JURNAL TEKNIK MESIN
(JOURNAL OF MECHANICAL ENGINEERING)

VOL. 14, NO. 02 , June 2025
https://publikasi.mercubuana.ac.id/index.php/jtm/index
DOI :10.22441/jtm.v14i2.33537

Utilization of Corn Cob Waste as Composite Board (Fiberboard) which will be Used as Soundproof Walls

Yusril Irwan[1], Agus Patih Hurahman[2], and Muhammad Naufal Amanullah[3]
[1]Mechanical Engineering, Faculty of Engineering, National Institute of Technology Bandung, 40124, Indonesia
[2]Mechanical Engineering, Faculty of Engineering, National Institute of Technology Bandung, 40124, Indonesia
[3]Department of Mechanical Engineering, Faculty of Engineering, Diponegoro University Semarang, 50275, Indonesia

E-mail: yusril@itenas.ac.id[1,2], amanullahnaufal@students.undip.ac.id[3]

Abstract-- *Currently, Ciherang Village in Nagreg Regency has abundant corn plantations that serve as the primary livelihood for its residents. While corn kernels are primarily used for food processing or resale, the corn cobs are only partially utilized to make briquettes, leaving large amounts of unused waste. These are often discarded in rivers or left in public areas, causing unsightly conditions and foul odors. As a potential solution, this study processes corn cob waste into composite boards (fiberboards) intended for use as soundproofing materials for rooms or vehicles, supporting waste recycling and the green economy. To evaluate the soundproofing performance and physical characteristics of the fiberboard, several tests were conducted, including acoustic absorption, Scanning Electron Microscopy (SEM), vibration, compressive strength, recovery, density, and water absorption. The results showed that the fiberboards met several standard requirements: densities ranged from 0.45–0.76 g/cm³, acoustic absorption coefficients reached up to 0.85 at certain frequencies, and recovery rates exceeded 70% after compression. The best sound absorption was observed in the 4 cm thick fiberboards made from 100 mesh corn cob particles, indicating strong potential for use as an eco-friendly acoustic material.*

Article History:
Received: May 13, 2025
Revised: June 02, 2025
Accepted: June 04, 2025
Published: June 09, 2025

Keywords: *Corn Cob Composite Board, Soundproofing, Acoustic Testing*

1. INTRODUCTION

One of the agricultural wastes found in Indonesia, particularly in Ciherang Village, Nagreg Regency, is cob sludge waste residual waste from corn cobs after harvesting and partial processing [1]. Although the waste generation rate per hectare of cob sludge is relatively low compared to other agricultural byproducts, the extensive cultivation area and the relatively short growing period of corn (75–120 days) result in multiple harvests per year [2]. This leads to a substantial accumulation of cob sludge waste, which often goes underutilized or is disposed of improperly in the environment [3].

Corn cobs represent the largest fraction of corn-related agricultural waste, while other components such as corn husks contribute a smaller portion. Improper disposal or handling of cob sludge waste can lead to serious environmental pollution [4][5]. In many communities, this type of waste is still perceived merely as a byproduct with no economic value. Therefore, it is necessary to explore its potential as a functional material in engineering applications, particularly as a replacement for conventional synthetic materials. This shift not only enhances material efficiency but also aligns with economic and environmental sustainability objectives. Corn cobs exhibit several advantageous properties such as small particle size, favorable mechanical strength, dimensional stability, a robust surface texture, and high compressive resistance. These attributes suggest their potential to be processed into sound-damping materials, especially when formulated into composite boards [4].

