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Natural Silencer : Assessing the Acoustic Excellence of Fiberboard Composites Derived from Sawdust and Coconut Husk Fiber for Soundproofing

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Abstract:

As societal evolution progresses, contemporary construction practices are witnessing a notable shift towards heightened innovation in material selection and utilization. In response to this trend, there has been a discernible rise in the adoption of organic and natural materials, driven by their perceived efficacy in providing cost-effective alternatives to conventional counterparts. Recent findings have unveiled the intrinsic sound-absorbing properties inherent in sawdust and coconut fiber husk, previously considered as natural waste, thereby highlighting their potential to significantly mitigate environmental noise pollution within our living environment. This study explores the viability of utilizing natural and organic substrates, namely sawdust and coconut fiber husk, for the production of acoustic fiberboards. The composite demonstrates satisfactory performance across various tests, including sound absorption, compressive strength, moisture content, water absorption, and fire resistance. The findings about the fiberboard indicate a notable impact on both the thickness of the samples and the composition ratio. The adoption of sawdust and coconut fiber in fiberboard manufacture provides more efficient sound absorption over commercially available materials. These findings suggest the potential for developing eco-friendly alternatives for fiberboards using agricultural waste.

Keywords —**Acoustic Fiberboard, Sawdust, Coconut Fiber Husk, Sound Absorption, Composites**

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I. INTRODUCTION

Throughout history, construction has been a formidable human endeavor, shaping the built environment and being one of the paramount industries. While it has been instrumental in societal progress, recent strides in the manufacturing of building materials and the broader construction industry have revealed a significant environmental impact. The demand for energy in manufacturing processes, coupled with the consumption of extensive natural resources, underscores the ecological implications of modern construction practices [1].

In our modern era, noise has become omnipresent, prompting the urgent need for control measures to foster a serene living environment. As technology progresses, machines play an increasingly prominent role in various industries, becoming the primary source of disruptive industrial noise. The consequences of industrial noise extend beyond momentary disturbances, significantly impacting the day-to-day lives of people residing in the vicinity of these noise sources. Over time, the cumulative exposure to industrial noise compounds challenges, creating a sustained burden on the mental and physical health of affected individuals [2]. The overall quality of life for those in noise-affected areas diminishes, emphasizing the critical role of noise control in enhancing well-being and creating more livable communities.

The rising interest in using organic waste and natural-based products in building materials is closely tied to growing concerns about human health. These materials are abundant, less expensive, renewable, and have fewer adverse health effects when used [3]. The use of organic waste materials in construction refers to the blending of biodegradable materials and processes originating from living things with other building processes. Rather than being disposed away, these organic wastes are recycled to fulfill specialized roles in the building industry, supporting environmental preservation and sustainability.

Sawdust and coconut fiber husk are two adaptable natural materials that are becoming more and more well-known and used in the construction sector due to their sustainable and environmentally beneficial qualities. Certain studies reveal that utilizing sawdust and coconut coir fiber, recognized as natural materials, in the production of panels can result in noteworthy noise absorption properties. Employing these environmental byproducts not only contributes to effective sound control but also serves as an environmentally friendly solution, mitigating environmental pollution. Given their classification as waste materials, incorporating these resources proves economically advantageous and enhances sustainability [4]. Wall panels made of recycled wood can take the place of other acoustic materials that are more costly to install and less ecologically friendly [5]. This panel can regulate the room temperature and has the highest capacity for fire resistance and sound absorption. In terms of sales value, this panel is also precious aesthetically. One of the materials that are sustainable technologies is the wall panel constructed from sawdust and coconut fiber husk.

The primary goal of this study was to assess the viability of employing coconut fiber husk and sawdust as natural materials for crafting soundproof fiberboard panels. By exploring these innovative materials, the aim was to contribute to sustainable and environmentally friendly practices in material development. Addressing the environmental challenges posed by construction requires a comprehensive approach. Innovations in sustainable building materials, such as recycled and eco-friendly alternatives, are gaining traction.

Additionally, advancements in construction techniques, such as modular construction and energy-efficient designs, aim to minimize the ecological footprint of construction projects. Embracing these sustainable practices is crucial for mitigating the construction industry's environmental impact, ensuring that it continues to meet society's needs while safeguarding the planet for future generations.

