INVESTIGATING THE EFFECTIVENESS OF RECYCLED MATERIAL LAYERS: AN ALTERNATIVE FOR ROOM ACOUSTICS

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ABSTRACT: *Recycling is beneficial for the environment as it repurposes old and discarded items, conserves resources, and reduces air and water pollution by sending less waste to landfills. On the other hand, noise pollution is a significant environmental concern affecting many people through various sources, leading to hearing loss in extreme cases. Noise and echo treatment play a crucial role in enhancing the sound quality of a space, and sound-absorbing materials can help improve acoustic clarity where needed. This study examined alternative recycled material layers as a novel approach to reducing domestic acoustic noise. The prototype consists of four layers: egg tile, coconut coir, fabric cutting waste, and an additional egg tile layer. The traditional noise reduction material is a single egg tray, so this study experimented with adding extra layers of recycled materials to the prototype. The researchers used Decibel X, an Android/iOS-compatible app, to measure the decibel levels in a household room. Three recordings were made for comparison purposes: a room in normal condition, a room with a single-layer sound absorption material, and a room with an innovative sound absorption material. The results from the three different setups were compared, revealing a notable improvement in acoustic performance when using the innovative, multi-layered recycled material instead of the traditional single egg tile/tray. The data and calculations provide evidence of enhanced acoustics in a household room, as measured by the reliable Decibel X app.*

Keywords: recycling, effectiveness, acoustics, noise pollution, environment, novel

1. INTRODUCTION

In recent years, there has been a growing global emphasis on environmental sustainability and resource conservation[1]. This focus has led to increased interest in exploring alternative materials for various applications, including those in the construction and design industries. One such application is room acoustics, where materials play a crucial role in determining the acoustic performance of a space. Traditionally, non-renewable materials such as fiberglass, mineral wool, and synthetic foams have been employed for acoustic treatment[2]. However, these materials pose concerns regarding their environmental impact, resource depletion, and waste generation. Consequently, there is an urgent need to investigate the potential of using recycled materials as an environmentally friendly and sustainable alternative for room acoustics.

The primary objective of this study, titled "Investigating the Effectiveness of Recycled Material layers: An Alternative for Room Acoustics," is to explore the feasibility and effectiveness of using recycled material layers for acoustic treatment in rooms. Several researchers [3]; [4]) have succeeded in developing particle composite boards using agricultural wastes. [5] produced rice straw-wood particle composite boards which properties are to absorb noise, preserve the temperature of indoor living spaces and to be able to partially or completely substitute for wood particleboard and insulation board in wooden construction. The research aims to provide insight into the acoustic properties of various recycled materials, such as paper, textiles, and plastics, in comparison to conventional materials. Furthermore, this study seeks to identify potential combinations and configurations of recycled material layers that could achieve optimal acoustic performance while minimizing environmental impact.

By undertaking this research, we hope to contribute to the development of sustainable and eco-friendly solutions for room acoustics, which could have wide-ranging implications in the fields of architecture, interior design, and construction. Moreover, the findings of this study have the potential to promote the use of recycled materials, thereby supporting waste reduction, resource conservation, and environmental sustainability objectives. Ultimately, this research can pave the way for creating healthier and more sustainable living and working environments for future generations.

2. MATERIALS AND METHODS

2.1 Material Selection

The first step in this study was to select appropriate recycled materials for acoustic treatment. Four materials were chosen based on their availability, potential acoustic properties, and environmental benefits: egg tile, coconut coir, fabric cutting waste, and an additional egg tile layer shown in Figure 1 below. These materials were sourced locally to minimize transportation emissions and support the local recycling industry.

