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Potential Application of Fabric Waste as Acoustic Materials in Building

Muhammad Ersyad Ahmad Jailani[1] & Mohd Hafizal Mohd Isa[2*]

[1, 2] *School of Housing, Building and Planning, USM, Penang Malaysia*

** hafizal@usm.my*

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The study aims to identify the potential of fabric waste to be converted into acoustic material to solve the problem of noise pollution. In a human's environment, acoustic comfort is one of the basic needs. The sound that is too high in decibel may create noise and harms the humans' hearing ability to the point it is called noise pollution. It can be argued that noise presents more negative effects on humans' health may it be physically or mentally affected. Millions of people are not excluded from being affected by noise pollution, which not only causing annoyance but also harming public health. The sound absorption coefficient measurement method is adopted in this study. The results show that fabric waste has the ability to absorb sound, eventually, reduce noise pollution. Cotton is one of the types of fabrics that shows better sound-absorbing efficiency compared to other materials. The use of acoustic panel is crucial in keeping the balance of comfort in humans' lives at the same times improving the environment.

Keywords: Acoustic, Noise Control, Noise Pollution, Fabric Waste, Sustainable

1. INTRODUCTION

According to Bhatia et al. (2014), since the industrial revolution, waste production has started and kept on developing. This is due to the production of goods in mass quantities because of the increase in demand, the evolution of the manufacturing industry, and the replacement of the manual labour systems with mechanised manufacturing (p. 77). In the past few decades, the world fibre production has been gradually increasing, which has exceeded 64 million tons per year (Wang, 2010).

The consumption of global fabric is estimated at over 30 million tons per year, which has a significant impact on society and the environment in the supply chain (Chen & Burns, 2006). Since there is awareness of fabric waste globally, the recycling trend has been seen growing. Hawley (2006) proved and has overseen this very trend of recycling fabric due to overconsumption and waste generation in global fashion and culture, fabric recycling has become key issues in achieving sustainable fashion worldwide. As fabric waste is continuously growing and public health faces harmful effects, it coherently gives humankind so many problems, especially with the prevalent water and air pollution. In this context, by using fabric waste as an acoustic material, it is like killing two birds with one stone. Both types of pollution can be controlled and reduced simultaneously.

2. PROBLEM STATEMENT

The most affected ones to noise pollution are the workers in manufacturing industries, since they work near and are frequently vulnerable to the noises (Ismalia & Odusote, 2014). This is the longer-term that may cause them injuries in auditory and non-auditory aspects, thus affecting their performance and comfort in the workplace. This statement is backed with research done by Rabinowitz (2000), claiming that the hearing loss among old folks is mostly caused by prolonged exposure of noise at the workplace during young age. This indicates that the consequence of noise pollution may not be detected at early times, but it shows physically later during late age.

The invention of acoustic materials may be the only solution to prevent noise pollution since most of the time, the noise source cannot be controlled. Acoustic material is any means of reducing the sound pressure with respect to the sound source and receiver specified (Hopkins, 2012). The only possibility for the time being is by reducing the impact of noise's loudness. It is important for research and development of efficient and environmentally friendly acoustic materials (Alcaraz et al., 2017).

3. RESEARCH QUESTIONS & STUDY PURPOSED

The following research questions will be used to frame this study to meet the research's objectives:

- Can industrial waste such as fabric waste be a substitute for conventional materials for an acoustic panel?
- What are the types of fabric waste that have the most effective sound absorption performance?

The purpose of this study is to assist the potential of the recycled fabric as an acoustic material in solving noise pollution issues and achieving acoustic comfort in a building. The study aims to identify the potential of the recycled fabric as an acoustic panel to solve the problem of noise pollution. The types of fabric waste also will be studied to investigate the type of fabric waste that can be converted into an acoustic material to reduce noise pollution.

4. METHODOLOGY

A quantitative approach adopted in this study as most of the past researchers adopted experiments to study acoustic material. The sound absorption coefficient measurement method is carried out to evaluate the performance of acoustic materials. Before executing the experiment, the main properties which include the thickness, mass, and fibre density of the samples are measured. This procedure is used to justify the correlation of the sample properties and sound absorption coefficient measurements. The sound absorption efficiency of samples is determined through the values of the Noise Reduction Coefficient. This study limits to five types of fabrics which are polyester, silk, linen, viscose, and cotton. This is to provide a better understanding of these common types. The fabric waste used in this study is supplied by Kloth Cares. Kloth Cares is an organization that collects both pre-consumer and post-consumer fabric waste. The fabric wastes are then distributed to partners and collaborators to give the fabric waste a new life and purpose.

Sample Preparation

The sample preparation is divided into two phases which are the pre-treatment and the preparation phase. In the pre-treatment phase, the fabrics are cleaned to prevent any errors that occur in measurement during the measurement procedures. All unwanted elements like buttons, metal parts, and sewing thread are removed. After removing the elements, the fabrics are washed with warm water. The temperature of the warm water used is around 32°C. Warm water is used in this process to remove any dirt and contaminants. Besides that, the usage of warm water offers good cleaning without fading or shrinking the fabrics significantly. In order to eliminate water, the washed fabrics are then sun-dried.

