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EVALUATING THE NOISE ABSORPTION PERFORMANCE OF ACOUSTIC PANELS MADE OF SOLID WASTES

Nijhum Afrin*[1], Ganesh Chandra Saha[1], H. M. Imran[2] , Shalah Uddin Ahmed[1] and H. M. Anwar[1]

[1]Department of Civil Engineering, Dhaka University of Engineering & Technology, Gazipur-1707, Bangladesh
[2]Institute of Water and Environment, Dhaka University of Engineering & Technology, Gazipur-1707, Bangladesh

***Corresponding Author**

ABSTRACT

Noise pollution and solid waste management are the most burning environmental issues worldwide particularly in developing countries. Inefficient management and disposal system of solid waste are obvious causes of environmental pollution in most megacities. Not only solid waste but also the noise pollution caused by machines, vehicles, and industries are liable for environmental degradation. Therefore, the aim of this research is to investigate the potential of turning solid wastes into acoustic panels for using as noise absorbers in reducing noise and providing a sustainable solution for solid waste management. Four locally available solid waste materials such as poultry feathers (PF), jute fiber (JF), tea leaves (TL) and human hair (HH) wastes are used to make acoustic panels for absorbing noise in which polyester resin is used as a binder. The noise drops are 11.68, 9.42, 9.18 and 10.77 dB for JF, TL, PF and HH panels respectively. The physical properties such as tensile strength and core shear strength of these panels are also investigated. The results show that tensile strength and the core shear strength of these panels are 22.17 MPa and 52.98MPa for JF, 6.35 MPa and 31.94MPa for PF, 10.16 MPa and 45.79 MPa for HH, 8.53 MPa and 21.41 MPa for TL wastes panels respectively. It can be concluded that the acoustic panel made of JF waste shows the maximum noise absorption capacity with higher tensile and core shear strength as compared to ther panels. All other panels also show satisfactory performance in absorbing noise at different magnitudes.

Keywords: *Noise pollution, Solid waste, Acoustic panels, Sound absorption.*

1. INTRODUCTION

Noise is generally unwanted sound which is caused by machines, transportation systems, engines and aircrafts (Bratu et al., 2011). Noise breaks concentration in works, disturbances in sleep, interferences in speech etc. Increased uses of mechanical and electrical appliances are influencing the noise pollution at homes and industries (Rimantho et al., 2019). Therefore, noise control is an important issue in assuring acoustically pleasant environment for human beings. Achieving a pleasing environment, sound absorbent materials are used within rooms and enclosed working areas to reduce the noise intensity. Thin, lightweight and low-cost materials which absorb sound in wider frequency are strongly desired (Ersoy & Küçük, 2009). Conventional materials such as glass fibers, open cell foams, and acoustic tiles are often used as the sound absorbent materials (Mahzan et a., 2009; Zulkifli et al., 2010). Recently, several investigations have been carried out considering natural mineral as the filler material of the sound absorbent such as wood, rubber and tea leaves (Ersoy & Küçük, 2009; Mohanty & Fatima, 2015; Wong et al., 2017; Yang et al., 2003). Natural fibers have many advantages as compared to the synthetic fibers, for example low weight, low density, low cost, acceptable specific properties and recyclable (Mahzan et al., 2009; Malawade & Mahamuni, 2018). One of the most important issues in developing noise reduction materials is the use of various solid waste materials. The use of composite noise absorber panels made of solid waste materials in reducing noise have two major advantages; namely noise control at low production cost and sustainable solid waste management. Bangladesh is facing serious environmental degradation and public-health risk due to the disposal of solid wastes on streets and other public areas, and contamination of water resources by uncontrolled dumping sites. The drainage system also clogged by indiscriminately dumped wastes. Manufacturing of noise aborsoption panels by using solid wastes will not only provide a solution in reducing noise pollution but also will help to develop a solid wastes management system.

