glass can be considered that it has insignificant effect of the thickness on the STL improvement.

STL for the rockwool specimen is shown in Figure 4(d). The STL results of rockwool for specimens in 10 mm and 20 mm thickness are almost the same STL result. However, the 20 mm specimen is showed greater STL compared to 10 mm specimen in overall. Figure 4(d) shows both specimens are steady, and low STL at the frequency range 200 – 3000 Hz, and the STL curve fluctuated at frequency 3000 – 5500 Hz. At the same time, it is also found that the STL peaks for both specimens are dropping at the same frequency of 3332 Hz and similar STL of 57 dB. The STL of rockwool is considered relatively low compared with others selected materials in this study. This phenomenon can be explained by the empirical mass law, where the STL is directly proportional to the surface density of the materials [4].

Comparison of Sound Transmission Loss between Different Building Materials

In this section, the STL comparison of four building materials with 10 mm and 20 mm thickness are shown in Figure 5(a) and Figure 5(b) respectively. For the specimen thickness 20 mm, the STL of four building materials show similar inflation trend. At the frequency range of 200 – 3000 Hz, all the building materials are showing low and steady STL. For this frequency range, AAC scores the highest STL. On the other hand, STL is fluctuating at the frequency range 300 – 5500 Hz. In overall, all the building materials score the STL peak value at the frequency of 3332 Hz. The differences in the STL of these four materials are very close for 10 mm thickness of the specimen.

In Figure 5(b), it shows that mostly the building materials have steady and low STL at frequency 200 – 3000 Hz. However, the expanded polystyrene has a fluttered trend of STL in overall. All the building materials achieve the STL peak at the frequency 3332 Hz, where expanded polystyrene scores the highest STL of 75 dB. In general, expanded polystyrene delivers the greatest STL compared to the others, and rockwool has the lowest STL for the specimen thickness of 20 mm.

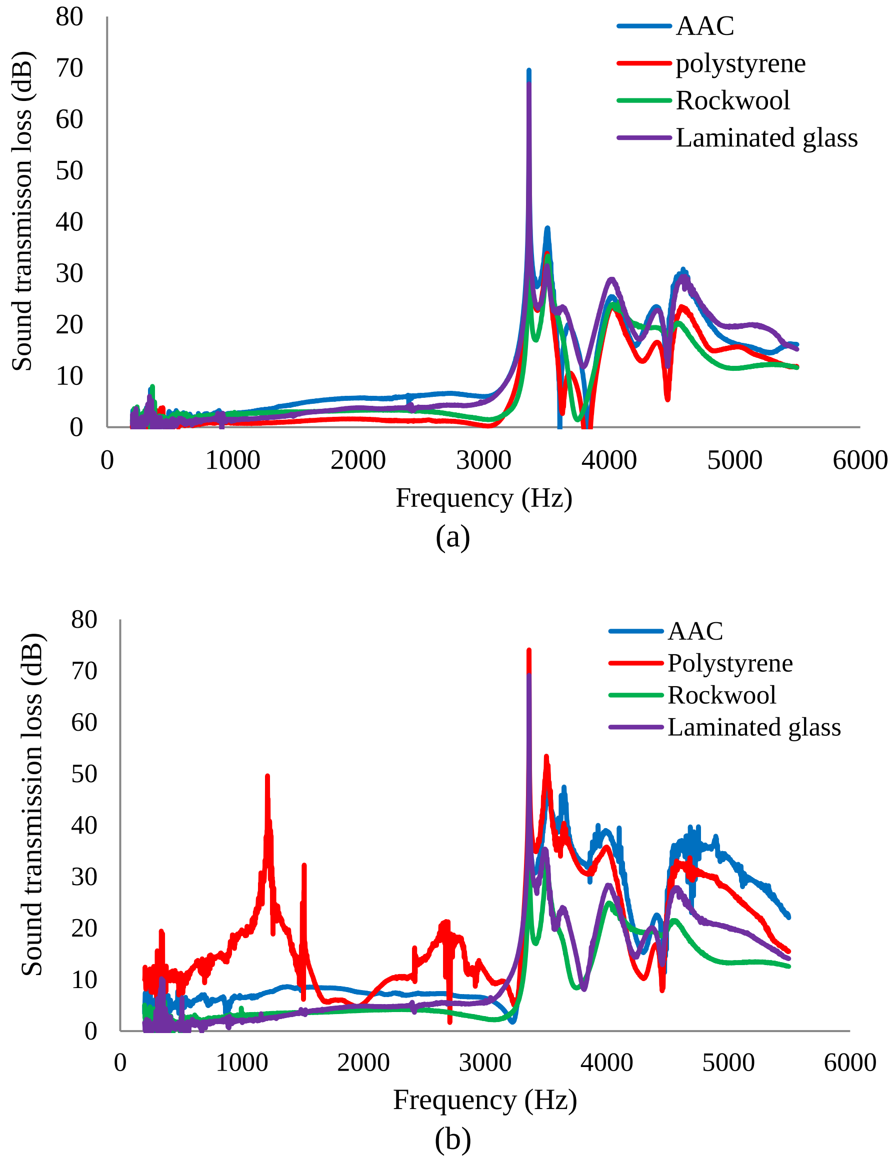


Figure 5. Sound transmission loss of four building material specimens in (a) 10 mm and; (b) 20 mm thickness.