Noise, defined as unwanted or disruptive sound, is a common environmental pollutant [6]. It can be influenced by structural elements of a building that either transmit or absorb sound depending on their density and configuration [7]. The acceptable indoor noise level should not exceed thresholds that interfere with human activities; for instance, Koeningsberger (as cited in Satwiko) recommends a maximum of 40 dBA for residential living rooms [6]. With increasing awareness of environmental and health concerns, attention has shifted toward developing eco-friendly sound-absorbing materials. Recent research trends focus on utilizing natural fibers or organic particles to create porous acoustic materials capable of absorbing sound waves efficiently [8]. Such materials work by inducing intermolecular friction as sound waves pass through their porous structure, thereby converting acoustic energy into thermal energy and effectively reducing noise levels [9][10].

To address this gap, the present study aims to develop composite fiberboards from corn cob sludge waste and evaluate their suitability as soundproofing materials through a comprehensive experimental approach. The research investigates various mesh sizes (50, 100, and a 50–100 mix), board thicknesses (3 cm and 4 cm), and board types (perforated and solid). The performance evaluation includes tests on density, acoustic absorption (using an impedance tube method per ISO 10534-2), compressive strength, recovery after compression, vibration damping, water absorption, and microstructural analysis using SEM.

The goal of this research is to determine the sound absorption characteristics and mechanical viability of fiberboards derived from corn cob sludge waste. The results are expected to contribute to the development of eco-friendly acoustic materials and provide practical recommendations for utilizing agricultural waste in engineering applications.

2. METHODOLOGY

2.1 Composition of Fiberboard Making

In this study, fiberboards were manufactured using three types of corn cob powder based on sieve sizes: 100 mesh, 50 mesh, and a mixture of 50 and 100 mesh (in a 50:50 ratio). The manufacturing process was carried out using a mold with dimensions of 50 cm × 40 cm × 6 cm, resulting in a total volume of 12,000 cm³. The composition of the corn cob powder was set at 80% of the mold's internal volume, which equals 9,600 cm³. The powder weights were adjusted based on their density: the 100 mesh powder weighed 700 grams, the 50 mesh powder 750 grams, and the 50:50 mixed mesh powder 730 grams.

For the adhesive, a homemade mixture based on polypropylene plastic and polyurethane thinner was prepared. The adhesive composition was 30% of the total mixture volume, totaling 850 mL. The adhesive was mixed with the corn cob powder using the hand lay-up method, stirred for more than 15 minutes to ensure uniform distribution. The final mixed weights were: 100 mesh = 1050 grams, 50 mesh = 800 grams, and mixed mesh = 850 grams. After mixing, the material was compressed in the mold using a 1:3 compaction ratio (from an initial thickness of 6 cm to a final thickness of 4 cm). The molded fiberboards were left to cure at room temperature for 24 hours, then air-dried for 30 days before testing.

2.2 Tests Conducted

In the testing process, it refers to the SNI 03–2105-2006 standard where this reference is the standard used to determine the characteristics of composite boards (fiberboard) and ASTM D -1751 is the standard reference used to determine whether the fiberboard meets the requirements for filling expansion joints that have been formed for concrete road paving and structural construction. The test standards can be seen in table 1 below.

Table 1. Testing Standards

Properties of fiberboard	Symbol	SNI 03-2105-2006	ASTM D–1751
Density	g/cm³	0.40 – 0.90	-
Water Absorption	%	-	≤ 20
Thickness Development	%	≤ 12	-
Compression Strength (50%)	MPa	-	0.68 – 5.17
Recovery	%	-	≥ 70

Several mechanical and physical tests were conducted to evaluate the properties of the fiberboard, as described below:

1. Density Test
   Conducted following SNI 03-2105-2006, this test measured the mass-to-volume ratio of specimens (10 cm × 10 cm × 4 cm). The density values were expected to fall within the standard range of 0.40–0.90 g/cm³.
2. Water Absorption Test
   Based on SNI 03-2105-2006 and ASTM D1751, specimens (10 cm × 6 cm × 4 cm) were immersed horizontally in water to a depth of 3 cm for up to 48 hours. Weight and thickness measurements were recorded every 4 hours to calculate absorption percentage and thickness swelling.
3. Compression Test
   Conducted using ASTM D1751 standards. Specimens were compressed until their thickness was reduced by 50%. The target compressive strength was between 0.68 MPa and 5.17 MPa.
4. Recovery Test

After compression, specimens were allowed to recover for 10 minutes. The recovery percentage was calculated by comparing the recovered thickness to the original thickness. A minimum of 70% recovery was expected as per ASTM D1751.