Therefore, the present study aims to fabricate noise absorbing panels by using solid waste materials bonded together with polystyrene and hardener. In addition, the study also investigates the acoustical and physical properties of the noise absorbing panels, and evaluates the performance of the panels in absorbing noise.

2. METHODOLOGY

2.1 Experimental design

Four specimens from the following waste materials having same size of 12 inch x 12ch in x 1/8 inch were made for investigating the acoustics and physical properties of the specimens. Table 1 shows the proportioning of the materials in preparing four different sound absorption panels (specimens) by using different solid waste materials.

Table 1 Proportions of different materials in preparing different sound absoption panels

Specimen	Name of Materials	Percentage by Volume
JF Panel (Jute fiber composite)	Waste jute fiber	58
	Polyester resin	21
	Hardener (Methyl Ethyl Ketone Peroxide)	01
TL Panel (Tea leaves composite)	Waste tea leaves	65
	Polyester resin	34
	Hardener (Methyl Ethyl Ketone Peroxide)	01
PF Panel (Poultry feather Composite)	Poultry feather waste	61
	Polyester resin	38
	Hardener (Methyl Ethyl Ketone Peroxide)	01
HH Panel (Human hair Composite)	Human hair waste	63
	Polyester resin	36
	Hardener (Methyl Ethyl Ketone Peroxide)	01

2.2 Preparation of the panels:

The following steps are followed to fabricate the sound absorption panels from the composition of different solid waste materials:

- Specified solid waste materials were dried after the collection and then cleaned to remove other unwantaed waste materials.
- After measuring and proportioning according to Table 1, materials were mixed and placed in the formwork.
- Casted materials were compacted properly and formworks were removed after 24 hours.
- The panels were joined together to make boxes for conducting the tests.

Jute Fiber — Poultry Feathers — Human Hair — Tea Leaves

Figure 1: Various types of solid waste materials

2.3 Experimental procedures for investigating acoustics properties

2.3.1 Sound absorption and noise reduction coefficient

Firstly, the performance of the four noise absorber panels is measured in terms of sound abosorption and noise reduction coefficients. The absorption coefficient denoted by α is defined as the ratio of energy absorbed by a material to the energy incident upon its surface. The variations of sound absorption coefficients for every panel were investigated at different frequencies of 125, 250, 500, 1000, 2000, and 4000 Hz following the ISO 10534-2 standard (International Organization for Standardization, 1998). Furthermore, the Noise Reduction Coefficient (NRC) is defined as the amount of sound energy absorbed upon striking a particular surface. The NRC was the average value of the absorption coefficient of the material, which was investigated at the frequencies of 250, 500, 1000, and 2000 Hz. It was rounded off to the nearest multiple of 0.05. An NRC of 0 indicates perfect reflection and an NRC of 1 indicates perfect absorption. The following steps were followed to determine the sound absorption coefficient and noise reduction coefficient of the four absorption panels:

1. Speaker was turned on and sound frequencies of 125, 250, 500, 1000, 2000, and 4000 Hz were generated.
2. The incident sound and absorbed sound were recorded without and with putting the composite noise absorber panels into the sound-tight glass box respectively for all frequencies.
3. The sound absorption coefficient was calculated by decibel drop which was calculated from the incident sound and absorbed sound.
4. Noise reduction coefficients were calculated from the sound absorption coefficient at the frequencies of 250, 500, 1000, and 2000 Hz.

Figure 2: Acoustic properties test of Composite panels

2.4 Experimental procedures for investigating physical properties:

2.4.1 Tensile strength test and three point bending test

A central region called the gauge length is expected to failure and two end regions are clamped into a grip mechanism connected to a test machine. This test specimen can be used for tensile and core shear stress test. Tensile strength tests of these composite panels are performed in IEE Lab of the University (DUET). Tensile test technique, ASTM D 3039M-17 and three point bending test technique ASTM C 393-00 at a speed of 3 mm/min were used to determine the tensile strength and the core shear stress (American Society for Testing and Materials, 2000, 2017).Three samples of each specimen were tested, and force versus stroke values were recorded.