In the preparation phase, each type of fabric is shaped into a few small round pieces with a 5cm diameter. A few layers of small pieces are then bound together with polyvinyl acetate (PVA). Then, the bound pieces are pressed into a mould of 0.5cm thickness using a compression moulding machine to achieve the size and thickness needed. This is to provide the same sample thickness which will be the fixed variable. This process is done to produce a round shape and size that can fit into the impedance tube measurement system. Each sample was given enough pressure to bind while retaining the sample porosity.

Porosity Measurement

Fabric porosity refers to the void fraction of the total void space within the volume of the fabric. Based on the data collected during sample preparation, the porosity, P (%), of the sample is calculated using the following equation (1).

$$P = 100\left(\frac{1-M}{1000}\cdot h\cdot \rho\right) \quad (1),$$

Where M is mass per unit area (g/m^2) of the fabric, h is thickness (mm) of the fabric and ρ is relative density of the fibre (g/cm^3) equations.

Sound Absorption Coefficient Measurement

According to Crocker (2007), engineers and scientists mostly refer to the property of sound absorption coefficient measurement in analysing acoustical environments. This method is used to obtain the sound absorption coefficient of acoustic material. The sound absorption coefficient is obtained from the ratio of reflected and incident waves produced (Doutres et al., 2010). The sound absorption coefficient (α) measurement can be expressed as seen in (2).

$$\alpha = 1 - \frac{I_r}{I_i} \quad (2),$$

Where α is the sound absorption coefficient, I_r is the intensity of reflected sound wave and I_i is the intensity of incident sound wave. The Noise Reduction Coefficient (NRC) is used to indicate the value of the sound-absorbing materials since the sound absorption coefficients value is varied at different frequencies. Based on the data of the sound absorption coefficient, the Noise Reduction Coefficient (NRC) value is calculated as seen in (3).

$$NRC = \frac{\alpha_{125}+\alpha_{250}+\alpha_{500}+\alpha_{1000}+\alpha_{2000}}{4} \quad (3),$$

5. FINDINGS

Porosity Measurement

Porosity is one of the most important factors to characterise its sound absorption properties. The porosity is measured to identify the physical properties of the material in damping sound. Based on the properties of the samples, the porosity, P (%), is calculated (refer to Table 1).

Table 1: The sample properties and porosity measurement.

Sample	h, Thickness (cm)	M, Mass (g/cm^2)	ρ, Fibre Density (g/cm^3)	Porosity (%)
Polyester	0.5	13.93	1.22	0.79
Silk	0.5	12.42	1.32	0.75
Linen	0.5	10.80	1.50	0.74
Viscose	0.5	10.07	1.53	0.69
Cotton	0.5	9.68	1.55	0.67

Sound Absorption Coefficient Measurement

Five different frequencies are recorded for each sample (refer to Table 2). Since the value of the sound absorption coefficient is varied, the Noise Reduction Coefficient (NRC) value is calculated to determine the material sound absorption capability.

Table 2: The sound absorption coefficient of the samples.

Sample	h, Thickness (cm)	Frequency (Hz)					NRC
		150	250	500	1000	2000	
Polyester	0.5	0.12	0.52	0.65	0.72	0.56	0.51
Silk	0.5	0.14	0.50	0.68	0.80	0.56	0.54
Linen	0.5	0.15	0.52	0.74	0.88	0.61	0.58
Viscose	0.5	0.18	0.54	0.76	0.89	0.66	0.61
Cotton	0.5	0.22	0.55	0.83	0.95	0.75	0.66

Data are plotted in the form of a line graph to identify the patterns. The line graph also provides a better illustration of the highest and lowest sound absorption coefficient. All types of material are combined to form plotted curves. Figure 1 shows the line graph of the sound absorption coefficient of the samples. The results indicate that the sound absorption coefficient varies in the range of 0.12 to 0.95. All materials form relatively common line graph patterns. Each material shows a very distinctive peak. As can be seen, the maximum sound absorption coefficient for all samples occurs at a frequency of 1000Hz while the minimum value of the sound absorption coefficient for all samples occurred at a frequency of 125Hz.

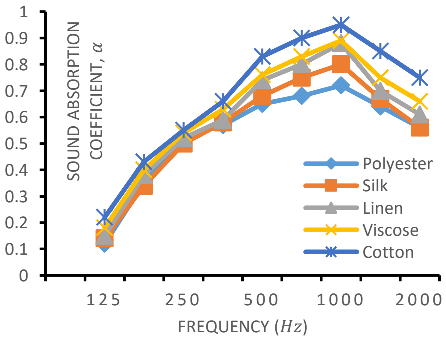

Figure 1: The sound absorption coefficient of the samples

The highest value of the sound absorption coefficient was produced by cotton which occurs at a frequency of 1000Hz. Cotton, linen, and silk are all from natural fibres while viscose is semi-synthetic. This can be analysed that most natural fibres exhibit better sound absorption coefficient where the results indicate more than 0.80Hz. However, at this frequency, polyester shows the lowest value of 0.72Hz. This shows that synthetic material has a lower ability in absorbing sound compared to natural fibre. Higher porosity value influences its ability in absorbing sound. Polyester’s high porosity value has led to its low sound absorption coefficient.