5. Acoustic Absorption Test
   Performed using an impedance tube and two microphones, following the ISO 10534-2 standard. Specimens with thicknesses of 3 cm and 4 cm (both perforated and solid types) were tested to determine the sound absorption coefficient at various frequencies.
6. Vibration Test
   The vibration damping capacity was tested by attaching specimens to a vibrating steel plate connected to a motor. Acceleration amplitudes were recorded using an accelerometer at varying RPMs (0–2500). Comparisons were made between untreated conditions and those with different fiberboard thicknesses and mesh types (5 mm, 8 mm, and 11 mm).
7. Scanning Electron Microscope (SEM) Analysis
   SEM analysis was used to examine the microstructure of the fiberboard surface and internal bonding quality.

2.3 Variables

- **Independent variables**:
  - Mesh size (50 mesh, 100 mesh, 50 and 100 mixed mesh)
  - Specimen thickness (3 cm, 4 cm)
- **Dependent variables**:
  - Density, water absorption, compressive strength, recovery rate, acoustic absorption coefficient, vibration damping, microstructure quality
- **Controlled variables**:
  - Adhesive composition and curing time
  - Test temperature and humidity

3. RESULT AND DISCUSSION

3.1 Water Absorption Test

Based on the test results that have been carried out, it shows that the specimen has a water absorption rate of 53.8% which was carried out for 24 hours. This value exceeds the standard limit set, which is less than 20%. After testing for 48 hours, water absorption increased significantly to 74.9%. Thus, there was an increase of 39% in the period between 24 and 48 hours. The following are each mesh with the level of increase in water absorption during the first 48 hours, 100 mesh which has a water absorption value of 84.4% and 70%, second 50 mesh with a water absorption value of 56.9% and 70.7%, and third mesh mix 50 and 100 with a water absorption value of 89% and 78.4%. Can be seen in Figure 1. below.

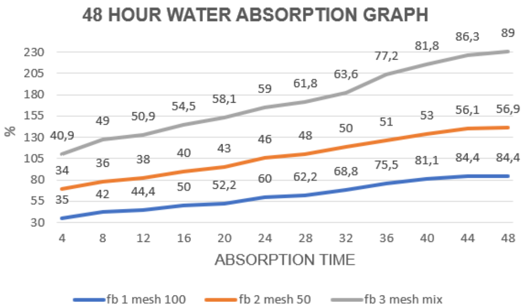

Figure 1. Water absorption 48 hours

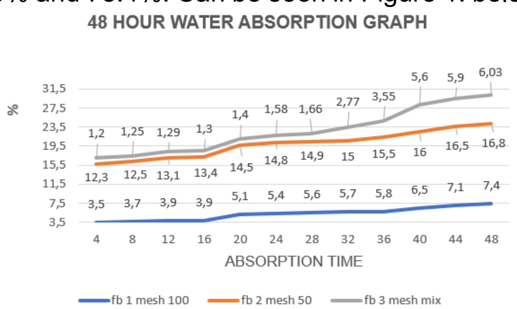

Figure 2. Development over 48 hours

In addition, in Figure 2 shows that Fiberboard mesh 100 experienced a stable increase in swelling from 3.5% to 7.4%, indicating a gradual but lower water absorption compared to 50 mesh. Fiberboard mesh 50 had the highest swelling, increasing from 12.3% to 16.8%, due to the larger particle size which increased water absorption. Meanwhile, the mixed fiberboard showed the lowest swelling, from 1.2 to 6.03, indicating that the combination of particles from 50 and 100 mesh reduced water absorption compared to 50 mesh.