3. RESULTS AND DISCUSSION

3.1 Acoustic properties of composite panels

3.1.1 Sound absorption coefficient (α)

Figure 1 shows the variations in sound absorption coefficients for different panels. The results show that all the sound absorption coefficients are increased with the increasing the sound frequency upto 2000 Hz and then the coefficients are slightly decreased with the increasing sound frequencies from 2100 to 4000 Hz . The absorption coefficients are higher for the panel made of waste jute fibre as compared to the other panels. Furthermore, Figure 1 shows that jute fibre composite panel shows the better performance in absorbing more noise while poultry feather composite panel shows the lowest performance. The tea leaves composite panel and human hair composite panel show nearly similar performance in reducing the noise level.

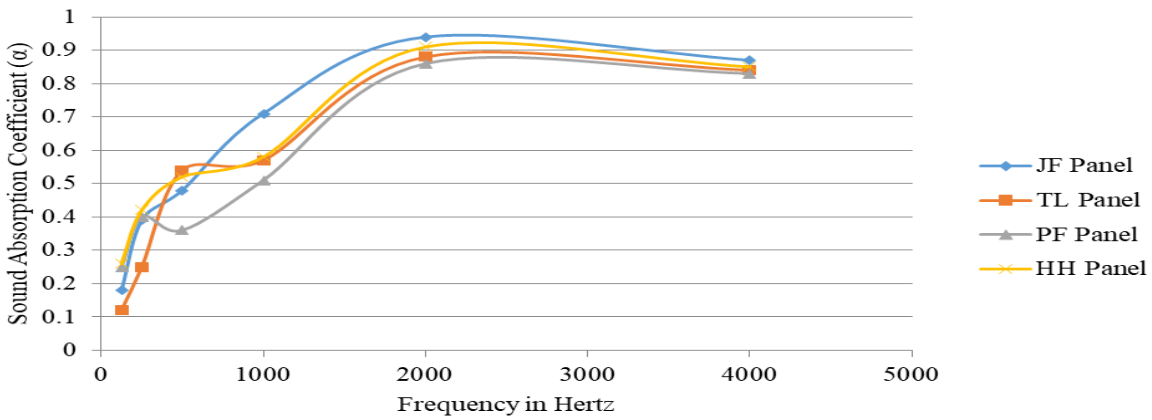

Figure 1. Variations in sound absorption coefficients at different frequencies

3.1.2 Noise Reduction Coefficient (NRC)

Figure 2 shows the values of noise reduction coefficients for all composite noise absorber panels. The higher the NRC values, the higher the noise reduction capacity. The results show that the highest NRC value (0.65) is obtained for the panel made of waste jute fiber and the lowest value (0.50) is obtained for the poultry feathers composite panel. The panels made of waste tea leaves and human hair waste show same NRC value 0.55.

