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Study of Potential of Polyethylene Foam as Sound Insulation for HVAC Rectangular Duct

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Abstract: Air conditioning system is very important in a building to distribute airflow with comfortable and quality. In the buildings, ventilation contributes to unwanted noise as the result of the interaction between the outlet air flow and the ventilation fins structure. The noise is caused due to design defect of air duct and it's also possible defect from supply unit. In order to ensure a comfortable living and working environment, it is important to reduce the noise generated by air duct flow. This air duct is equipped with insulation made of fiberglass rather than to overcome this noise problem. In this study, polyethylene foam was used to study the sound insulator characteristics as alternative material compared to the origin insulation that were presented by glass wool. A study has been conducted on polyethylene foam and glass wool to determine the level of efficiency in solving this noise problem. Two methods were performed in this study that is sound absorption coefficient and sound transmission loss and two devices were used that is impedance tube and reverberation chamber to complete this both experiments. Two thicknesses on both materials were used that is 12 mm and 25 mm as observations in this study. Overall, Findings from this experiment indicate that glass wool has a higher level as sound insulator than polyethylene foam. The thickness level of these two materials also greatly influenced the experimental results when it showed better results for the higher thickness.

Keywords: Sound Absorption Coefficient, Sound Transmission Loss.

1. Introduction

Ducts are conduits or passages used in heating, ventilation, and air conditioning. [1] A ductwork system is designed to Distribute airflow from your HVAC equipment from the Air Handling (AHU) Unit to your entire home or commercial building. [2] This involves the air sucked from the whole building into the air conditioner or heater where it is cooled or heated and then forced back into your living space through the ducts. Air handling units (AHU) produces noise and vibration that can be

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disruptive, and this can be amplified as ductwork moves through spaces that are acoustically distinct [3].

The intake and output of the air are determined by efficient a duct system is. If the ducts are not properly constructed, potential issues such as vibration and noise may be caused. The cooling and heating system's balance and air pressure will be off. This makes your climate control and the productivity of your home invariably suffer. Unwanted noise makes an unpleasant and less efficient workplace and when people are surveyed about ease in the workplace, their most prevalent complaints involve the heating, ventilating and air-conditioning (HVAC) systems. [4] Aside from temperature regulation, the concerns they discuss most often have to do with unnecessary noise and vibration.

This research is to counteract the duct insulation problems caused by the origin material characteristics. Two experiment was conducted to study the potential of polyethylene foam as sound insulator for alternative material between origin material that was presented by glass wool. The inner insulation is functioned to control he noise that can occur at outlet diffuser vent. Glass wool is the material that most common insulation used in HVAC industries because it's had a several criteria such as good in noise absorption. For this research polyethylene foam was used to solve this problem. This material was chosen because it has a criterion such as durable, lightweight, flexible and closed-cell material. Due to its excellent vibration dampening and insulation properties, it is also used for noise absorption. [5] It is also very resistant to chemicals and humidity. Other than that, this material was used because it's easy to install to entire duct different to glass wool is difficult to install cause by the material that easy to dissolve.

In this study, two experiments were performed on the selected material to determine if it had good sound absorption characteristics. First, we need to measure the noise absorption coefficient. This experiment to determine the sound absorption efficiency of materials. This experiment was performed using 100 mm and 28 mm impedance tube. Next, we need to measure a sound transmission lost to material because this experiment to know the ability of a material or wall to act as a barrier to prevent the transmission of airborne sound from one room to another. These two experiments also applied to mineral fiberglass to compare the results to be achieved from both materials.

2. Materials and Methods

2.1 Materials

2.1.1 Glass Wool 12 mm and 25 mm

- Glass wool (originally also known as fiberglass) is an insulating medium made of glass fibers arranged into a wool-like texture using a binder. From mineral fiber, glass wool and stone wool are made and are therefore sometimes referred to as 'mineral wools.' [6] Glass wool is a general name for fiber materials which are produced by molten minerals being spinning or drawn. Glass wool uses include structural insulation, insulation of the tubing, filtration and soundproofing. Glass wool is a flexible material which can be used for wall, roof and floor insulation. It should be kept dry at all times during the installation of glass wool, as an increase in the moisture content allows the thermal conductivity to increase significantly. Other than that, glass wool has a good in noise absorption and it proved by noise reduction coefficient value 0.90 to 0.95 from 1 [7].