3.2 Compression Testing

Based on Figure 3, it can be seen that each type of mesh has a different compressive strength test value. Fiberboard with mesh 100 has a compressive strength value (5.552 MPa), fiberboard with 50 mesh has a compressive strength value (7.262 MPa), and fiberboard combination of 50 and 100 mesh has a compressive strength (4.576 MPa).

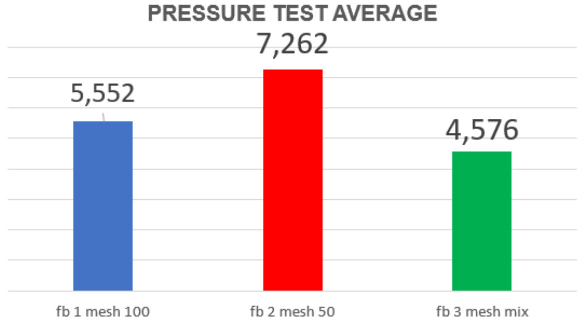

Figure 3. Compressive strength of specimens

Of the three specimens, the 50 mesh specimen has the highest compressive strength because its particle size is larger, increasing its resistance to pressure by 50%. The 100 mesh specimen is in second place with medium compressive strength, because its particles are smaller and form a denser structure, but is less able to withstand compressive loads of up to 50%. The mixed specimen of 50 and 100 mesh has the lowest compressive strength because the combination of large and small particles is less effective in resisting compressive forces. However, all three specimens of 50 mesh, 100 mesh, and a combination of 50 and 100 mesh with the ASTM D-1751 standard, which requires a 50% compressive strength value between 0.68 MPa and 5.17 MPa.

3.3 Recovery Testing

From the test results shown in Figure 4, the average recovery data obtained in the three variations of fiberboard mesh has a recovery rate below the standard, namely 90%, for 100 mesh (63.855%), 50 mesh (76.055%), and mix 50 and 100 mesh (74.72%). Of the three values obtained, 50 mesh and mix 50 and 100 mesh are better because 50 mesh has larger particles, allowing the fibers in the fiberboard to form a more stable and strong structure. Thus, when the fiberboard experiences pressure reaching 50%, the material still has the ability to return to its original shape. While the mixed mesh fiberboard (50 & 100) is a combination of large and small particles, where small particles from 100 mesh can fill the large cavity gaps of 50 mesh. This results in a denser and more balanced structure in distributing pressure, so that the recovery value is better.

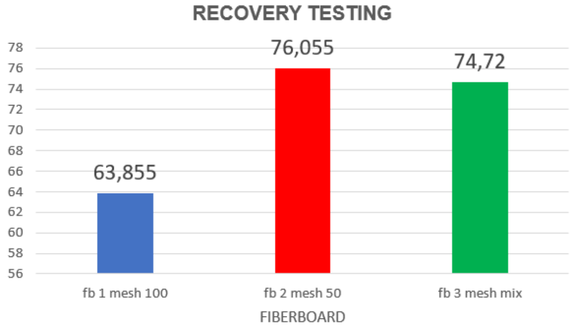

Figure 4. Recovery Testing

3.4 Acoustic Testing

Based on Figure 5 and Figure 6, the results show that at frequencies (16 to 250 Hz) samples with a thickness of 4 cm have an increase in absorption from 0.038 (16 Hz) to 0.586 (250 Hz), samples with a thickness of 3 cm have no absorption until (250 Hz), while at a frequency of 315 Hz there is an increase in sound absorption (0.049) In the medium frequency (315-630 Hz) samples with a thickness of 4 cm have an increase in sound absorption from 0.153 to 0.546, as well as samples with a thickness of 3 cm from the medium frequency (315-630 Hz) experienced an increase in value from 0.049 to 0.482. While in high frequencies (800-1600 Hz) the sound absorption value of the two samples did not change significantly, this shows that specimens with a thickness of 4 cm and 3 cm can absorb sound in the high frequency range.