Polyester has the lowest value of the sound absorption coefficient was found to occur at a frequency of 125Hz. In fact, polyester produces low value in each frequency compared to other materials except at frequency 250Hz. At this frequency, polyester produces more than 2Hz compared to silk. Polyester has the lowest sound absorption coefficient is due to the greater porosity value in comparison to other materials.

The line graphs increase from frequency 125Hz to 1000Hz but start to drop at the frequency of 2000Hz. The sound absorption coefficient value seems to drop as low as 0.56. The reduction of the sound absorption coefficient at a frequency of 2000Hz can be due to the coincidence dip phenomenon. Typically, this phenomenon is called the critical frequency which can severely limit the sample’s ability to absorb sound. The coincidence dip happens as the incident sound wave is in line with the reflected wave from the sample. The samples are not able to absorb sound at high frequency. This sound wave system is regarded as the standing wave (refer to Figure 2).

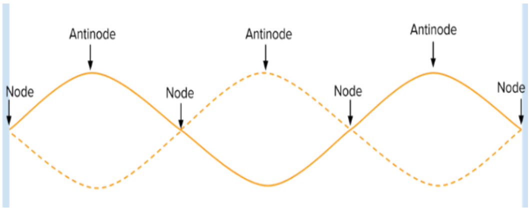

Figure 2: The phenomenon of the standing wave

Noise Reduction Coefficient Measurement

Noise Reduction Coefficient (NRC) values for the fabrics are presented in Figure 3. A bar graph is used to provide a clear presentation in order to compare the quality of the sound absorption coefficient of each material. The results show that NRC values vary from 0.51 to 0.66. The maximum and minimum NRC values were obtained for each type of fabric. Cotton has the highest NRC value of 0.66 compared to other fabrics while polyester has the lowest NRC value of 0.51.

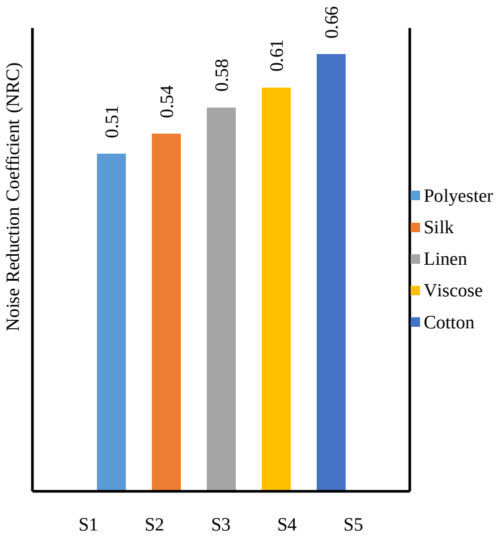

Figure 3: The noise reduction coefficient of the samples

In general, it can be observed that a sample with a higher fibre density generates a slight enhancement of the performance of sound absorption. This is due to the different physical properties of each fabric. The fibre density plays a vital role in enhancing the quality of the material. Fibre density affects the number of voids in the material. This number of voids is where the porosity of the material is determined. The porosity of the fabric has influenced the NRC value. This can be seen in Figure 3, cotton has the highest NRC value even though cotton has the lowest porosity value. In contrast, polyester has the lowest NRC value, but the porosity value is the highest. The results show that the fibre density and porosity value influence the quality of the sound absorption coefficient of fabrics.

6. CONCLUSION

The research objectives in identifying the potential of recycled fabrics as an acoustic panel are achieved. Fabric waste has the potential to be developed as an acoustic panel. It has the essential function of an acoustic panel to improve the quality of a sound in a space. Most sound is absorbed by the materials which reduce the reflected sound that can cause noise. The existing porosity structure of the fabric helps to absorb the sound. This confirms that fabrics represent a valid option for an acoustic panel. The results obtained have answered the research questions. All five types of fabrics can be a substitute for conventional materials for acoustic panels. The structures of the fabric, fibre density, porosity, and types of fabrics have a very significant influence on its acoustical properties. Fabric too is confirmed by Moholkar & Warmoeskerken (2003), that the properties or composition of fabrics provides better acoustic and improvement as it has small air spaces similar to air pores.

Different types of fabrics produced a different range of NRC. This is because every type of fabric has a different density. Density is one of the major factors that can contribute to sound absorption efficiency. The types of fabrics needed to be chosen correctly according to their usage. If space is at high frequency, it is best to choose higher NRC value materials. However, low NRC materials have their benefits too. It can help reduce noise for space with low frequency. Cotton material shows a better sound-absorbing property compared to other materials. Cotton has the best capacity to absorb sound due to its number of pores present in the material.

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