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**ORIGINAL**

# Corn Husk Fiber Composite as a Noise Reducer for Galvalume Roofs

## Compuesto de Fibra de Hoja de Maíz como Reductor de Ruido para Techos de Galvalume

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**ABSTRACT**

Galvalume roofing, widely used for its durability and cost-efficiency, often generates significant noise during rainfall, impacting indoor acoustic comfort. This study aims to evaluate the impact of incorporating corn husk fibre on the effectiveness of noise reduction through epoxy matrix-based composite coatings on galvalume roofs. Applying a sound-dampening layer on the surface of galvalume roofing is expected to reduce the noise level generated, especially during rainfall. The composite used as a coating consists of natural fibres—in this case, corn husk fibres—which serve as the filler material to support the soundproofing function. The samples used in this study are galvalume roof panels coated with a composite material, which were tested through simulated artificial rainfall and measurements using a sound absorption coefficient testing device. The coating process was carried out using the hand lay-up method, with a mixture of epoxy resin and corn husk fibres in varying weight fractions: 0 %:100 %, 20 %:80 %, 30 %:70 %, 40 %:60 %, and 50 %:50 %. Based on macroscopic observations of fibre distribution, the 50 %:50 % weight fraction showed the most even distribution, with a uniformity rate of up to 93 %. In noise level testing, the 50 %:50 % composition resulted in the lowest recorded noise level of 74 500 dB. The sound absorption coefficient test was conducted by placing the specimen in a rectangular testing chamber measuring 100 cm × 50 cm × 50 cm, equipped with two sound level meters. The results showed the lowest absorption coefficient (α = 0,3695 cm) at the 20 %:80 % fraction and the highest (α = 0,6365 cm) at the 50 %:50 % fraction. Overall, the study concludes that increasing the content of corn husk fibre significantly influences the effectiveness of noise reduction on galvalume roofs.

**Keywords:** Galvalume Roofing; Acoustic Comfort; Corn Husk Fiber; Epoxy; Noise Reduction; Coating.

**RESUMEN**

Los techos de galvalume, ampliamente utilizados por su durabilidad y rentabilidad, suelen generar un ruido considerable durante las lluvias, lo que afecta al confort acústico interior. El objetivo de este estudio es evaluar el impacto de la incorporación de fibra de hoja de maíz en la eficacia de la reducción del ruido mediante recubrimientos compuestos basados en matrices epoxi en techos de galvalume. Se espera que la aplicación de una capa insonorizante en la superficie de los techos de galvalume reduzca el nivel de ruido generado, especialmente durante las lluvias. El compuesto utilizado como recubrimiento está formado por fibras naturales —en este caso, fibras de hoja de maíz— que sirven como material de relleno para reforzar la función de insonorización. Las muestras utilizadas en este estudio son paneles de techo de galvalume recubiertos con un material compuesto, que se sometieron a pruebas mediante lluvia artificial simulada y mediciones con un dispositivo de prueba del coeficiente de absorción acústica. El proceso de recubrimiento se llevó a cabo utilizando el método de laminado manual, con una mezcla de resina epoxi y fibras de cáscara de maíz en diferentes fracciones de peso: 0 %:100 %, 20 %:80 %, 30 %:70 %, 40 %:60 % y 50 %:50 %. Según las observaciones macroscópicas de la distribución de las fibras, la fracción de peso 50 %:50 % mostró la distribución más uniforme, con una tasa de uniformidad de hasta el 93 %. En las pruebas de nivel de ruido, la composición 50 %:50 % dio como resultado el nivel de ruido más bajo registrado, de 74 500 dB. La prueba del coeficiente de absorción acústica se llevó a cabo colocando la muestra en una cámara de pruebas rectangular de 100 cm × 50 cm × 50 cm, equipada con dos sonómetros. Los resultados mostraron el coeficiente de absorción más bajo (α = 0,3695 cm) en la fracción 20 %:80 % y el más alto (α = 0,6365 cm) en la fracción 50 %:50 %. En general, el estudio concluye que el aumento del contenido de fibra de cáscara de maíz influye significativamente en la eficacia de la reducción del ruido en los techos de galvalume.