Sound Transmission Loss Different Combination of Building Materials

There are six combinations of building materials are selected to investigate and compare the sound transmission loss (STL) performance in this section. The six combinations include AAC & laminated glass, AAC & rockwool, AAC & polystyrene, rockwool & laminated glass, rockwool & polystyrene, and polystyrene & laminated glass. The STL results of different building materials combination are shown in Figure 6.

Most of the combinations show transient and low STL at the frequency range of 200 – 3000 Hz except the AAC & expanded polystyrene combination which fluttered at the frequency 200 Hz – 1500 Hz. All the building materials combinations have the similar zig-zagged trend at frequency 3000 – 5500 Hz except AAC & expanded polystyrene combination. Based on Figure 12, AAC & expanded polystyrene combination consists of two STL peaks compared to the others combinations. The first STL peak is dropped at 3332 Hz as the others combined, the second peak is located at 3769 Hz. The STL value of the first peak and second peak for the AAC & expanded polystyrene combination are 81 dB and 77 dB respectively. The results also show that the AAC & expanded polystyrene combination is considered the optimum performance combination which delivers the highest STL among the selected combinations in this study.

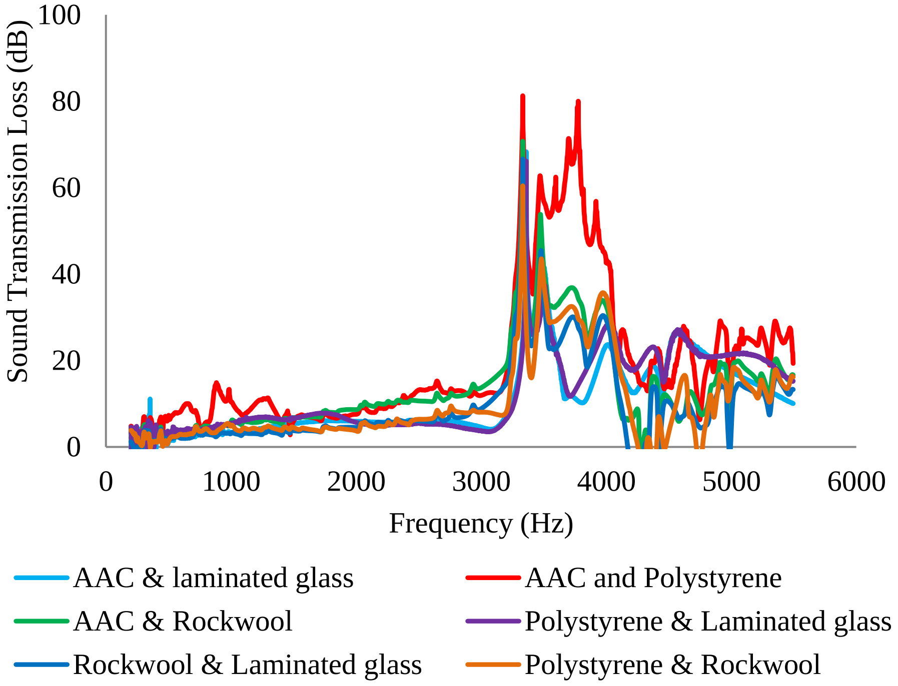


Figure 6. Sound transmission loss of different combination of building materials.

CONCLUSION

In this study, it is found that AAC is considered the greatest sound insulator among the four materials chosen to investigate as AAC scores the highest sound transmission loss (STL) for 10 mm and 20 mm specimen thickness. According to the empirical mass law, the laminated glass should be the best sound insulation materials; however the STL investigation in this study does not comply it and it may need to do further clarification in the next study.

The combination building materials effect also has been determined in this study. Based on the STL results for the different combination of the building materials, it shows clearly that AAC & expanded polystyrene combination is the best for sound insulation. The combination effect is considered better than only one type of material for the same thickness. By lining the expanded polystyrene on the building wall built from AAC, it is expected that sound insulation performance will be very significant and effective.

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