Analysis of the Acoustic Tile Shapes Effectiveness towards Noise Absorption

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Abstract: This research has utilized a combination of recycled cotton and non-phenolic resin (as a bonding agent) for sound-absorbing tiles in a room or hall. The purpose of this acoustic tile is to reduce the reflection of sound in other means absorbs the sound in order to create a serene environment. In this research is used acoustic wall tiles in order to increase the sound absorption and reduce the reflection of the sound by changing the geometry of the surface of the acoustic wall tiles into various shapes (three types). The study was first conducted using felt of 10-mm thickness and this shape has better absorption quality in the low-frequency range. For the second set of studies, the same design was tested in an impedance tube with a felt thickness of 40-mm and this set of designs showed an overall increase in the sound absorb ton coefficient. The design that has the best sound absorption quality was the slotted absorber has it has an increment drastically in sound absorption quality compared to the currently available design. Hence, we can conclude that the geometry of shape will affect the sound absorption coefficient of this material and increase the sound absorption rate.

Keywords: Acoustic wall tiles; Noise absorption; Slotted noise absorber; Wedge noise absorber; Micro-perforated panel absorber

1. Introduction

In the current generation living in noise pollution is not a new thing. It seems like every corner is noisy. People in the current generation are searching for a quiet place to relax. Some people try to find an alternative method to reduce sound leaks where it would not be disturbing for others. For instance, nowadays houses are built very close to each other so that they have common walls, such as in condominiums and semi-detached houses, in this kind of situation the sound from one house can be heard in the other house and this can be a nuisance. Another example, in a restaurant or coffee shop, most people would like to sit and relax but due to the noise from the kitchen and other people speaking loudly, providing such an environment seems vital. To overcome the sound pollution acoustic wall tiles are used to absorb the sound waves. Acoustic wall tiles act as a reducer where absorbs the sound created by humans or other things and provide a quieter environment.

A Micro-Perforated Panel has been introduced as the alternative design for using wood and fiberglass as a sound-absorbing material. This acoustic panel does not cause harm to nature and is fully environmentally friendly. They are most effective when the acoustic particle velocity is maximum at the pores (Herrin, Liu, & Seybert, 2011). Micro-Perforated Panels (MPP) with a tuned cavity depth behind the panels are effective for indoor sound absorption within a certain frequency range (Maa, 1998). This is because it allows the sound wave to travel faster into the pores where inside the pores sound wave are trapped and there will be no reflection. The micro-perforated material can be constructed from almost anything including the Felt. MPP can be designed by using biodegradable materials such as fiber (Chin, Yahya, Din, & Ong, 2018). This flexibility in the design allows me to propose a design on this. It has been demonstrated that the absorption frequency bandwidth can be extended up to 3 or 4 octaves as the diameters of the micro-holes decrease to 0.3 mm (Li & Fenglei, 2006). The wedge structure is known as Helmholtz Absorbers. This design is named after German physician Hermann von Helmholtz. These types are also known as diffusers. This type of absorber best works in the range of high frequency when the particle velocity is the maximum. This structure suggests that with the small slits or openings, the losses in the slits can increase the rate of absorption (Chanaud, 1994). From the experiment, wedge design has the highly sensitive indication among all the materials compared (Fuchs, 2013). Suggested also this design has a high cut-off frequency, that this improves the sound absorption rate of a design that has a good sound absorber requires high cut-off frequency (Rusz, 2015). This study also suggests that the height of the wedge should be increased proportionally to the width of the design. This study also suggests that this design works best on material with high porosity because of the need for an air gap in this material design.

A combination of cotton as a raw product and non-phenolic resin as a bonding agent is used, the product is made of recycled items such as tetra and poly cotton. This material is used to produce acoustic wall tiles which will be used as sound absorption material placed on the wall of a room or hall. This will reduce the sound reflection creating a quieter environment. The purpose of this study is to increase the sound absorption of this material by altering the current design hence increasing the sound absorption quality of this product. The cases that make this research unique are:

- Use of new recycled material
- Effect of thickness change of acoustic tile to absorb noise
- Geometric deformation effect of acoustic tile surface to absorb noise

In the end, according to the results, the best design for the acoustic tile is introduced.

2. Methodology

2.1 Design

In this research two scenarios are considered. In the first scenario, results are tested with several designs which are shown in Figure 1. The detailed geometry of the first set is shown in table 1. Table 1 is shown all designs that have the same material (combination of recycled tetra and poly cotton as a raw product and non-phenolic resin) and thickness (10-mm).