**Palabras clave:** Techos de Galvalume; Confort Acústico; Fibra de Cáscara de Maíz; Epoxi; Reducción del Ruido; Recubrimiento.

## INTRODUCTION

Roofing systems provide shelter, protection, and comfort in buildings. Among various roofing materials, galvalume a combination of galvanised steel coated with aluminium and zinc is widely used due to its corrosion resistance, lightweight nature, and affordability.(1) However, one major drawback of galvalume roofing is its poor acoustic performance, particularly under rain impact, which can generate high noise levels and compromise indoor comfort.(2,3) This issue is especially problematic in tropical regions with frequent rainfall, where noise pollution from metal roofs becomes a significant concern.

In recent years, growing attention has been directed toward enhancing the acoustic performance of building materials by incorporating natural fibres into composite structures(4,5,6,7,8) Natural fibres offer biodegradability, low cost, light weight, and good acoustic absorption capabilities.(9,10,11,12,13) Corn husk fibers—an agricultural by-product of corn processing—have emerged as a promising material due to their availability, fibrous structure, and sustainability. Indonesia, one of the major corn-producing countries, generates abundant corn husk waste, which remains underutilized and often discarded.(14,15,16)

The use of corn husk fibre in composite applications, particularly acoustic insulation, remains relatively unexplored. Corn husk fibres have shown potential in reinforcing polymer matrices due to their cellulose content, which improves interfacial bonding and energy dissipation under acoustic waves. Moreover, when embedded in epoxy resin, corn husk fibre can create a porous and fibrous internal structure that enhances sound absorption through scattering, friction, and viscous losses.(17) This makes it a viable candidate for developing eco-friendly sound- dampening materials, especially for roofing systems like galvalume.

This study aims to evaluate the performance of corn husk fiber-reinforced epoxy composites as noise-reducing coatings for galvalume roofs. By varying the weight fraction of corn husk fibers, this research investigates their effects on noise level reduction and sound absorption coefficient. The hand lay-up technique is used for composite fabrication due to its simplicity and effectiveness in distributing natural fibers within a polymer matrix.(18,19,20,21,1) The final specimens are tested under simulated rainfall conditions and in a controlled acoustic environment to assess their damping performance.

The expected outcome of this study is to identify an optimal composition that maximises acoustic damping while maintaining structural integrity. Additionally, this research promotes the utilization of agricultural waste and supports the development of sustainable, low-cost, and high-performance building materials. Integrating corn husk fibres into roofing systems could significantly reduce noise pollution in residential and commercial buildings, thereby improving the quality of life for occupants.

## METHOD

This study was conducted experimentally between 8:00 AM and 4:00 PM. The research took place at Brawijaya University, Malang City, East Java, Indonesia. Data from the sound level meter was recorded and noted using Excel for 10 minutes, then averaged to represent the output data. The average values were used to determine the final results, which were compared in a graph using Origin software. The research used corn husk fibre as a filler mixed with epoxy resin in the following fibre-to-resin weight ratios: 0 %:100 %, 20 %:80 %, 30 %:70 %, 40 %:60 %, and 50 %:50 %. Initially, the corn husk fibres underwent an alkalisation process for 1 hour using a 5 % NaOH solution to remove impurities and ineffective components from the fibres.

The specimens were fabricated using a hand lay-up coating method, in which epoxy resin was first applied onto a galvanized plate, followed by the placement of corn husk fibers, and then coated again with epoxy resin.

The composition test was conducted using a Van Soest apparatus at the Laboratory of Animal Nutrition and Feed, Faculty of Animal Husbandry, Universitas Brawijaya. This test aimed to determine the chemical composition of the corn husk fibers.

Microscopic analysis was carried out at the Materials Testing Laboratory, Department of Mechanical Engineering, Universitas Brawijaya. The purpose of this test was to observe the microstructural morphology of the corn husk fibers. Images were taken at magnifications of 100× and 200× (figure 1).