II. RESEARCH DESIGN

2.1. Research Design

This study applied an experimental type and a mixed method of research. In experimental research, control samples were assessed and compared to experimental samples to determine the product mixtures' effectiveness. These variables can be examined, measured, computed, and compared. This research considered an experimental design approach since the researchers had three (3) different unique proportions of the main variable of the study. The researchers gathered data and tested the materials by investigating the characteristics of each material to obtain a favorable outcome. On another note, mixed-method research was utilized in this study. It is a combination strategy where the qualitative approach of the formulated statistics from the researchers was complemented and strengthened by the statistical information acquired from quantitative assessment. In short, it is an approach that combines both quantitative and qualitative research methods within a single study. This method aims to provide a more comprehensive understanding of a research question by employing the strengths of both approaches. Subsequently, careful surveillance was utilized to see if there was betterment in the creation of the product.

2.2. Research Setting

2.2.1. Materials Collection

The acquisition of materials for this study occurred off-campus. Researchers procured coconut husks from public markets in Mabalacat City, and Apalit, Pampanga. Additionally, sawdust was gathered in Betis, Guagua, Pampanga, renowned for its thriving wood-making industry.

2.2.2 Preparation of the Experiment

The acquisition of materials for this study occurred off-campus. The researchers prepared the natural drying of coconut husks in Apalit, Pampanga. Furthermore, the granulation of sawdust took place in Betis, Pampanga, renowned for its thriving wood-making industry. Additionally, heating and drying were conducted in the Department of Public Works and Highways 2nd District at San Antonio, Guagua, Pampanga.

2.3. Materials Used in the Study

2.3.1. Sawdust

Sawdust, a byproduct of woodworking and the result of cutting, grinding, or sanding wood, has diverse applications and an intriguing profile. Despite its origins as a seemingly insignificant waste product, sawdust has proven to be a valuable resource in various industries, embodying practicality and sustainability.

In woodworking, sawdust is a natural outcome of shaping and refining wood. Its fine particles find purpose beyond the workshop. Sawdust serves as a raw material for wood-based products, such as fiberboards. This utilization minimizes waste and contributes to the wood industry's efficiency by creating a closed-loop system.


Figure 1: Sawdust

2.3.2. Coconut Husk Fiber

Coconut fiber husk, the fibrous outer shell of the coconut fruit, is a remarkably versatile and meaningful natural material with many applications. Known for its resilience and eco-friendly properties, coconut fiber husk has played significant roles in traditional practices and has gained renewed importance in the context of living.

In contemporary times, coconut fiber husk has found a new purpose in promoting eco-friendly materials. Its role in acoustic conditioning is particularly noteworthy. The fibers of the husk act as soundproofing, improving its acoustic resistance. This makes it an eco-friendly alternative to ply boards, contributing to valuable composite materials from recycled agricultural waste. As the world increasingly prioritizes environmentally friendly practices, coconut husk emerges as a symbol of adaptability and responsible resource utilization.


Figure 2: Coconut Husk

2.3.3. Urea-formaldehyde (UF)

Urea-formaldehyde (UF) resins are commonly used glues for making wood panels because they are affordable and quick to react. However, due to a reversible link in the resin, they struggle with water resistance. To fix this, additional components like melamine can be added. Over the years, formaldehyde emissions have decreased, and advanced lab tests help understand the resin's structure and how it hardens [29].

In the realm of indoor panel production, individuals often opt for urea formaldehyde at a lower cost. However, these binders, while cost-effective, lack waterproofing properties and release toxic and carcinogenic formaldehyde. The health and environmental hazards associated with these binders are widely acknowledged.

Notably, diminishing formaldehyde usage can result in subpar mechanical properties for particle boards. To address this issue, efforts are made to mitigate the negative impact through methods such as plating or chemical modification, aiming to reduce harmful emissions without compromising mechanical performance [6].

In the future, UF adhesive resins are expected to be crucial for making wood panels because of their advantages, despite some downsides. The significant progress made in the last 20 years and recent advancements give confidence that UF-bonded boards will continue to meet various requirements, ensuring their importance in the wood-based panel industry [29].

Urea formaldehyde is a type of resin widely used as a binder or adhesive in producing wood-based composite materials such as particleboard, medium-density fiberboard (MDF), and plywood. It is formed through the reaction of urea and formaldehyde under controlled conditions. This reaction produces a resin that can be cured to create a solid and durable bond.

In the context of wood products, urea-formaldehyde resin is often employed in wood products because of its cost-effectiveness and ability to provide good bonding properties. However, one notable drawback is that it needs to be waterproof. Additionally, there are concerns about the emission of formaldehyde gas from products using urea formaldehyde, which can adversely affect human health and indoor air quality. Efforts are made to mitigate these concerns through modifications, alternative binders, or other means to reduce formaldehyde emissions.