Table 1. Geometric characteristics of different designs of acoustic tiles with a fixed thickness of 10 mm

	Design	Diameter of hole (mm)	Distance (mm)	Height (mm)
1	Flat panel	-	-	-
2	Micro-perforated	2	10	5
3	Micro-perforated	2	20	5
4	Micro-perforated	3	10	5
5	Micro-perforated	3	20	5
6	Wedge	-	20	4
7	Wedge	-	20	6
8	Slotted	-	10	5

In the second scenario of the experiment three designs such as the flat, wedge, and slotted with a constant thickness (40-mm) are considered. The height of the wedge and the slotted were considered 20-mm.

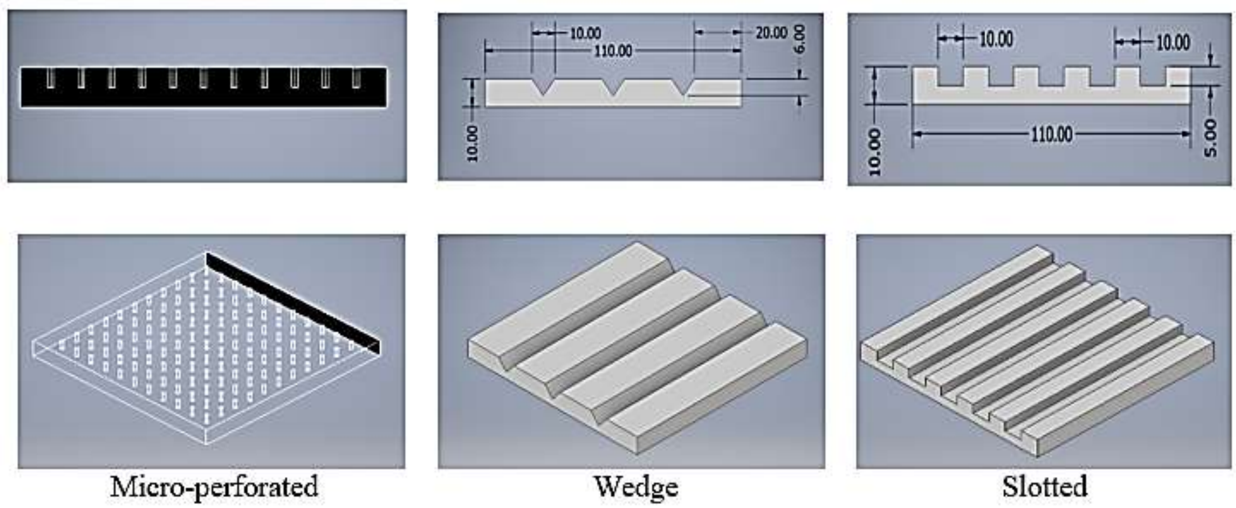

Figure 1. Front and top view of samples noise absorber design

2.2 Experiment Equipment

The method of testing which are used in this research is a method of impedance tube. Figures 2(a) and 2(b) show 100-mm and 30-mm diameter impedance tubes with lengths of 1-meter in order to measure impedance and absorption. Figure 2(c) shows a schematic illustrating the applicant approach of impedance tube and software (VA-LAB4 Basic + VA-Lab4 IMP-AT). The test is conducted using the guidelines which are set according to the ISO 10534-2:1998 (GB/T 18696.2-2002). Using these standards, the transfer function method using two microphones (MPA416) is used. The range of the test varies with the frequency of the sound which is from low to high. The experiment is conducted in a controlled environment following the ISO 10534-2:1998 (GB/T 18696.2-2002) standard.

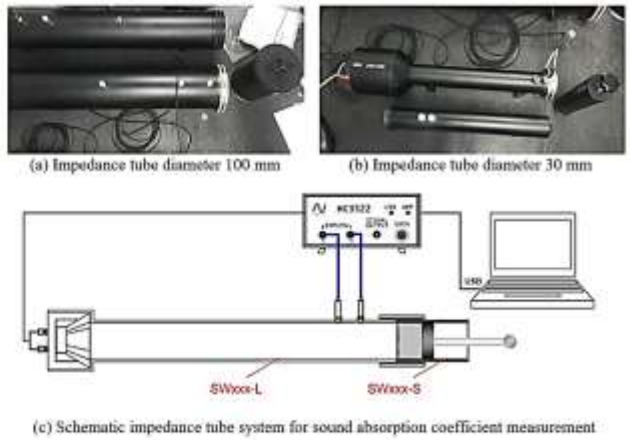

Figure 2. Impedance tube, Models SW422 and SW477, Microphone (MPA416)(Gumanová, Džuňová, Sobotová, & Králiková)