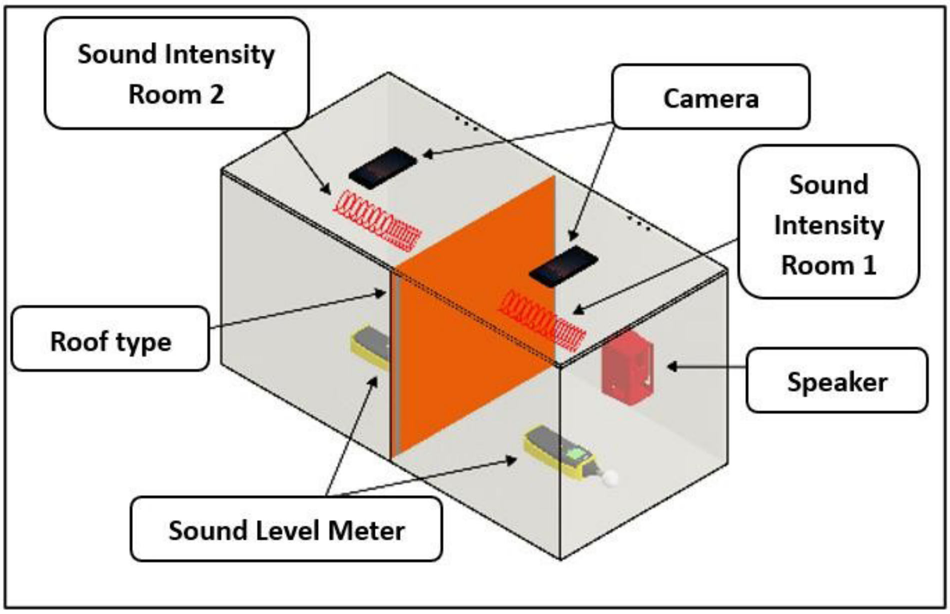



**Figure 1.** Sound Absorption Coefficient Testing Apparatus

Macroscopic image testing examined the fiber distribution level on the galvalume roof composite. The analysis involved dividing the macroscopic photo into 400 square segments. The number of segments covered by corn husk fibers was compared to the total number of squares on the galvanized specimen to determine the percentage of fiber distribution uniformity. Two chambers were constructed to determine the tested roof's sound-damping capability. In the first chamber, a sound source in the form of a speaker was placed. The composite roof specimen separated the second chamber, and sound level meters were positioned on both sides—before and after the composite roof partition. For further clarity, refer to figure 2.

**Figure 2.** Data collection process for roof sound attenuation capability

To measure the level of sound attenuation caused by raindrops, a shower was used with a stable water flow rate controlled by a flowmeter. A sound level meter was placed inside the chamber to measure the noise, and a piezoelectric sensor was positioned directly beneath the composite roof to measure the resulting vibrations (figure 3).