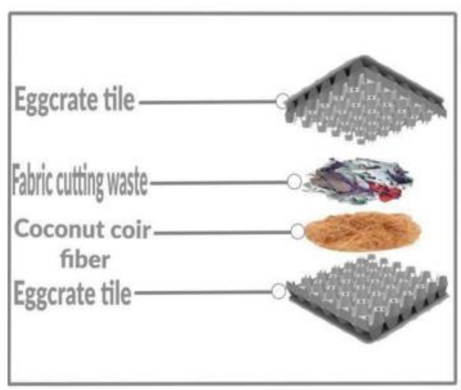

Figure 1 – Material Selection

2.2 Prototype Development

A multi-layered acoustic panel prototype was developed using the selected recycled materials. The panel consisted of the following layers (from outer to inner): egg tile, coconut coir, fabric cutting waste, and another layer of egg tile. These layers were assembled using an eco-friendly adhesive to ensure structural stability and minimal environmental impact. The thickness and dimensions of the prototype were standardized to allow for accurate comparisons with conventional materials.

Figure 2 – Multi-Layered Acoustic Panel

2.3 Acoustic Measurement

To evaluate the acoustic performance of the prototype, a household room was chosen as the test site. The Decibel X app, compatible with Android and iOS devices, was used to measure the decibel levels in the room. A calibrated speaker was placed at a fixed distance from the prototype, and a consistent sound frequency was used throughout the experiments.

Figure 3 – Decibel X App Pro

2.4 Experimental Setup

Three different room setups were compared to assess the effectiveness of the recycled material layers:

a) Room in normal condition (without any acoustic treatment)

b) Room with conventional single-layer sound absorption material (e.g., a single egg tray)

c) Room with the innovative sound absorption material (recycled material prototype)

For each setup, the sound levels were measured at multiple locations within the room to account for spatial variations in acoustic performance. Measurements were taken before and after the introduction of the sound absorption materials to evaluate their impact on room acoustics.

2.5 Data Analysis

The decibel readings obtained from the Decibel X app were compiled and analyzed using statistical methods to determine the effectiveness of the recycled material layers in comparison to the conventional single-layer material. A paired t-test was conducted to evaluate the statistical significance of the observed differences in sound levels between the three-room setups.

2.6 Replication and Validation

To ensure the reliability and validity of the results, the experiments were replicated multiple times using different rooms and sound sources. This process allowed for the identification of potential variations in acoustic performance due to room size, shape, and other factors. The results were then compared to existing literature on recycled materials for acoustic treatment to validate the findings.

3. RESULTS AND DISCUSSION

The analysis of the decibel readings obtained from the Decibel X app revealed notable differences in sound levels between the three-room setups. The findings can be summarized as follows:

1. The room in normal condition (without any acoustic treatment) exhibited the highest sound levels, indicating poor acoustic performance and high levels of noise reverberation. Table shows acoustic simulation results of an over-all average decibel of 97.2 dB with the average minimum 81.9 dB, however the highest recorded decibel reached at 104 dB. Based on the standard acceptable noise level of human hearing, this sound level will result negative effects to a person's hearing.