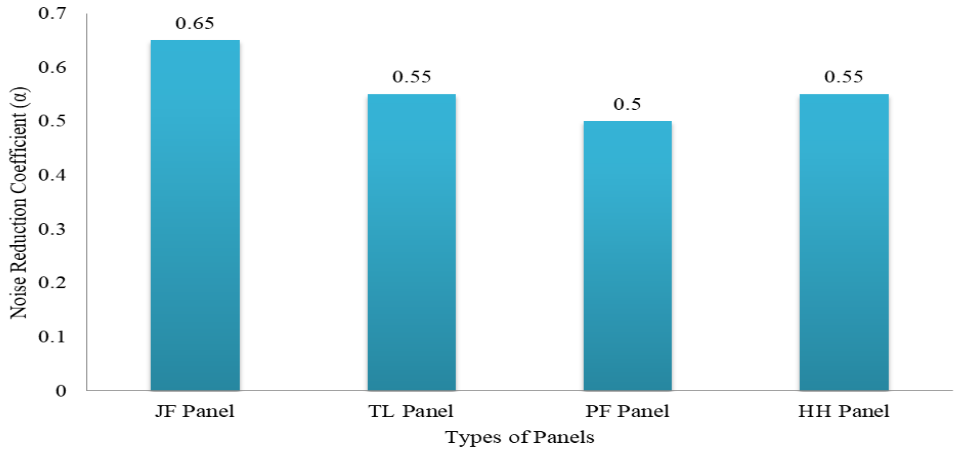

Figure 2. Variations in noise reduction coefficients

The variations in noise drop at dB scale against different frequencies are shown in Figure 3. The drop of noise levels for all panels upto the frequency 1000 Hz is negligible while the drop is remarkable at frequencies from 1000 to 2000 Hz. Maximum noise drop for all panels occurs at frequency nearly 2200 Hz. The jute fiber composite panel drops the maximum noise level 11.68 dB. Both the Tea leaves and poultry feather composite panels drop noise level 9.4 dB, and tea leaves composite panel drops noise level 10.77 dB.

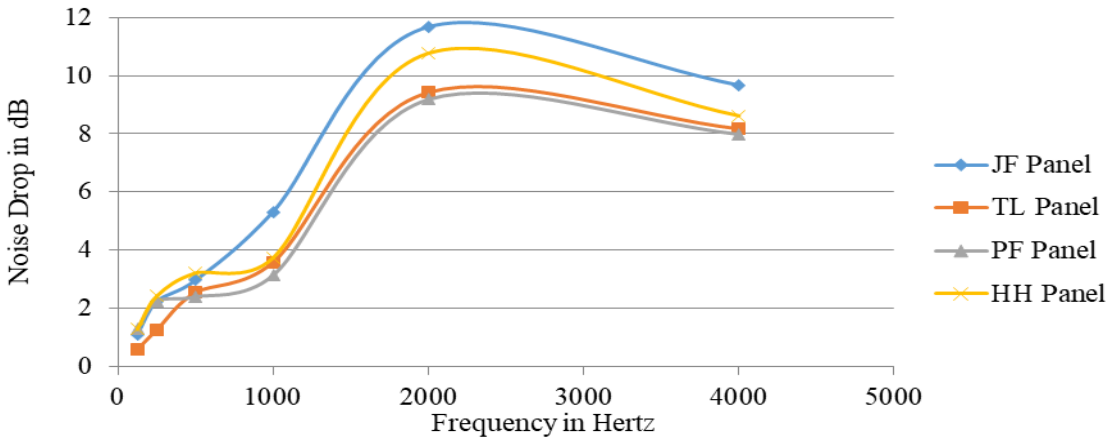

Figure 3. Variations in noise level drop for the four panels

3.2 Physical properties of composite samples

3.2.1 Tensile strength of composite samples

Figure 4 shows the graphical representation of the tensile strength of all sound absorber composite panels. The maximum tensile strength 22.17 MPa is obtained for waste jute fiber composite panel and the minimum tensile strength 6.35 MPa is found for poultry feathers composite panel. The jute fibre composite panel shows higher tensile strength as compared to the other panels.