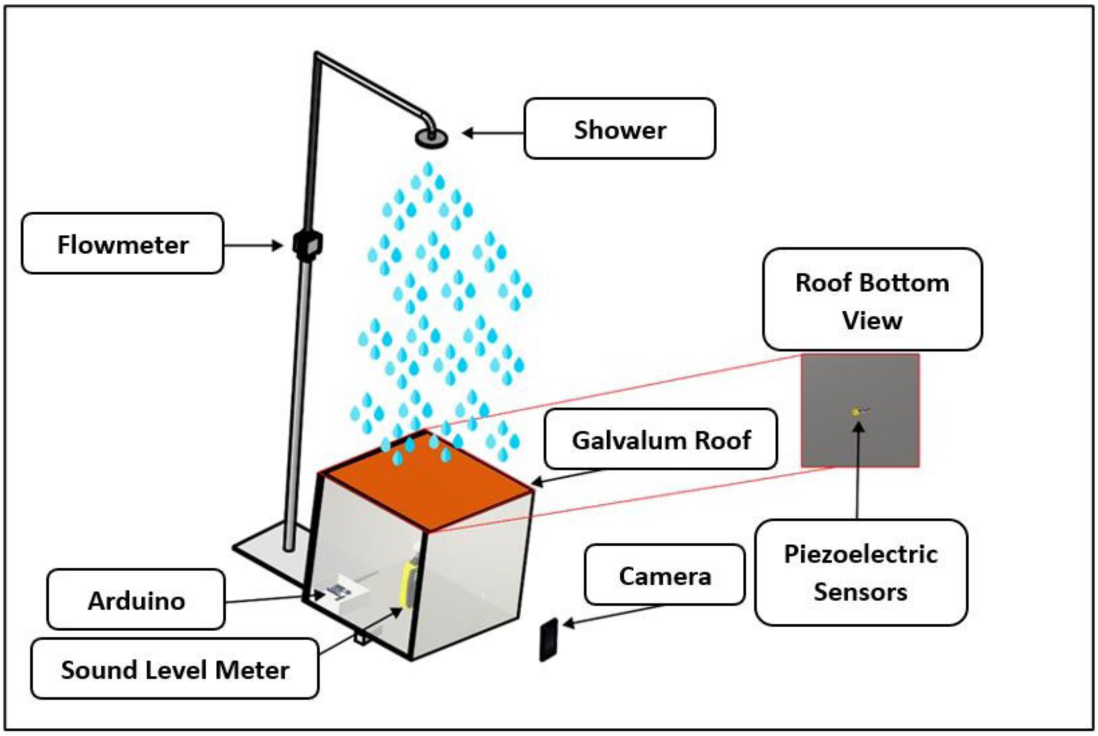



**Figure 3.** Sound Level Meter and Piezoelectric Sensor

The entire process was also recorded with a camera to identify potential anomalies. For further clarity, refer to figure 4.

**Figure 4.** Noise data collection process

## RESULTS AND DISCUSSION

### The Effect of Cellulose Composition in Corn Husk Fibers

Corn husk material was tested using the Van Soest method to determine its content and composition. From this analysis, it is expected that conclusions can be drawn regarding the primary and secondary factors contributing to the observed sound absorption. The results of this test are presented in table 1.

**Table 1.** Corn Husk Fiber Content

| NDF | ADF | Hemicellulose | Cellulose | Silica | Lignin |
|---|---|---|---|---|---|
| (%) | (%) | (%) | (%) | (%) | (%) |
| 68,93 | 64,88 | 4,05 | 38,36 | 24,13 | 2,39 |

Based on the Van Soest analysis results, cellulose was identified as the dominant component, with a content of 38,36 %. Cellulose plays a significant role in the sound attenuation mechanism. When sound waves encounter the cellulose structure, part of the vibrational energy is converted into thermal energy due to friction within the fibres, reducing the intensity of the sound transmitted through the corn husk fibres. Additionally, the complex structure of cellulose contributes to wave dispersion caused by reflections, leading to the fragmentation of sound waves and the loss of a portion of their energy.

### The Influence of Microstructure in Corn Husk Fibres

Based on the results of the microstructural analysis, it was found that the corn husk fibre structure consists of pores that are closely packed together. Figure 5 shows that the pores are randomly shaped and sized, with uneven, wavy surfaces. This porous structure can reduce air flow resistance, dissipating sound waves within the pores. Additionally, the irregular surface causes repeated random reflections between the sound waves and the fibre structure, leading the sound waves to scatter in various directions. As a result, the sound intensity within the fibre is significantly reduced.