Table 1- Acoustic Simulation results under NORMAL

Time (insec)	Number of Trials Attempted (db-A)															
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	14th	15th	Ave.
0.6	101.2	101.6	101.0	101.5	101.7	101.5	101.3	102.6	102.0	101.8	100.8	101.0	102.1	101.9	101.6	101.6
1.2	102.1	100.9	101.7	98.4	100.3	99.0	98.0	102.3	101.2	101.4	101.9	99.1	102.0	100.4	99.2	100.5
1.8	99.7	98.0	99.2	96.9	97.7	97.7	97.0	99.5	98.3	97.9	99.9	96.1	98.8	97.5	96.4	98.0
2.4	98.0	98.3	97.7	98.1	100.7	98.0	98.5	99.0	101.6	97.4	98.2	98.1	98.4	97.8	97.9	98.5
3.0	103.6	104.5	103.8	103.4	99.2	104.3	103.3	103.5	99.2	104.5	103.7	102.8	103.7	104.5	103.8	103.2
3.6	103.6	99.3	103.5	99.0	99.9	98.5	99.2	103.1	100.1	102.0	104.1	100.7	103.8	99.8	99.2	101.1
4.2	100.8	99.1	100.6	97.9	89.2	99.1	97.5	99.3	91.3	101.3	101.0	95.5	99.6	98.8	95.8	97.8
4.8	82.3	87.3	84.6	87.0	88.2	86.6	87.2	85.1	86.2	80.8	82.2	86.2	85.3	85.3	86.4	85.4
5.4	88.6	88.3	89.4	90.7	84.9	87.2	89.3	87.8	86.4	89.1	88.7	88.0	88.8	87.3	88.1	88.2
6.0	82.6	80.2	84.9	80.5	86.5	80.8	80.7	84.7	87.3	82.8	83.9	80.7	83.8	80.3	78.6	82.6
6.6	89.2	91.0	87.0	90.6	89.4	91.4	91.7	88.2	89.3	90.3	87.4	90.6	87.3	90.8	90.5	89.6
7.2	89.0	90.5	89.3	89.2	8.3	90.0	91.0	89.3	88.7	89.6	89.1	89.9	89.3	90.0	90.0	89.3
7.8	82.7	79.7	85.3	80.1	82.1	80.5	79.3	87.3	79.9	82.4	86.1	81.6	86.2	80.5	80.7	82.3
8.4	88.0	98.8	81.4	100.9	101.4	97.2	95.5	80.8	102.0	89.7	82.2	93.0	80.3	96.8	96.8	92.3
9.0	98.8	101.4	102.6	99.7	101.2	100.5	100.3	102.1	98.8	98.3	102.1	99.8	102.2	100.1	100.5	100.6
9.6	102.6	100.9	101.4	100.8	100.9	99.8	99.9	99.0	100.5	102.0	100.5	99.0	100.4	99.3	99.8	100.5
10.2	101.6	101.7	100.2	101.6	101.8	100.9	100.1	100.3	101.4	104.7	100.8	101.6	100.4	101.2	103.5	101.5
10.8	102.0	102.1	101.0	100.6	102.7	102.6	103.4	101.8	99.0	103.8	100.3	103.4	100.9	102.5	103.8	102.0
11.4	102.1	101.7	101.5	101.5	101.0	100.2	99.2	99.2	99.2	101.8	100.6	99.8	100.2	100.0	100.0	100.5
12.0	101.3	99.7	98.5	100.2	99.6	98.5	98.5	100.3	99.5	101.9	99.2	100.3	99.1	99.5	99.5	99.7
12.6	99.7	101.3	99.5	100.5	100.9	100.7	100.5	99.9	101.3	101.1	100.1	100.9	99.8	102.1	101.7	100.7
13.2	99.6	101.5	102.4	100.5	104.0	100.7	100.0	100.2	100.8	98.7	99.9	99.1	99.8	98.7	99.5	100.4
13.8	102.4	89.6	101.6	88.3	90.3	86.5	86.1	100.6	87.6	102.3	100.4	101.6	100.6	100.4	90.8	95.3
14.4	94.4	91.4	88.2	89.4	94.5	90.3	91.7	86.8	92.9	94.5	88.4	94.4	88.1	94.7	92.8	91.5
15.0	90.3	93.6	93.5	93.9	94.2	94.2	94.6	91.9	91.2	90.8	90.3	88.5	89.7	88.4	91.9	91.8
15.6	95.3	98.7	92.6	98.6	97.7	97.7	97.3	92.8	98.2	94.5	92.7	94.6	92.7	96.1	94.5	95.6
16.2	97.8	102.3	99.6	100.1	102.9	100.5	98.9	97.4	100.5	98.7	97.0	98.3	97.7	97.6	98.5	99.2
16.8	103.2	105.9	101.3	104.0	105.8	104.6	102.4	99.9	103.6	102.9	99.9	103.2	99.6	103.4	103.4	102.9
17.4	103.0	103.6	105.0	103.8	103.6	103.1	103.9	103.6	101.8	104.5	104.1	104.2	104.4	103.2	104.6	103.8
18.0	101.8	101.1	103.7	100.9	100.6	99.8	100.4	103.4	99.0	100.6	103.4	101.8	103.9	102.4	102.6	101.7
18.6	99.8	99.0	100.8	99.4	99.7	98.8	98.1	100.0	98.4	100.0	100.5	98.8	100.6	99.4	99.5	99.5
19.2	101.3	104.7	99.3	104.4	104.6	104.1	103.9	98.0	104.4	102.0	98.2	103.2	98.2	100.5	102.4	101.9
19.8	101.7	101.7	105.3	100.7	100.2	100.9	100.6	103.6	99.7	101.3	103.9	100.0	103.4	101.8	101.3	101.7