Figure 1: Glass Wool

2.1.2 Polyethylene Foam 12 mm and 25 mm

- In the world of plastics, polyethylene foam is the simplest and most popular polymer. It's a closed cell material with strong compression resistance, lightweight, elastic, is physical polyethylene foam. It has significant chemical inertia and can also tolerate extended exposure as a thermal insulator to many chemical compounds, ozone and UV radiation. [5] Polyethylene foam is durable, strong and lightweight. Due to the excellent vibration dampening and insulation properties, it is also used for packing products. It also provides high moisture and temperature tolerant resistance to chemicals between -60c and 90c. It is easy to process and fabricate polyethylene foam [5].

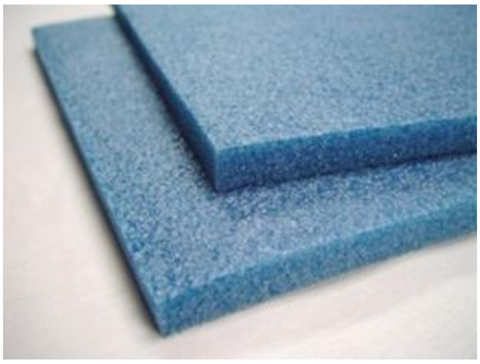

Figure 2: Polyethylene Foam [8]

2.2 Methods

2.2.1 Sound Absorption Coefficient

Sound absorption coefficient is used to measure the efficiency of sound absorption efficiency to selected materials. It is the ratio of energy consumed and incident energy and is expressed by α. If the acoustic energy can be fully absorbed, then $\alpha = 1$. The sound absorption coefficient of materials is correlated with frequency, and it varies with different frequencies. The frequency characteristic curves of the sound absorption coefficient can be used to exactly explain the sound absorption properties of various frequencies. For this experiment, there are using impedance tube with two microphones to test the sound absorption coefficient and there are using 100 mm tube for low frequency and 28 mm tube for high frequency.

Figure 3: Impedance Tube

The evaluation and processing of data in the program generated in the program is a two-microphone transfer system that is. AED 1001. from which the transfer function of the signals was evaluated. This software is used to measure the signals that the two microphones transmit. The amplifier is connected to the speaker of the impedance tube and to the PC with AED 1001 program where the excitation signal is generated. The microphones mounted in the tube are connected to the data acquisition hardware in which it is connected to the PC.

In this experiment, the material used is polyethylene foam as a test of the potential level of sound absorption compared to glass wool. This study also uses different thickness sizes for each experimental material to determine whether the thickness affects the results of the study. The material sizes used are 12 mm and 24 mm for both experimental materials. Both materials are tasted with 28 mm impedance tube for high frequency and 100 mm tube for low frequency. High frequency is measured started from 2000 Hz to 6000 Hz and for low frequency is measured starts from 150Hz to 1550 Hz.

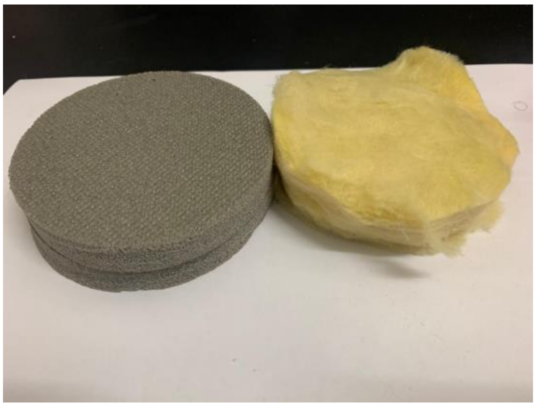

Figure 4: Testing Sample

While the testing material is different, the density for both materials also different but the thickness is still same. The density uses for 25 mm thickness polyethylene foam is 60 kg/m^3 and for the 25 mm thickness glass wool is 32 kg/m^3. For the 12 mm thickness polyethylene foam, the density is 60 kg/m^3 and for the glass wool 12 mm thickness is 32 kg/m^3.

2.2.2 Sound Transmission Loss

Sound Transmission Loss (STL) describes the sound levels in decibels (dB) separated in a particular octave by a substance or partition. The loss of sound transmission often describes the cumulative decrease in waveform energy intensity as a wave propagates outward from a source, or as it propagates through a certain place or structure type. The basic conception of sound transmission loss is shown in Figure 2.3. When sound reaches the partition, the partition between two rooms absorbs part of the sound waves, some will bounce back into the room, and some will transmit through the wall into the adjacent room.