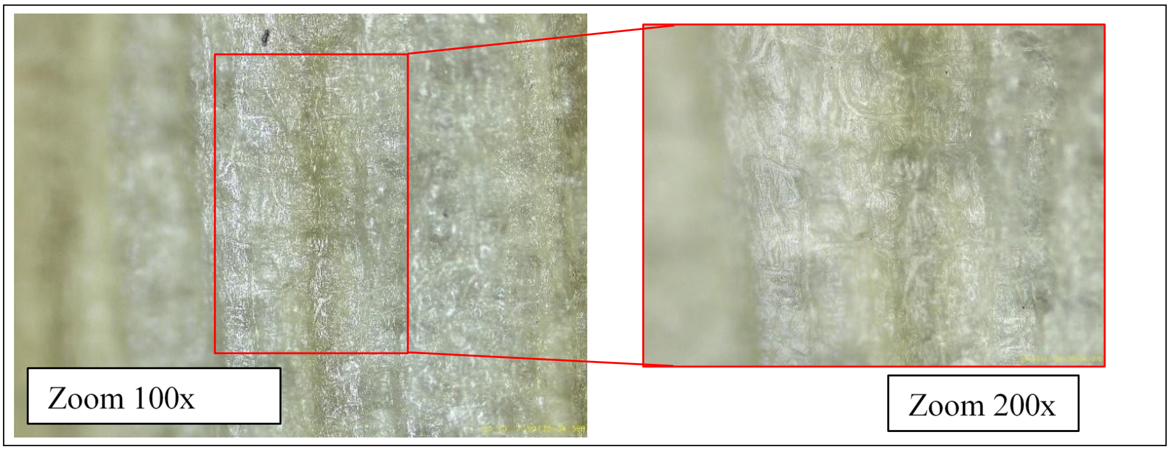
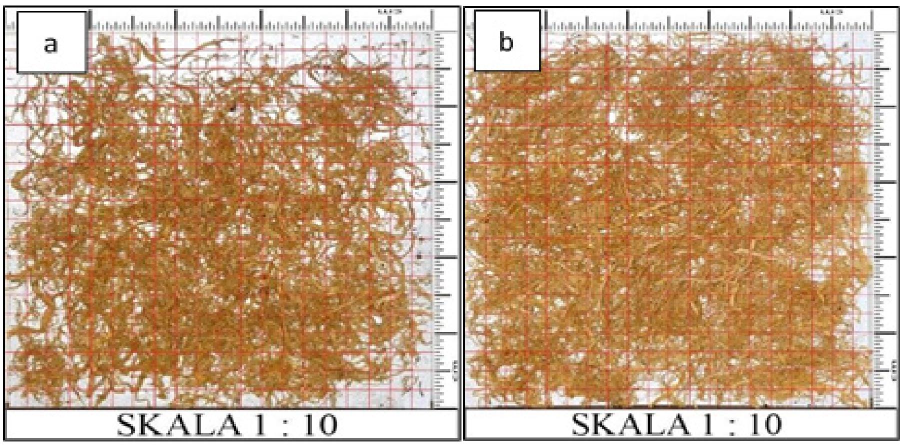



**Figure 5.** Microscopic Image of Corn Husk Fibers

### Effect of Corn Husk Fibre Distribution on Galvalume Roof Coating



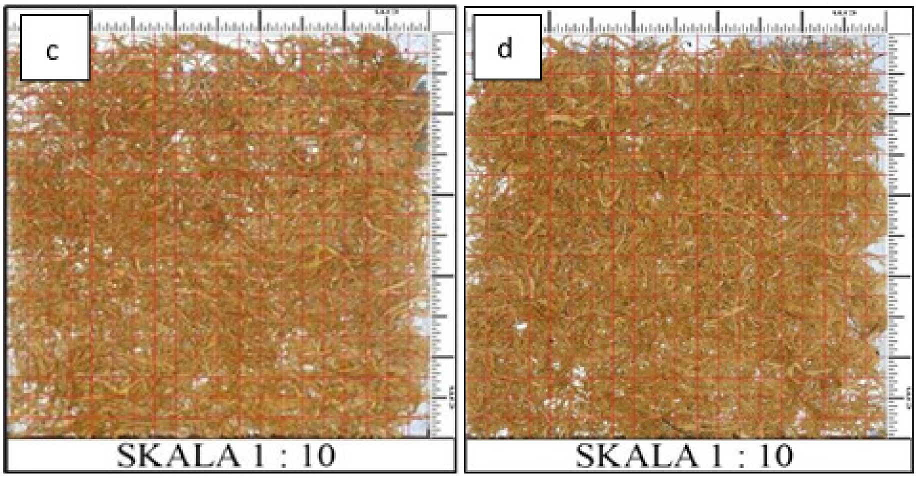



**Figure 6.** Microscopic Image of Specimen with Weight Fraction (a) 20:80; (b) 30:70); (c) 40:60; (d) 50:50

Visual observation of the macroscopic images of corn husk fibre-coated specimens was conducted to examine the fibre distribution and density on the galvalume roof surface. Distribution in this context refers to the corn husk fibre's ability to cover the galvalume roof plate according to its weight fraction ratio (figure 6).

The analysis was performed by overlaying a grid of square boxes on the macroscopic images, resulting in 400 square sections per image. Each square was evaluated to determine how many were covered and uncovered by corn husk fibre.