CONDITION

Minimum recorded value = 81.9 dB

Maximum recorded vale= 104 dB

Over- all Average = 97.2 dB

2. The room with conventional single-layer sound absorption material (e.g., a single egg tray) showed a moderate reduction in sound levels compared to the untreated room. Table 3 illustrates that the average decibel level for the acoustics simulation is 84.6, with a minimum average of 72.5 decibels and a maximum recorded decibel level of 90.7. Notably, there is a considerable impact when using a single-layer eggcrate tile

for the Sound Acoustics Panel. Based on the standard acceptable noise levels, this falls just below the harmful range, meaning it is unlikely to cause significant harm to an individual's hearing. However, it is crucial to note that this is near the borderline of acceptable environmental noise levels.

3. The room with the innovative sound absorption material (recycled material prototype) displayed the lowest sound levels, with a significant improvement in acoustic performance over both the untreated room and the room with conventional single-layer material.

The paired t-test results indicated that the observed differences in sound levels between the room setups were statistically significant ($p < 0.05$). Furthermore, the repeated experiments conducted in different rooms and with various sound sources confirmed the consistency of these findings.

The results of this study suggest that the innovative recycled material prototype is effective in improving room acoustics compared to conventional single-layer materials. The multi-layered structure of the prototype, which combines egg tile, coconut coir, and fabric cutting waste, appears to enhance sound absorption and reduce noise reverberation more efficiently than a single egg tray.