Figure 3: Urea-formaldehyde (UF)

2.3.4. Flour

Flour is a powdery stuff made by grinding grains, nuts, seeds, or roots. It can be used as a binder in fiberboard production. When combined with other materials like sawdust and coconut fiber husk, flour acts as a glue, helping to hold the fibers together during manufacturing. This helps create a sturdy and durable fiberboard product [30].

Flour and water could act as extenders or fillers in the resin mixture, affecting its viscosity and curing characteristics. However, this would require careful experimentation to ensure that the resulting fiberboards meet the required strength, durability, and moisture resistance standards.

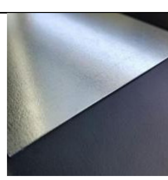
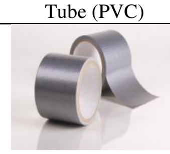
Combining flour, water, and urea as a resin in fiberboard production is an interesting concept. Urea-formaldehyde resin is commonly used in commercial fiberboard manufacturing due to its excellent binding properties and cost-effectiveness. However, the addition of flour and water would likely alter the properties of the resin mixture. Flour can be used as a raw material for environment-friendly adhesives used in fiberboard production [30].

Studies were done on flour to explore its potential as a new adhesive application. Flour is abundant, renewable, inexpensive, and readily available [31].

Figure 4: Flour

2.4. Tools and Equipment Used in the Study

TABLE I.
Tools and Equipment Used in the Study

TOOLS AND EQUIPMENT		
 Mixing Bowl	 Plywood	 Zip-Lock Bag
 Protective Mask	 Hand Gloves	 Lumber
 Tape Measure	 Plastic Wrap	 Heavy Duty Oven
 Weighing Scale	 Metal Sheets	 Candle
 Polyvinyl Chloride Tube (PVC)	 Sound Level Meter	 Speaker
 Duct Tape		

2.5. Utilizing the Acoustic Fiberboard

2.5.1. Mixing and Proportion

Experimentalsamples were categorized into three different proportions.

TABLEII.
Experimental Sample Proportions using 2 inches thickness

Sample	**Sawdust (%)**	**Coconut Husk (%)**	**Thickness**
Proportion 1	70	30	2 inches
Proportion 2	60	40	2 inches
Proportion 3	50	50	2 inches

TABLEIII.
Experimental Sample Proportions using 3 inches thickness

Sample	**Sawdust (%)**	**Coconut Husk (%)**	**Thickness**
Proportion 1	70	30	3 inches
Proportion 2	60	40	3 inches
Proportion 3	50	50	3 inches

TABLE IV.
Experimental Sample Proportions using 4 inches thickness

Sample	**Sawdust (%)**	**Coconut Husk (%)**	**Thickness**
Proportion 1	70	30	4 inches
Proportion 2	60	40	4 inches
Proportion 3	50	50	4 inches

The Journal of Applied Engineering and Technological Science (vol. 4) served as the basis for portions 1 and 2 while the researchers designed Proportion 3. To determine which of the samples would yield the best results, the researchers created various ratios.

Each experimental sample proportion was used in analyzing acoustic properties, compressive strength, moisture content, water absorption, and fire resistance as the researchers aimed to obtain which ratio or proportion and thickness satisfies the conventional standards.

2.5.2. *Production of the Acoustic Fiberboard Samples*

a. The two primary composites, comprising sawdust and coconut fiber husk, were meticulously enclosed within zip-lock bags and subsequently subjected to a sterilization procedure.

Figure 5. Sterilization

b. Principles of ratio and proportion were conducted to the primary composites based on the desired sample mixture of the study. Three ratios were considered: 70% sawdust, 30% coconut fiber husk; 60% sawdust, 40% coconut fiber husk; and 50% sawdust, 50% coconut fiber husk.

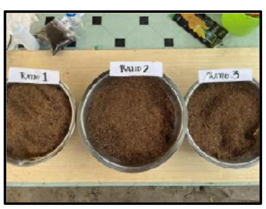


Figure 6. Ratio and Proportion of the Primary Composites

c. Mix the primary composites with the binding agent.
d. Put the saturated mixed composites in the molders to take the desired shape; after a few minutes, remove it and set it aside.

Figure7. Saturated Fiberboard Specimens

III. RESULTS AND DISCUSSION

3.1 *Data Description*

This study carefully examined the results from the experimental variable group, ensuring a comprehensive analysis of their impact on the overall research outcomes. The sound absorption test of each sample mixture was tested individually; each sample logged an individual decibel and was calculated by computing their average decibel outcome. On the other side, the compressive strength, moisture content, and water absorption test of each proportion were assessed by tabulating the average strength of three samples of each proportion, and fire resistance testing ran a comparative analysis on the fiberboard composites and the conventional materials used.