From the macroscopic images, the percentage of fibre coverage on the galvalume surface increased with higher fibre content. The distribution percentages were recorded as follows: 79,25 % for 20 %:80 %, 82,5 % for 30 %:70 %, 90,25 % for 40 %: 60 %, and 93 % for 50 %:50 % weight fractions. These findings indicate that a higher weight fraction of corn husk fibre leads to better distribution and coverage across the galvalume roof surface.

### The Effect of Corn Husk Fibre and Epoxy Resin Weight Fraction Percentage on the Noise Level of Galvalume Roofing

Based on the test results, it was found that increasing the weight fraction of corn husk fibre in the coating of galvalume roofing is inversely proportional to the intensity of noise. The highest noise level was recorded on untreated galvalume roofing at 91,17 dB, followed by resin coating without fibre at 87,37 dB. As corn husk fibre was added, a significant decrease in sound intensity occurred: 79,67 dB (20:80), 77,77 dB (30:70), 75,27 dB (40:60), and 72,51 dB (50:50) – figure 7. This noise reduction indicates the effectiveness of corn husk fibre as a natural sound- absorbing material.

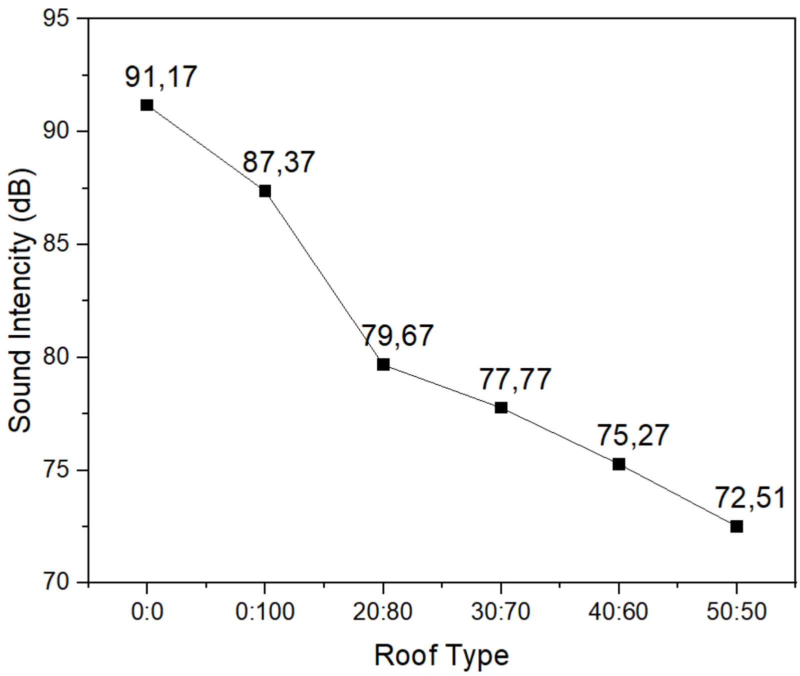



**Figure 7.** Graph of the Effect of Composite Weight Fraction Percentage on the Noise Level of Galvalume Roofing

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The damping ability increases with adding more fibre due to its high cellulose content and porous microstructure, which can absorb and disperse sound waves. The rougher surface resulting from the fibre addition also expands the contact area, reduces the force per unit area, and minimises deflection that generates noise. Furthermore, the more evenly distributed fibre improves the overall damping performance.

Thus, the use of corn husk fibre in galvalume roofing coatings effectively reduces noise, especially when applied in outdoor environments. The higher the fibre content in the mixture, the more optimal the soundproofing function becomes. This makes corn husk fibre-based composite materials a promising solution for developing environmentally friendly building materials capable of sound absorption.

**Effect of Composite Resin Weight Fraction Percentage on the Power Output of Piezoelectric**

Based on the test data obtained, the piezoelectric power values from highest to lowest were recorded for the following weight fraction variations (untreated galvalume roofing, 0 %:100 %, 20 %:80 %, 30 %:70 %, 40 %:60 %, and 50 %:50 %), with power values (Watts) of 0,186; 0,157; 0,127; 0,093; 0,039; and 0,021, respectively. These results show that increasing the weight fraction percentage of corn husk fibre affects the piezoelectric power output (figure 8).