Table 2- Acoustic Simulation results with ONE LAYER EGG CRATE TILE

Time (in sec)	Number of Trials Attempted (db-A)															
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	14th	15th	Ave
0.6	86.1	88.0	82.6	89.1	86.2	88.5	85.7	87.4	86.2	88.9	86.2	86.1	90.4	88.0	89.1	85.2
1.2	86.7	87.4	83.9	85.6	87.2	86.8	88.8	87.6	87.2	88.0	86.8	86.6	85.7	86.9	86.1	84.8
1.8	84.5	88.2	85.1	88.3	84.6	85.9	86.8	86.8	86.9	87.1	86.3	88.1	88.9	83.7	88.2	84.6
2.4	82.7	82.9	88.3	87.0	82.2	83.7	84.0	85.2	83.9	83.7	83.7	85.3	84.5	82.9	84.1	82.3
3.0	85.3	86.1	87.4	84.5	84.5	84.5	82.6	84.8	81.9	84.7	82.6	85.1	85.1	84.9	84.4	82.6
3.6	89.4	86.7	87.9	88.6	87.1	88.5	85.1	89.8	84.2	88.1	83.8	83.0	91.4	87.3	90.3	85.4
4.2	90.0	86.1	84.3	88.0	90.0	89.2	90.1	90.5	90.2	90.1	90.7	87.1	89.1	90.5	90.2	87.1
4.8	76.1	76.1	85.8	84.8	79.2	82.4	87.8	87.2	88.3	79.3	86.9	75.8	86.4	75.0	85.8	80.5
5.4	71.3	71.1	84.6	74.4	72.9	72.7	83.8	70.9	83.1	73.0	86.4	70.6	67.9	71.8	70.3	73.0
6.0	77.0	75.1	85.2	71.2	75.3	74.3	70.0	73.1	71.6	72.2	66.2	74.0	65.7	76.0	72.2	71.3
6.6	62.0	67.1	75.8	75.2	65.7	67.8	67.4	72.8	73.9	66.8	70.3	71.1	68.5	64.7	72.3	67.4
7.2	74.3	72.0	71.0	70.3	77.9	77.9	69.0	72.4	58.0	76.2	70.1	70.8	77.6	74.4	71.2	70.2
7.8	71.7	70.0	74.4	70.7	69.8	69.5	75.8	74.2	75.8	74.3	73.8	71.3	71.0	73.9	74.6	70.7
8.4	64.3	62.6	63.9	70.6	65.4	65.3	73.8	67.3	73.6	65.2	75.0	63.7	65.5	62.6	66.4	65.0
9.0	85.8	87.8	72.3	63.6	76.3	74.3	66.8	67.4	62.3	76.2	68.7	88.8	75.3	86.4	65.5	72.5
9.6	85.7	86.0	70.3	88.8	86.5	85.5	71.0	89.6	80.4	85.4	68.9	84.3	87.7	86.4	88.9	81.0
10.2	87.1	85.7	63.9	84.1	86.0	86.0	85.2	86.5	86.7	86.3	86.3	86.3	88.4	87.2	86.1	82.8
10.8	86.5	87.4	86.6	86.7	87.9	88.9	88.2	84.5	84.8	88.4	88.1	88.1	90.0	86.7	84.8	85.2
11.4	85.9	84.2	87.1	87.7	89.9	89.9	88.2	86.2	87.2	89.7	88.9	86.1	91.6	85.1	86.8	85.6
12.0	87.2	86.4	87.6	85.0	85.5	85.1	88.6	86.4	89.1	86.6	87.8	86.6	85.6	87.0	87.2	84.8
12.6	86.4	86.2	87.4	87.6	88.2	86.8	88.1	87.0	85.8	86.8	87.9	85.0	86.7	86.6	86.8	84.9
13.2	86.0	88.4	84.8	85.7	89.2	89.8	87.5	86.0	86.3	89.3	86.2	88.8	87.7	86.1	86.1	85.2
13.8	87.8	89.0	88.9	86.4	86.0	85.6	85.3	85.7	86.7	86.2	85.2	89.2	86.7	87.5	89.1	85.0
14.4	74.7	74.4	87.7	87.0	89.5	85.6	88.1	87.1	85.9	86.3	88.9	71.8	76.5	76.6	89.4	81.3
15.0	75.7	77.8	85.1	76.8	76.9	79.8	90.9	76.1	77.8	82.2	89.0	77.6	76.0	72.6	75.0	77.3
15.6	75.0	77.1	87.8	78.7	77.8	75.8	71.4	73.8	81.0	71.5	74.6	76.5	77.9	77.9	77.3	74.9
16.2	79.9	81.7	77.6	78.1	80.0	79.6	79.6	77.1	73.9	79.4	76.1	80.5	82.1	81.9	76.4	76.9
16.8	87.6	89.2	76.7	79.0	81.4	84.2	76.7	81.5	79.1	83.8	75.9	86.6	84.2	85.0	80.2	80.1
17.4	87.6	90.7	77.8	83.7	87.4	86.2	79.8	83.8	84.4	86.2	81.7	87.5	86.6	87.9	88.2	83.3

RECYCLED MATERIALS
Minimum recorded value = 72.5 dB
Maximum recorded vale= 90.7 dB
Over- all Average = 72.5 dB

The superior acoustic performance of the recycled material prototype may be attributed to the synergistic effect of the different layers, each contributing to sound attenuation in

Table 3- Acoustic Simulation results with MIXED
Minimum recorded value = 72.5 dB
Maximum recorded vale= 90.7 dB
Over- all Average = 72.5 dB