3. Results and Discussion

Figure 3 shows, the result obtained by testing four types of micro-perforated design. In order to achieve the best absorption coefficient in low frequency in the micro-perforated design, the size of the hole has to be smaller as we can see in the result obtained design 2 has the best absorption coefficient compared to other designs. In terms of the high-frequency region, the diameter of the hole must be bigger, therefore the design with a 3-mm hole diameter which is design 4 and design 5 performed better compared to design 2 and design 3. In terms of the spacing between the hole for the range of lower frequency, the holes have the spaced near, this can be seen that in design 2 and design 4 has better sound absorption coefficient is the lower range compared to other two design. In the range of higher frequency, the holes must be spaced apart as it has a better absorption coefficient as can be seen in design 3 and design 5. To conclude the design for the micro-perforated panel for this felt material to absorb more sound energy, in the low frequency are the diameter of the holes must be smaller and the spacing of the holes must be nearer and in the range of high frequency the diameter of the holes must be bigger and spacing between the holes must be bigger. To compare the result of absorption between design 5 and which are the wedge absorber result, in the range of low frequency we can observe design 6 has a better absorption coefficient compared to design 7 even though both designs are the same with different depths. This shows different depths or heights are important parameters in designing this design. For the range of higher frequency, the result shows that design 7 has a better absorption rate compared to design 6. Therefore, this shows that in order to achieve a higher absorption rate in a lower frequency, the height of the triangle must be shorter as it produces a bigger surface area. Since at the low frequency the speed of the sound energy is low, the bigger surface area provides more area for the felt to be exposed to the sound energy and due to the absorption characteristic of the felt, the reflected sound energy is lower this is the reason why in low frequency, shorter design with 4mm height has better absorption rate. In the range of high frequency, the deeper the triangle the better has triangle creates a better angle of reflection, when sound energy with high-frequency travel into the region, the reflected incident angle stays in the deep slots as the angle of incident is lower in the deeper slot. Added to this at high frequency the impedance of porous material will decrease, which will result in the same impedance of the air. This incident will cause more sound energy to enter the slot and the lesser surface area will increase the absorption rate of the material. Based on the result compared above, the wedge and slotted absorber shapes are selected to be further tested. The reason why wedge was selected is that compared to other designs, the wedge design has the best natural range coefficient. The slotted design was chosen because comparing the natural range coefficient, design 8 has also a better result compared to the micro-perforated hole design.

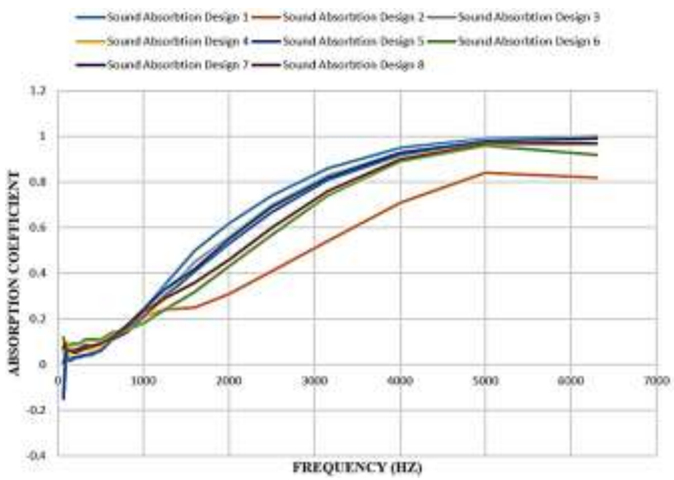

Figure 3. Relationship between the absorption coefficient and the frequency of 10 mm thickness

Figure 4 shows the material with a thickness of 40mm. Figure 4 shows that at low frequencies, 40 mm thick sound tiles have much higher frequency absorption (energy absorption) than the 10 mm thick sound tiles shown in Figure 3. In the range of medium frequency, we can observe the newly designed slotted absorber and wedge absorber design has a better absorption rate compared to the flat panel design at the high-frequency range, the slotted absorber design has the best absorption coefficient compared to all the designs. The design with the best natural range coefficient is the design with a 1-inch air gap. This is because, porous material normalizes the impedance of the material, to solve this issue there is a need for an air gap between the material. This shows by adding an air gap, the absorption rate of the material increases. this can be seen by the comparison of design with 1-inch air gap and flat panel design. The difference in the natural impedance of the porous material is normalized by the porosity of this felt. To improve this issue, an air gap should be fit in the back cavity of the porous material. This air gap will increase the absorption rate because when the sound energy enters the porous material it travels through the porosity, by adding this air gap, the sound energy which travels will be reflected inside the air gap preventing the reflection of sound energy from exiting the surface of the material. This causes the sound absorption coefficient of the material to increase. By comparing the designs that is proposed by the authors in this article and the other designs that are initially designed also by authors. It can be seen from the graph the light blue line and the red line represent the initial design while the green and purple are the proposals designed design. From the graph. It can be observed that the proposed has a better absorption coefficient in frequency above 1000 Hz. Especially the slotted absorber design performs better, and it reaches the maximum absorption rate in 2500 Hz. This proves the newly designed design has better sound absorption properties compared to all the other designs in the high-frequency range. Based on the result, by comparing the two new designs that can observe the slotted absorber design has a better absorption coefficient compared to the wedge absorber design. Several factors affect the absorption coefficient of the wedge absorber design. In general, why the two new designs are better in high-frequency range absorption is because, at high frequency, the normalized impedance of porous material will decrease gradually due to the velocity of sound energy on the surface of the material. When the normalized impedance decreases, the pressure will increase at the surface which results in more reflection of sound energy back. By adding wedge or slotted shape into this porous material, the surface area on the top of the material increase, this allows sounder energy to travel into the wedge or slot and this also increases the absorption band of the material. when the sound energy or sound wave travels into this design, due to the shape factor the reflected ray keeps being reflected inside the shape itself. Hence, the irregular shape on the top of the design absorbs more sound at a higher frequency range.