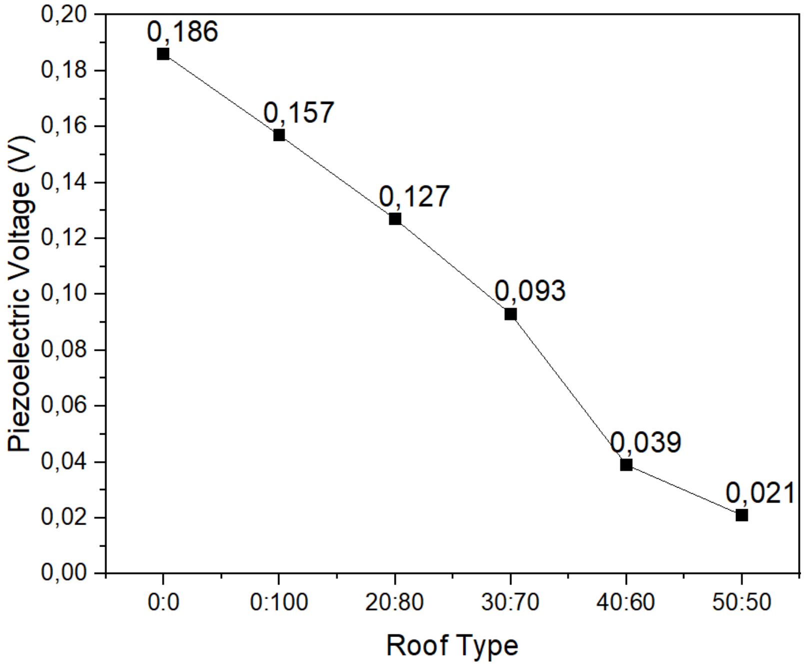


**Figure 8.** Graph of the Relationship Between Fibre Weight Fraction and Piezoelectric voltage

The trend of decreasing power output with increasing corn husk fibre content is attributed to the reduction in specimen deflection caused by the impact of water showers. This occurs because adding the corn husk fibre and epoxy resin composite coating increases the stiffness of the galvalume roofing, resulting in lower deflection values. Furthermore, the incorporation of corn husk fibre into the composite coating affects the surface roughness of the specimen. The added fibres increase surface roughness, reducing the energy transferred from the water shower impact onto the roofing.

In addition, the increased roughness creates peaks and valleys on the surface, effectively enlarging the surface area. This increase in surface area leads to more distributed impact forces, resulting in less energy transferred by the water shower. Consequently, the piezoelectric power output decreases as the fibre content increases in the composite layer.

**Effect of Varying Weight Fraction Percentages of the composite on the Sound Damping Coefficient**

Based on the test results, the order of the sound-damping coefficient values from highest to lowest for the weight fraction variations is as follows: 50:50, 40:60, 30:70, 20:80, 0:100, and untreated galvalume roofing. The corresponding damping coefficient values are 0,64, 0,55, 0,43, 0,37, 0,14, and 0,07, respectively (figure 9).

These results indicate that increasing the proportion of corn husk fiber in the composite significantly enhances the material's sound absorption capability, making it a promising candidate for acoustic insulation.

The graph shows that both the untreated galvalume roof and the specimen with a 0:100 weight fraction (pure epoxy resin) have damping coefficient values below 0,15, indicating they do not meet the criteria for soundproofing materials. In contrast, specimens with fiber-to-resin weight fractions ranging from 20:80 to 50:50

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exhibit damping coefficients above the 0,15 threshold, suggesting that incorporating corn husk fiber within this range is effective for producing acoustic insulating materials.