Time (in sec)	Number of Trials Attempted (db-A)															
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	14th	15th	Ave
0.6	87.4	87.7	88.6	87.7	86.7	89.1	87.2	87.3	86.9	86.0	87.9	86.6	87.7	88.4	89.9	87.7
1.2	87.9	86.3	89.2	90.2	87.2	90.1	88.5	90.2	87.3	87.5	89.4	90.0	86.7	85.1	89.7	88.4
1.8	89.8	89.5	88.6	89.6	89.0	88.8	85.4	89.4	88.7	85.8	88.8	89.2	90.5	90.5	85.7	88.6
2.4	88.9	87.2	85.3	85.7	88.0	86.3	84.3	85.4	85.8	84.1	86.6	86.4	88.9	89.1	84.2	86.4
3.0	85.4	84.9	87.2	86.3	84.7	86.1	86.6	88.5	82.9	85.6	86.3	89.9	85.0	85.5	93.0	86.5
3.6	87.8	85.0	83.1	88.8	86.0	92.2	87.9	83.2	85.4	91.8	92.8	91.0	88.4	88.0	86.5	87.9
4.2	84.3	93.0	87.4	90.0	92.5	91.3	88.9	88.1	92.8	85.5	91.1	89.7	83.2	81.5	86.0	88.4
4.8	86.7	86.4	75.2	77.6	85.5	91.1	76.6	76.6	89.1	86.3	90.3	74.0	87.9	89.1	70.6	82.9
5.4	73.0	87.6	74.9	75.1	88.0	69.6	75.8	75.9	91.7	68.7	72.1	76.9	77.2	76.6	73.5	77.1
6.0	75.3	70.2	76.8	77.3	69.3	73.8	78.2	77.8	68.2	72.8	76.6	70.9	76.1	76.3	67.0	73.8
6.6	75.6	74.2	69.0	65.8	69.1	69.4	63.6	72.7	76.1	67.1	72.5	80.6	78.8	78.1	80.1	72.8
7.2	73.0	69.9	78.3	80.1	69.9	79.8	78.8	75.3	69.8	80.7	75.3	77.8	63.8	64.1	77.2	74.3
7.8	75.2	79.1	77.0	75.9	80.1	77.2	77.3	76.5	77.2	77.0	76.5	70.7	79.1	79.2	67.1	76.3
8.4	72.1	80.4	67.6	70.5	76.5	69.6	67.1	65.2	76.6	66.8	71.8	72.0	76.8	77.2	78.8	72.6
9.0	65.2	75.7	87.0	73.6	70.1	74.3	79.7	88.9	73.9	79.6	69.0	87.4	66.5	66.5	88.3	76.4
9.6	89.8	68.4	87.3	87.5	71.4	87.0	88.6	86.5	67.3	88.5	88.1	89.0	86.1	85.5	88.1	83.9
10.2	87.8	88.8	88.6	89.2	88.1	89.2	87.9	88.3	89.9	88.0	89.5	90.4	87.4	87.4	89.6	88.7
10.8	86.5	90.0	89.1	90.5	90.1	91.5	89.2	89.4	89.7	88.0	88.1	91.7	89.1	88.4	90.7	89.5
11.4	88.8	88.3	87.5	91.7	89.4	91.5	91.3	87.3	88.7	91.0	90.1	86.9	89.2	88.7	87.4	89.2
12.0	88.8	90.5	87.8	86.7	89.7	87.5	86.8	87.5	90.3	87.0	89.4	87.7	88.7	89.5	85.8	88.2
12.6	87.2	90.7	85.8	87.9	90.3	87.9	85.5	88.1	90.2	86.6	87.3	89.4	88.6	87.7	86.7	88.0
13.2	86.5	89.6	87.5	89.2	87.2	89.7	90.1	89.2	86.3	88.8	85.5	84.8	87.3	86.8	87.1	87.7
13.8	90.6	87.3	88.2	85.9	85.2	84.7	85.9	90.3	85.2	86.4	89.1	85.2	87.4	89.6	75.6	86.4
14.4	89.7	86.9	76.1	90.4	88.4	90.9	86.5	76.0	89.8	76.5	90.6	82.1	88.4	86.1	77.6	85.1
15.0	75.1	92.8	77.8	78.0	92.3	80.5	81.0	82.0	89.6	78.4	74.8	77.0	74.9	88.6	79.8	81.5
15.6	77.0	78.4	81.4	80.1	73.7	78.1	77.9	79.2	74.9	80.5	79.4	81.5	79.8	80.0	80.2	78.8
16.2	78.5	79.3	81.1	81.3	82.0	80.7	80.9	83.3	78.3	80.6	77.0	85.8	81.5	76.6	85.7	80.8
16.8	83.2	81.4	86.7	83.0	82.2	84.9	86.3	89.9	77.7	85.7	82.1	90.8	82.2	79.9	90.7	84.4
17.4	89.6	84.1	90.7	89.0	84.5	89.2	89.7	92.1	83.4	90.0	89.7	91.0	87.3	84.2	90.5	88.3
18.0	92.3	89.9	89.5	91.4	89.8	90.9	90.7	90.5	87.1	90.7	90.8	90.8	91.6	89.6	89.8	90.4
18.6	90.6	90.3	89.5	91.3	90.9	92.5	91.1	90.4	91.2	89.2	90.9	88.3	90.1	90.8	88.5	90.4
19.2	89.6	90.5	87.8	90.1	92.9	88.9	87.7	86.5	88.5	87.4	90.0	93.6	89.3	92.4	92.9	89.9
19.8	87.9	88.7	91.7	87.5	89.1	90.4	93.1	92.6	89.3	92.8	88.2	89.7	87.7	89.1	88.2	89.7
20.4	92.4	88.5	89.2	91.2	88.2	88.7	88.1	89.8	88.1	89.3	93.0	88.9	92.3	91.1	88.7	89.8
21.0	89.5	90.8	87.2	90.8	90.9	90.3	88.2	88.7	93.2	87.7	90.6	90.5	90.0	88.8	89.2	89.8