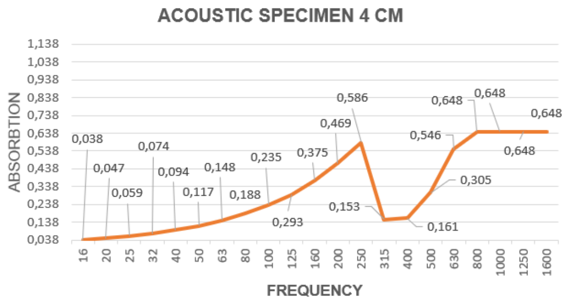

Figure 5. Acoustic testing of 4 cm specimen

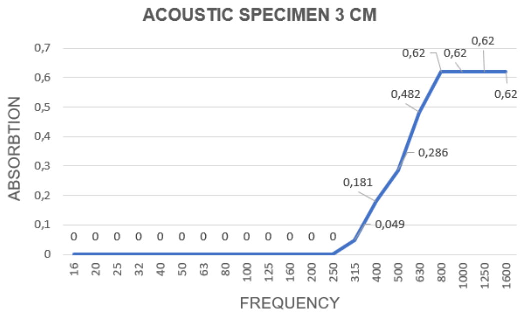

Figure 6. Acoustic testing of 3 cm specimen

3.5 Vibration Testing

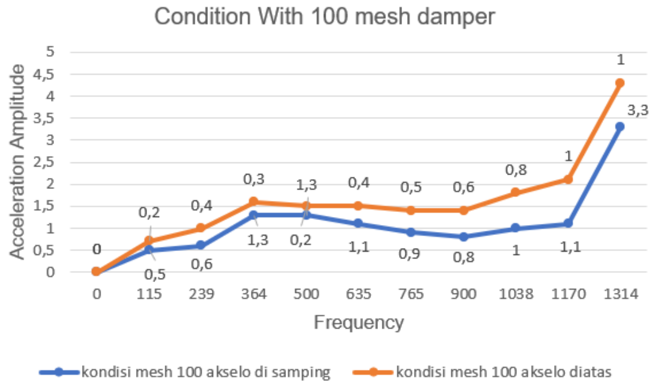

Figure 7. Vibration condition of mesh damper 100

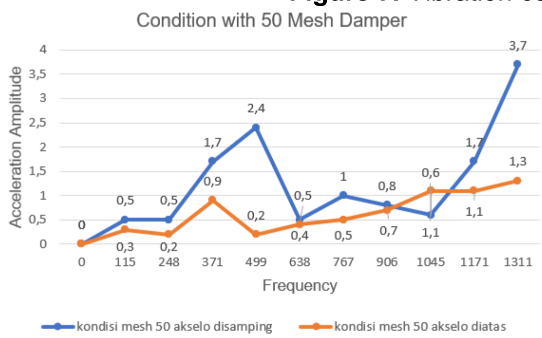

Figure 8. Vibration condition of mesh damper 50

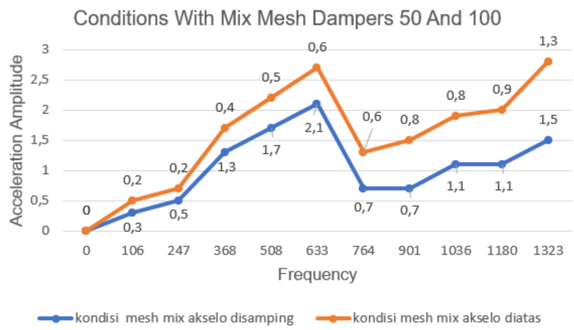

Figure 9. Vibration conditions of mixed mesh dampers 50 and 100

The vibration testing was conducted to assess the damping performance of the fiberboard panels at various rotational speeds (RPM). Two accelerometers were used to measure the vibration amplitudes: one mounted on the side of the steel plate (to capture lateral vibrations), and the other placed on top of the motor (to capture vertical vibrations transmitted through the system). This setup was intended to evaluate how effectively the fiberboard can reduce vibration in different orientations and mechanical paths an important factor for applications in soundproofing walls or motor vehicle interiors, where vibrations contribute to secondary noise. Figure 7 shows the vibration test results for the condition without any damping material. In the initial frequency range (0–500 rpm), there was a gradual increase in acceleration amplitude for both sensors. At 500 rpm, the lateral sensor recorded a significant drop, indicating a shift in resonance, while the top sensor maintained a relatively stable amplitude. At higher speeds (900–1314 rpm), amplitudes increased sharply, reaching 3.3 m/s² on the side sensor and 4.0 m/s² on the top sensor, indicating a strong vibration transmission in the absence of any damping material.