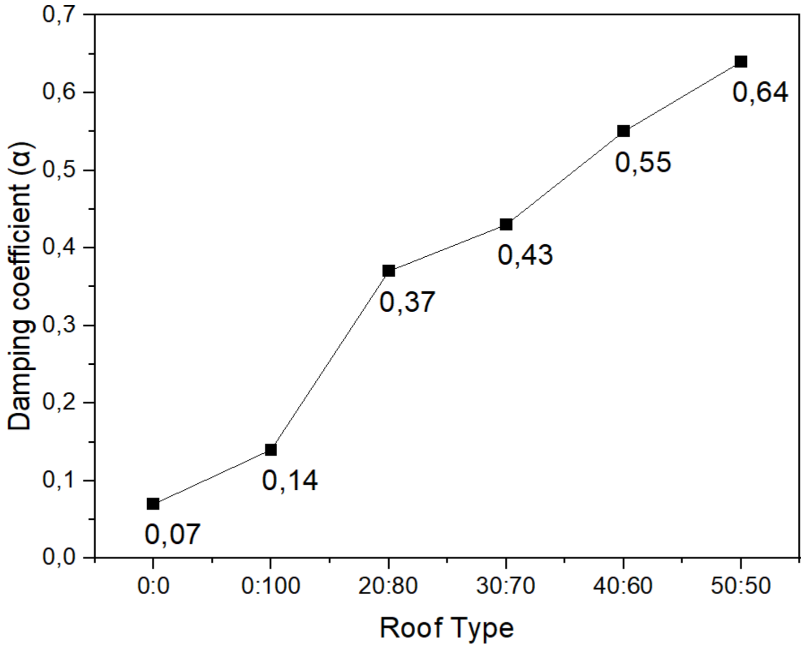


**Figure 9.** Graph of the Relationship Between Fibre Weight Fraction and Damping Coefficient

## DISCUSSION

The application of corn husk fiber composite as a sound-dampening layer on galvalume roofs demonstrated significant potential in reducing noise generated by rainfall. Based on the experimental data, the incorporation of corn husk fiber within an epoxy matrix effectively disrupted the transmission of sound waves, resulting in measurable reductions in decibel levels compared to uncoated galvalume sheets. This can be attributed to the porous structure of the fiber, which enhances sound absorption by trapping and dissipating acoustic energy. The thickness and uniformity of the coating influenced the composite's performance. Thicker layers provided better noise reduction, aligning with previous studies on natural fiber-based acoustic materials. Environmental sustainability is a notable advantage of utilizing agricultural waste, such as corn husks. It offers a low-cost, biodegradable alternative to synthetic acoustic insulators. Nonetheless, durability under prolonged exposure to weather conditions remains a concern, warranting further study. Overall, the findings support the viability of corn husk fiber composite as a practical and eco-friendly noise reduction solution for lightweight roofing systems, especially in tropical regions where heavy rainfall is frequent.

## CONCLUSIONS

The effectiveness of the corn husk fiber composite composition in reducing noise on galvalume roofs, as well as its potential use as an environmentally friendly and sustainable soundproofing material, has been demonstrated in this study. Macroscopic observations revealed that the 50:50 composition exhibited the most uniform fibre distribution, with an evenness level of 93 %. This even distribution likely contributed to its superior acoustic performance. Noise level tests during artificial rain simulations confirmed that the 50 %: 50 % specimen recorded the lowest sound intensity at 74,5 dB. Furthermore, sound absorption coefficient testing revealed that this composition achieved the highest coefficient value of 0,6365 $cm^{1}$, indicating better sound attenuation capabilities than lower fibre content samples.

The study concludes that increasing the proportion of corn husk fibre significantly improves the composite's noise-reduction performance. This enhancement is attributed to the fibrous structure of the corn husk, which increases the material's ability to absorb and dissipate sound energy. Additionally, the alkali treatment of the fibres helped improve fibre-matrix bonding, further enhancing the effectiveness of the composite. Corn husk fibre composites offer a promising, eco-friendly, and cost-effective solution for reducing noise pollution in metal roofing systems, particularly in tropical climates prone to heavy rainfall.

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## CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

## AUTHORSHIP CONTRIBUTION

*Conceptualization:* Redi Bintarto.
*Data curation:* Redi Bintarto.
*Formal analysis:* Redi Bintarto.
*Research:* Redi Bintarto.
*Methodology:* Redi Bintarto.
*Project management:* Redi Bintarto.
Resources: Redi Bintarto.
*Software:* Kamil Gatnar.
*Supervision:* Wahyu Caesarendra.
*Validation:* Wahyu Caesarendra.
*Display:* Kamil Gatnar.
*Drafting - original draft:* Wahyu Caesarendra.
*Writing - proofreading and editing:* Wahyu Caesarendra.