various ways. The egg tile layers provide a structured surface that diffuses and scatters sound waves, while the coconut coir and fabric cutting waste layers offer additional insulation and absorption.

This combination allows for a more effective reduction of sound transmission and reverberation within the room.

In addition to its acoustic benefits, the recycled material prototype offers several environmental advantages. By utilizing locally sourced waste materials, the prototype supports waste reduction, resource conservation, and local recycling industries. Additionally, the eco-friendly adhesive used in assembling the layers minimizes the environmental impact of the prototype.

These findings have implications for the fields of architecture, interior design, and construction, as they demonstrate the potential of using recycled materials as an alternative solution for room acoustics. Future research could explore other combinations of recycled materials and different layer configurations to optimize acoustic performance further. Additionally, long-term durability and potential cost savings associated with the use of recycled materials for acoustic treatment should be investigated to assess the practicality of implementing these solutions on a larger scale.

Table 4 presents the average noise levels in decibels, logged for every 0.6-second interval, calculated from fifteen (15) trial attempts for each setup. A noticeable decline in noise levels is observed from the initial setup to the final one, indicating an improvement in the performance of the sound acoustic panels.

Table 4- Summary of Efficiency of the Sound Absorption Panel with Simulation Result

	Ave (Normal)	Ave (One Layer)	Ave (Mixed)
Average Decibel Meter	97.2	84.6	80.6
Percentage of Noise Decibel Decrease *(Baseline is Normal Environment)*		12.96%	17.08%
Improvement Percentage			31.79%

Time (in sec)	*Summary of Simulations*		
	Ave (Normal)	*Ave (OneLayer)*	*Ave (Mixed Layer)*
0.6	101.6	88.8	85.2
1.2	100.5	88.5	84.8
1.8	98.0	86.9	84.6
2.4	98.5	86.3	82.3
3.0	103.2	88.8	82.6
3.6	101.1	89.2	85.4
4.2	97.8	86.5	87.1
4.8	85.4	78.4	80.5
5.4	88.2	73.6	73.0
6.0	82.6	72.5	71.3
6.6	89.6	74.7	67.4
7.2	89.3	75.5	70.2
7.8	82.3	73.4	70.7
8.4	92.3	73.2	65.0
9.0	100.6	82.1	72.5
9.6	100.5	88.4	81.0
10.2	101.5	88.5	82.8
10.8	102.0	89.8	85.2
11.4	100.5	89.1	85.6
12.0	99.7	87.8	84.8
12.6	100.7	87.5	84.9
13.2	100.4	88.2	85.2

Figure 4 displays the sound acoustics behavior based on the simulation data found in Table 5. The graphs clearly demonstrate that the second sound panel prototype, which utilizes mixed recycled materials, significantly reduces noise levels compared to the baseline from the standard controlled environment. Furthermore, the graph reveals that Prototype II demonstrates substantial improvement compared to Prototype I. There is a noteworthy decrease in noise levels within the controlled room, amounting to roughly 4 to 5 decibels.

Table 5 below, indicates a 31.79% improvement in noise reduction when using mixed recycled materials for the sound absorption panel, compared to the traditional single egg tile panel. This significant

enhancement demonstrates the potential of such sound acoustic panels for decreasing noise levels in a typical household room.