In Figure 8, with the application of fiberboard made from 100 mesh corn cob powder as the damping material, a notable change in vibration behavior was observed. In the 0–500 rpm range, amplitudes remained low; the side sensor reached 2.4 m/s², while the top sensor showed a decrease to 0.2 m/s², demonstrating the material's effectiveness in isolating vertical vibrations. At higher speeds, particularly around 1311 rpm, the side sensor showed 3.7 m/s², but the top sensor remained at 1.3 m/s², suggesting that the fiberboard effectively dampens upward-transmitted vibrations, which are more relevant in wallmounted applications. Figure 9 presents the results for the fiberboard using a mixture of 50 and 100 mesh particles. From 0–500 rpm, both sensors showed a mild increase in amplitude. The first notable peak occurred at 633 rpm, where the side sensor reached 2.1 m/s² and the top sensor recorded a slightly higher value of 2.6 m/s². This was followed by a sharp drop at 764 rpm to a minimum amplitude of 0.7 m/s², indicating effective damping. However, at 1323 rpm, the side sensor recorded a smaller rise to 1.5 m/s², while the top sensor was higher by 0.8 m/s².

3.6 SEM Testing

The results of the SEM test on the 100 mesh specimen in Figure 10, show that the specimen with a 100 mesh has a high density level, so that the corn cob powder particles contained in the specimen can be said to be evenly distributed and have a small cavity size with a value of 27.2 μ. This can be concluded that the structure in the 100 mesh is more uniform and fills the empty cavities.