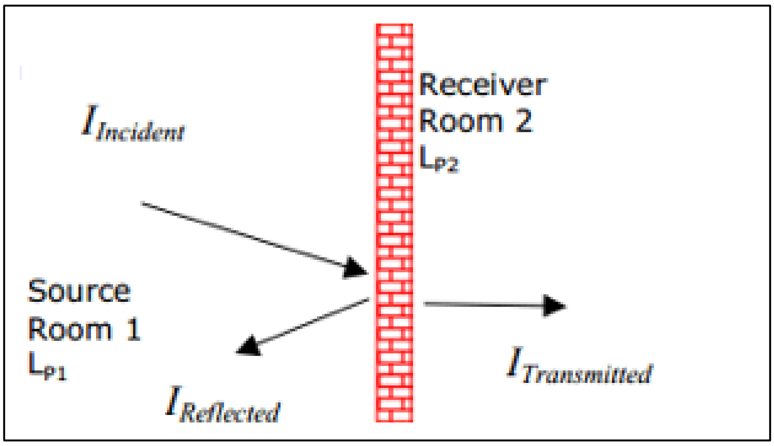

Figure 5: Basic Concept of Sound Transmission Loss [9]

In this experiment, the sound transmission loss is measured using reverberation chamber. High frequency and low frequency are used to perform the experiment. High frequency is measured from 700 Hz to 3500 Hz and for the low frequency is measured from 100 Hz to 690 Hz. The reverberation chamber comes with size 1.2 m^2 for source room and receiver room.

Figure 6: Reverberation Chamber

In this experiment, both testing material polyethylene foam and glass wool is used to perform this experiment and the thickness for the testing material is 12 mm and 25 mm. Both materials are tasted with 1.2 m^3 reverberation chamber for high and low frequency. Figure 7 shows the schematic diagram for experimental setup to perform this testing.

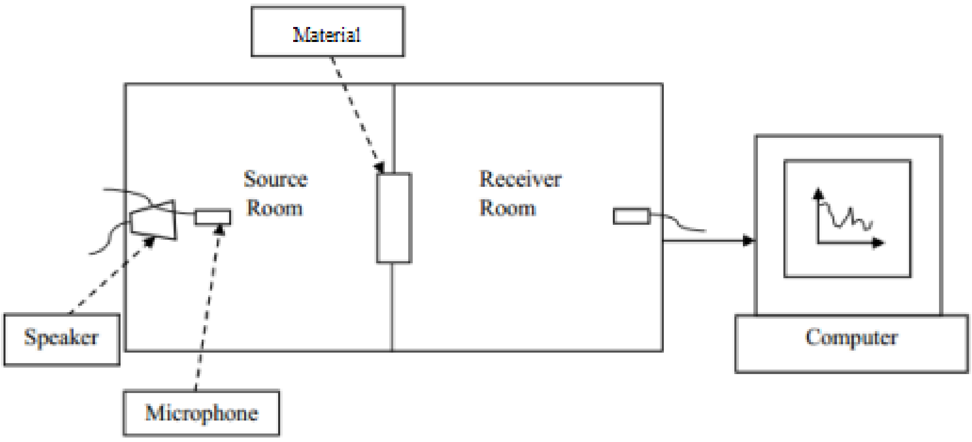

Figure 7: Schematic diagram for experimental setup [9]