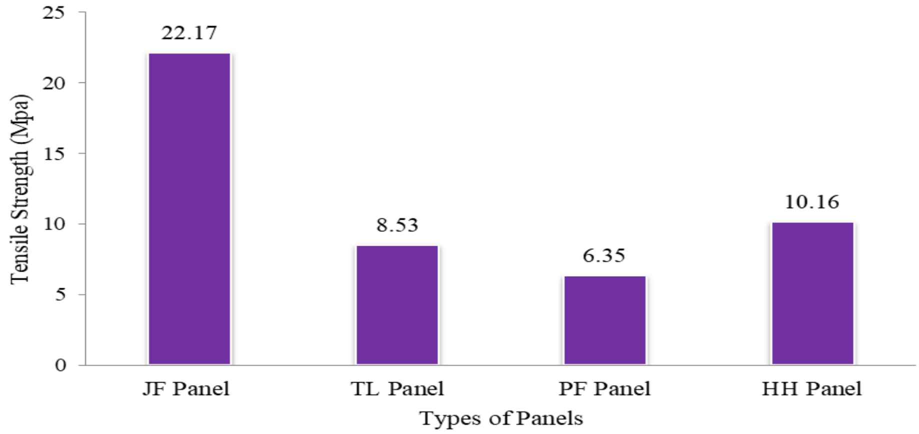

Figure 4. Tensile strength for the four panels

3.2.2 Three point bending test of composite panels

The graphical representation of the core shear stress (τ) of the composite panels is shown in Figure 5. Results represent that the maximum and minimum core shear stress are 52.98 Mpa and 21.41 Mpa for jute fiber composite panel and tea leaves composite panel respectively. The jute fibre and human hair composite panels results higher (~30 -20 Mpa) core share strength as compared to tea leaves and poultry feathers composite panels.

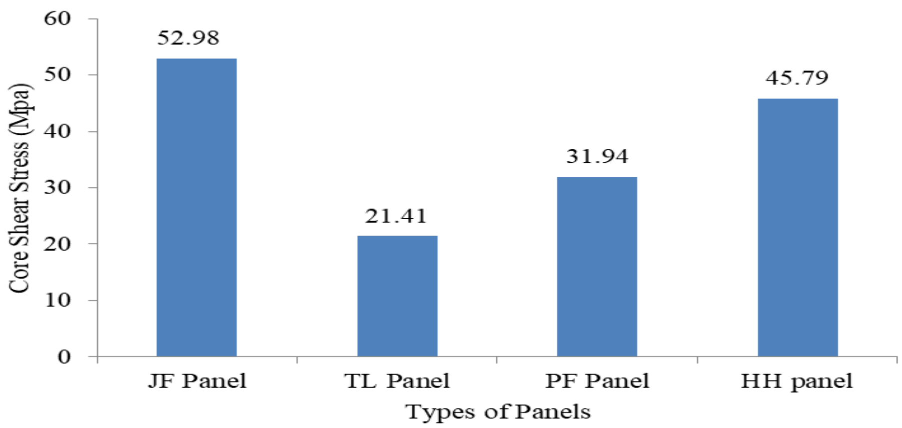

Figure 5. Core shear stress (τ) for the four panels

4. CONCLUSIONS

In this study, the diffuse sound absorption coefficients and physical properties of different noise absorption panels, fabricated by various types of solid waste materials such as jute fibre, poultry feathers, used tea leaves and human hair waste, have been investigated. The sound absorption coefficients have been determined based on the sound absorption capacity at specified frequencies of 125, 250, 500, 1000, 2000 and 4000 Hz. The physical properties such as tensile strength and cores shear strength have also been conducted. The study has shown that the average sound absorption coefficient at specified frequency (e.g., 125 Hz, 250 Hz, 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz) for all panels made of jute fibre, waste tea leaves, poultry feathers, human hair waste are ranged from 0.12 to 0.92 while the noise level drops ranged from 1 to 12 dB. Tensile strengths are 22.17 MPa, 8.53MPa, 6.35 MPa and 10.16 MPa for the panels made of jute fiber, waste tea leaves, poultry feathers, and human hair waste respectively while the core shear strengths are 52.98 Mpa, 21.41 Mpa, 31.94 Mpa and 45.79 MPa for the same panels respectively. The important finding of this study is that the jute fibre composite panel shows better performance in absorbing more noise. In addition, the jute fibre composite panel shows higher tensile and shear strength as compared to other panels. The jute fibre composite panel might be used as noise absorber in wall, ceiling and floor. All other panels also show satisfactory performance and the possible application of all these panels might be in decorative works.

In this study, the four composite noise absorption panels are fabricated manually. If the composite panels are fabricated by an automatic machine, then there is a good possibility to get more accurate results because it is too difficult to made uniform cross section in manual process. Furthermore, sound absorption coefficient depends on the roughness of the surface. Therefore, the surface roughness of these composite panels can be investigated in future studies.

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