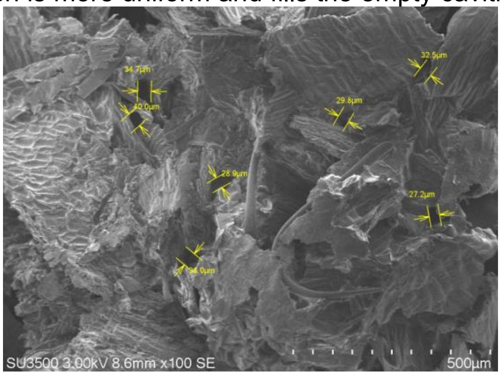

Figure 10. SEM test results of 100 mesh specimens

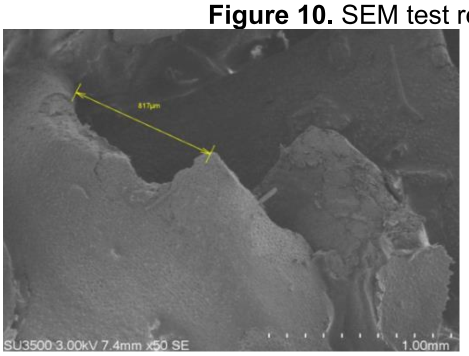

Figure 11. SEM test results of 50 mesh specimens

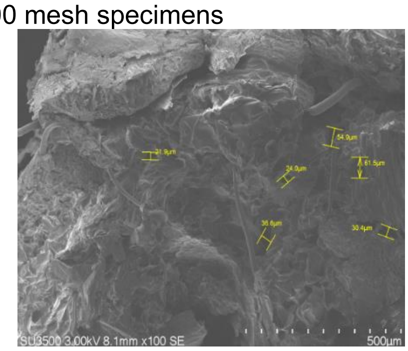

Figure 12. SEM test results of mixed mesh specimens of 50 and 100

The Scanning Electron Microscope (SEM) test was conducted to examine the surface morphology and particle distribution of the fiberboard specimens made from different mesh sizes of corn cob powder. For the 50 mesh specimen, the SEM imaging was limited to a maximum magnification of 50 SE. This limitation occurred due to the presence of large pore gaps in the microstructure, which made it difficult for the microscope to focus accurately at higher magnifications. The particles in this specimen appeared to be irregularly distributed, resulting in wider inter-particle voids. The average pore diameter observed was 817 μm, indicating a relatively porous and less compact microstructure. This lack of uniformity can affect the mechanical strength and sound insulation performance of the material.

In contrast, the 100 mesh specimen exhibited a much finer and more uniform particle distribution. The smaller particle size allowed for better compaction, reducing the average pore size significantly. The microstructure appeared denser and more homogeneous, as shown in Figure 11, which suggests improved bonding between particles and potentially better acoustic and mechanical performance. Meanwhile, the mixed mesh specimen (a 50:50 blend of 50 mesh and 100 mesh powders) showed a non-homogeneous particle mixture. The surface morphology revealed a variation in pore sizes due to the inconsistent particle sizes. From the SEM image (Figure 12), the average pore size was measured at 21.9 μm. This variation indicates that the blending of two different mesh sizes created a structure with mixed porosity characteristics, combining features of both fine and coarse particles. Such a structure may influence how the material behaves in terms of both flexibility and absorption properties.

4. CONCLUSION

Based on the test results and analysis data that have been carried out, the following conclusions can be drawn:

1. Fiberboards made from 50 mesh and 50–100 mesh mixtures met the density standards specified in SNI 03-2105-2006 (0.40–0.90 g/cm³), while the 100 mesh specimen had a density below the minimum limit. This indicates that particle size significantly affects the compaction and structural integrity of the fiberboard. All specimens exhibited very high water absorption, exceeding the standard maximum of 20%, suggesting that the material is highly hygroscopic. This indicates the need for surface treatment or coating if the material is to be used in humid environments.
2. None of the specimens met the ASTM D-1751 standard for compressive strength (0.68–5.17 MPa). However, the 50 mesh and mixed mesh specimens showed higher compressive values than the 100 mesh type, indicating better structural resilience. In terms of recovery after compression, no specimen achieved the minimum 90% recovery rate, although 50 mesh and mixed mesh types performed better than the 100 mesh sample.
3. Fiberboards with a 4 cm thickness were more effective at absorbing low-frequency sounds than the 3 cm boards. At medium frequencies, both thicknesses showed similar performance, and at high frequencies, both maintained stable and effective absorption rates. Perforated fiberboards also demonstrated potential for improved sound absorption, although the impact depends on hole distribution and overall material thickness.
4. Vibration testing revealed that 100 mesh fiberboards had the best performance in vertical vibration damping (as measured by the top-mounted accelerometer), while the mixed mesh specimen showed moderate damping. In contrast, the undamped (no fiberboard) condition showed significant amplitude increases at high RPMs, while the damped specimens stabilized the amplitude more effectively.
5. SEM images showed that 100 mesh fiberboards had the most compact and uniform microstructure, with evenly distributed particles and minimal pore sizes. In contrast, 50 mesh specimens had large pores averaging 817 μm, resulting from irregular particle distribution. The mixed mesh specimens exhibited a non-homogeneous structure with a combination of large and small particles. The average pore size was measured at 21.9 μm, indicating a varied morphology that may offer a balance between strength and flexibility

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