3. Results and Discussion

3.1 Sound Absorption Coefficient

- High Frequency Testing

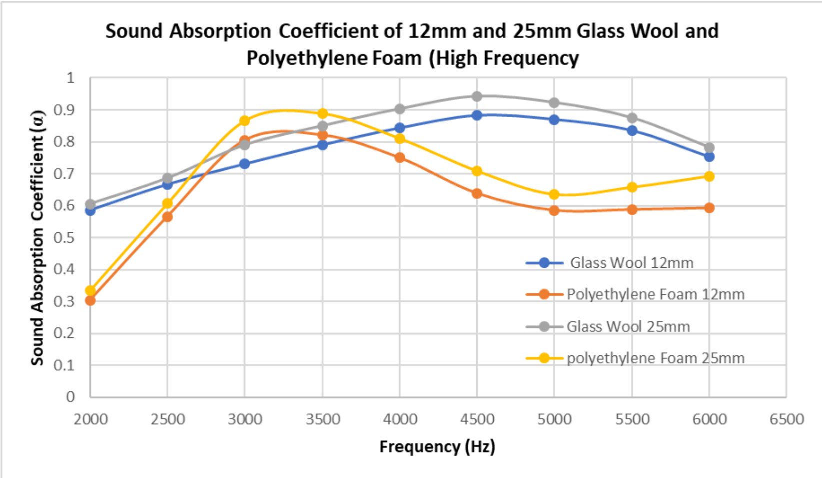

Figure 8: SAC 12 mm and 25 mm Glass Wool and Polyethylene foam

From the result above, it shows the glass wool for 25 mm have a highest peak sound absorption coefficient, that is 0.94 at frequency 4500 Hz while the polyethylene foam is 0.89 at frequency 3200 Hz. From the results 12 mm, it's shows the glass wool's highest peak is 0.88 at frequency 4500 Hz while the polyethylene foam is 0.88 at frequency 3300 Hz. For the early of the high frequency, it shows the glass wool have a high sound absorption coefficient different to polyethylene foam that have a value less than glass wool. But for the end of the highest frequency, it shows the graph for glass wool slowly started decrease and its shows the same result to the polyethylene foam that have decrease of the sound absorption coefficient.

From the graphs above it can conclude that material thickness greatly affects the result of sound absorption coefficient. It shows the highest peak of glass wool 25 mm thickness is 0.94 different to 12 mm that have least value than that is 0.88.

- Low Frequency Testing

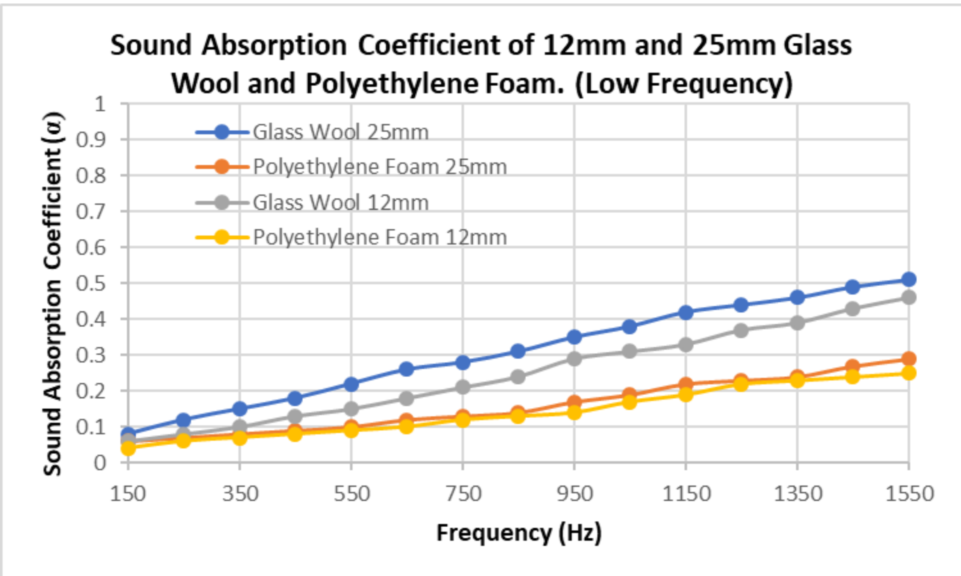

Figure 9: SAC 12 mm and 25 mm of Glass Wool and Polyethylene Foam

Figure 9 shows the sound absorption coefficient result for glass wool and polyethylene foam that have been labelled as blue and yellow colour with thickness 25 mm respectively. For these results, it is observed that value of sound absorption coefficient for glass wool is increasing starts from 0.06 at 150 Hz until 0.51 for 1550 Hz. For the polyethylene foam, it shows the highest peak at frequency 1550 Hz that is 0.29. By referring at the same figure it shows for 12mm thickness of glass wool and polyethylene foam, with labelled as silver and yellow.