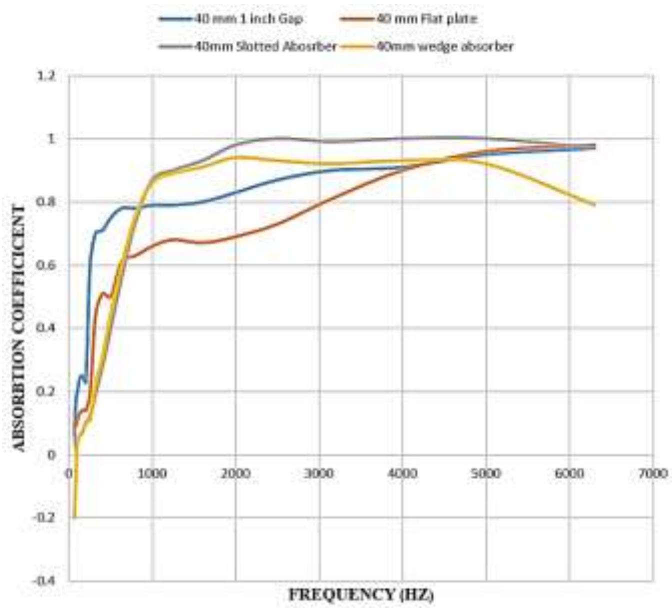

Figure 4. Relationship between the absorption coefficient and the frequency of 40 mm thickness

4. Conclusion

Based on the investigation above, it can be seen for 10-mm thickness felt for absorption coefficient in the low range frequency, the newly proposed designs (slotted absorber design and wedge absorber design) have shown better absorption coefficient compared to the current design (flat panel). The usual room frequency is around 200-Hz and all these newly proposed designs have shown that they have a better absorption coefficient. They are a few advantages over other designs and the best design for the wall panel by using new material will be a slotted absorber. This is verified by testing the slotted absorber design in 40-mm thickness and it shows that the slotted absorber has a better absorption coefficient in the mid and high-frequency range. When compared the new design on the 40-mm thickness with the flat plate, the design shows a drastic improvement in sound absorption coefficient. According to the results, it can be concluded that the shape will have a significant effect on the sound absorption coefficient with the proposed material.

References

Chanaud, R. (1994). Effects of geometry on the resonance frequency of Helmholtz resonators. *Journal of Sound and Vibration, 178*(3), 337-348.

Chin, D. D. V. S., Yahya, M. N. B., Din, N. B. C., & Ong, P. (2018). Acoustic properties of biodegradable composite micro-perforated panel (BC-MPP) made from kenaf fibre and polylactic acid (PLA). *Applied Acoustics, 138*, 179-187.

Fuchs, H. V. (2013). *Applied acoustics: Concepts, absorbers, and silencers for acoustical comfort and noise control: Alternative solutions-Innovative tools-Practical examples*: Springer Science & Business Media.

Gumanová, V., Džuňová, L., Sobotová, L., & Králiková, R. Impedance Tube as a Tool for Evaluating Acoustic Noise Descriptors–The Experimental Measurement of Acoustic Parameters.
Herrin, D., Liu, J., & Seybert, A. (2011). Properties and applications of microperforated panels. *Sound & Vibration, 45*(7), 6-9.

Li, K. L. J. T. X., & Fenglei, J. (2006). One of Ideal Absorbing Materials in Architectural Acoustics: Micro-Perforated Panel Absorbers. *the Journal of the Acoustical Society of America, 119*(5), 197-202.

Maa, D.-Y. (1998). Potential of microperforated panel absorber. *the Journal of the Acoustical Society of America, 104*(5), 2861-2866.
Rusz, R. (2015). Design of a fully anechoic chamber.