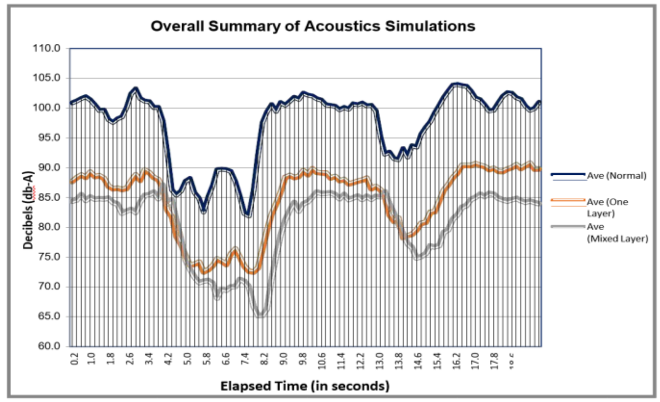

Figure 4 –Graphical Summary of Acoustic Simulation

Table 4- Summary of Efficiency of the Sound Absorption Panel in terms of Improvement Percentage

Table 5 below, presents the one-way ANOVA calculation based on the simulation data from Table 5. Given a 5% level of significance, sufficient evidence exists to reject the null hypothesis. As a result, a significant difference can be observed among the three sound absorption panel simulations.

Table 5- One- Way Anova Computation

Indicators	*Values*
$\bar{x}_3$	80.5
$\bar{x}$	87.5
d_f numerator $(k-1)$	$3-1=2$
d_f denominator $(N-k)$	$105-3=102$
$(Sum\ of\ Squares)\ SS_{Total}$	8965.3
$(Sum\ of\ Squares)\ SS_{Within}$	3720.2
$(Sum\ of\ Squares)\ SS_{Between}$	5245.2
$(Mean\ Squares)\ MS_{Between}$	2622.58
$(Mean\ Squares)\ MS_{Within}$	36.472
***F* Statistic** F_S	71.91
***F* Statistic Critical** F_{SC}	3.07

Table 6 demonstrates that the cost of using mixed alternative materials (Prototype II) is significantly lower compared to commercially available soundproofing options in the market.

Table 6- Cost Comparison of Sound Absorption Panels

Materials	Prototype I (Only Eggcrate Tile)			Prototype II (Mixed Alternative Materials)			Commercial Soundproofing
	Price (PhP)	*Qty*	*Total*	*Price (PhP)*	*Qty*	*Total*	*Price (PhP)*
Eggcrate Tile *(28.5cm x 28cm)*	2.00	324 pcs	648.00	2.00	648	1,296.00	*Acoustic Sponge Studio Foam (30cm x 30cm) at PhP 438/pack (12pcs/pack) *To cover the same area, 26packs are needed*
Coconut Coir	-	-	-	50.00/sack	1sack	50.00	
Fabric Cutting Waste	-	-	-	0.00 *(used from waste old clothes)*	20 pcs	0.00	
Used Cardboard Boxes	300/kilo	0.5 kilo	150.00	300/kilo	0.5 kilo	150.00	
Stick Glue	40.00/pack *(4 pcs per pack)*	10 packs	400.00	40.00/pack *(4 pcs per pack)*	10 packs	400.00	
Suction cups	45.00/pack *(8 pcs per pack)*	15 packs	675.00	45.00/pack *(8 pcs per pack)*	10 packs	675.00	
Overall Total			***1,873.00***			***2,571.00***	***11,388.00***

4. CONCLUSIONS

The simulations reveal a notable enhancement when updating traditional sound absorption materials like single egg tiles or egg trays. Graphs and calculations both supply scientific proof of improved acoustics in a residential room, as assessed by the dependable Decibel X mobile app. A 31.79% boost in efficiency for noise reduction in a home environment is evident with the sound panel prototype made from recycled mixed materials. Moreover, when examining costs, Prototype II (recycled mixed materials) proves more economically feasible than commercial soundproofing solutions. Although Prototype I (single egg tray layer) is the most affordable of the two prototypes, it underperforms in comparison to Prototype II. In conclusion, Prototype II (recycled mixed materials) excels in terms of both efficiency and cost-effectiveness.

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