It can be observed that the distributions of sound absorption coefficient curve of the glass wool have a lower value than 25 mm thickness that is 0.46 at the frequency 1550 Hz. For Polyethylene with 12 mm thickness, it shows the least value than 25 mm thickness but the thickness for these two materials greatly affect the result, it can conclude that the value showed from graph above is the glass wool have a good in sound absorption coefficient different compared to polyethylene foam that have least value. The main factor affecting the sound absorption coefficient is thickness of the material. It shows the value of sound absorption coefficient at 25 mm thickness is larger than 12 mm.

3.2 Sound Transmission Loss

- This section will discuss the comparison result of 12 mm and 25 mm glass wool and polyethylene foam in 1/3 octave band graphical form. Figure 10 shows this testing is evaluated from aspect thickness, frequency and output of the sound transmission loss. It uses frequency starts from 100 Hz until 4000 Hz.

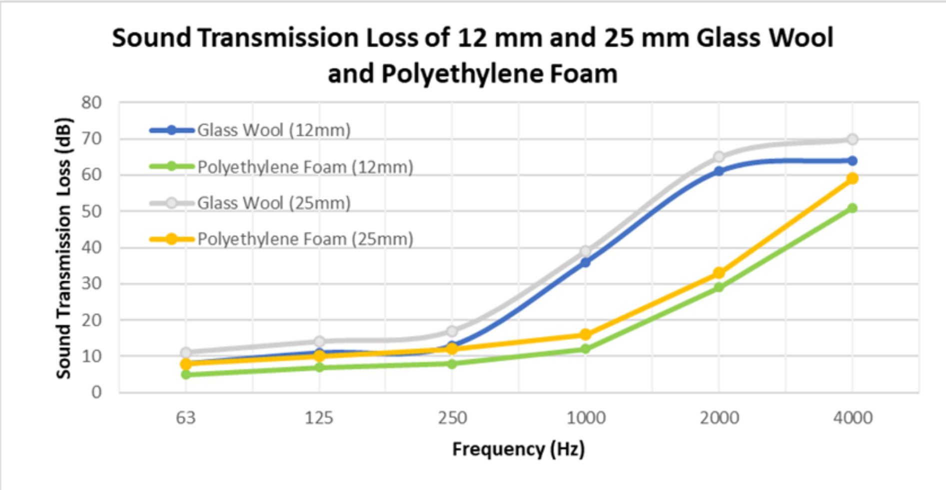

Figure 10: Comparison of 12 mm and 25 mm Glass Wool and Polyethylene Foam

From result above, it's shows that the 25 mm thickness for both materials have a high value compared to 12 mm for this experiment. it can be observed that the distributions of sound transmission loss curve at 25 mm of the glass wool have a higher value that is 72 dB at 4000 Hz different to polyethylene foam that is 59 dB.at 4000 Hz while at thickness 12 mm the highest peak of glass wool at frequency 4000 Hz that is 64 dB. For the polyethylene foam, the highest value peak value is 52 dB at frequency 4000 Hz It shows that both materials have a good in sound transmission loss when it has much thicker. But for glass wool it has very higher value for this experiment to make it as the best material that perform in this experiment.

4. Conclusion

In this study, the evaluation of sound transmission loss and sound absorption coefficient for the glass wool and polyethylene foam in the aspect of thickness, and frequency has been achieved. Overall, for sound transmission loss and, sound absorption coefficient the selected frequency range in this study it is observed that higher frequencies (2 000Hz and 4000 Hz) for sound transmission loss are having high sound transmission loss compared with lower frequencies (100 Hz to 1550 Hz). For the sound absorption coefficient frequency range in this study, it is observed that higher frequencies (1500 Hz and 4000 Hz) for sound absorption coefficient also having high value of sound absorption coefficient compared with lower frequencies (150 Hz to 1550 Hz) It is because high frequencies sound wave could transmit better than higher frequencies sound wave through the material.

Besides this, it is also found that the most effective way to enhance the sound transmission loss and sound absorption coefficient is increasing the thickness of the material. Therefore, the thickness of the material is one of the important parameters which can be tuned for sound transmission loss enhancement for the applications of sound insulation. From the result above, it was found that glass wool could be used as the sound proofing for the reduction of noise at inner rectangular HVAC duct compared to polyethylene foam that have least value for both experiments. Last but not least, As mentioned above, glass wool insulation helps to reduce noise by absorbing sound. The thicker of the glass wool, the better it will absorb the noise. It is one of the best soundproofing materials, compare to polyethylene foam.

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