3.2 *Data Analysis and Findings*

The experiments used a composite board as the experimental substrate, employing a standardized specimen by ASTM standards (D3501, D4442, D1037) and ISO criterion (11925-2). The experimental setups were performed on different amounts of substrates: Proportion 1 (P1) - 70% sawdust and 30% Coconut Fiber Husk (CFH); Proportion 2 (P2) - 60% sawdust and 40% Coconut Fiber Husk; Proportion 3 (P3) - 50% sawdust, 50% Coconut Fiber Husk. The researchers did a self-directed analysis for the sound absorption test of the sample specimen after all the mechanical and physical tests. A mechanical test was accomplished for the Compressive Strength Test (CST). Meanwhile, physical examinations were conducted for the Moisture Content, Water Absorption, and Fire Ignitability Tests. The results obtained during the process are presented in the following table; each was organized in a tabular format for more transparent comprehension as follows:

3.2.1 *Sound Absorption*

A. Sound Absorption Ability Testing of the Fiberboard

The researchers used decibels as the unit of sound in this study. Decibels (dB) serve as a measurement unit to quantify the intensity of sound, as well as for expressing signal strength in fields like acoustics, telecommunications, and electronics.

In this study, the researchers used self-directed inquiry to test the sound absorption ability of the sample specimens. The researchers used a test that is designed by echo engineering where the sample specimen is inserted inside a tube; on one end of the tube a speaker is in, and on the other end a decibel meter is measuring the sound.

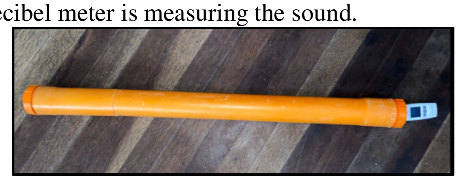


Figure 8. Sound Absorption Testing Apparatus

The researchers tested nine sample specimens in a cylindrical shape with a 3-inch diameter base. They were grouped into three categories based on their mixture ratio, which was 70% sawdust, 30% coconut fiber husk, 60% sawdust, 40% coconut fiber husk, 50% sawdust, and 50% sawdust. Each ratio had three different thicknesses, which were 2 inches,3 inches, and 4 inches.

Each sample was inserted in the 1-meter polyvinyl chloride pipe and tested individually. A white noise with a decibel sound of 90 decibels was played on one end of the tube while the sound level meter was placed on the other end of the PVC pipe to record the needed data.

TABLE V.
Test Result For Sound Absorption

Sample Identification	Thickness	Decibel Recorded	Average
P1 – 1	2 inches	40.3 dB	34. 53 dB
P1 – 2	3 inches	33.7 dB	
P1 – 3	4 inches	29.6 dB	
P2 – 1	2 inches	44.1 dB	36.17 dB
P2 – 2	3 inches	32.9 dB	
P2 – 3	4 inches	31.5 dB	
P3 – 1	2 inches	43.2 dB	43.4 dB
P3 – 2	3 inches	45.1 dB	
P3 – 3	4 inches	41.9 dB	

The results from the sound absorption testing of the nine sample specimens are shown in the table above. Three different proportions (P1, P2, and P3) had three different thicknesses, and their respective recorded decibel were recorded. Each proportion of the decibel average data is displayed in the table.

Proportion 1 was a mixture of 70% sawdust and 30% coconut fiber husk; its sample with a 2-inch thickness recorded 40.3 dB, while its sample with a 3-inch thickness captured 33.7 dB. The sample with 4 inches of thickness in P1 logged an impressive 29.6 dB. The total average decibel of the P1 file was 34.53 dB.

Proportion 2 was a fusion of 60% sawdust and 40% coconut fiber husk. Its sample with 2 inches of thickness captured 44.1 dB, its sample with 3 inches registered 32.9 dB, and its sample with 4 inches of thickness stored 31.5 dB. P2 cataloged a total average of 36.17 dB.

Proportion 3 was a combination of 50% sawdust and 50% coconut fiber husk; its sample with 2 inches of thickness resulted in 43.2 dB, its sample with 3 inches of thickness had an outcome of 45.1 dB, and the sample with 4 inches of thickness in P3 produced 41.9 dB. The total average decibel of P3 was logged at 43.4 dB. Following prevailing construction standards and regulations, the minimum soundproofing specification for walls and partitions must adhere to a threshold of at least 40 decibels. This requirement ensured adequate measures to mitigate noise transmission between adjacent spaces, enhancing overall acoustic comfort and privacy within the built environment.

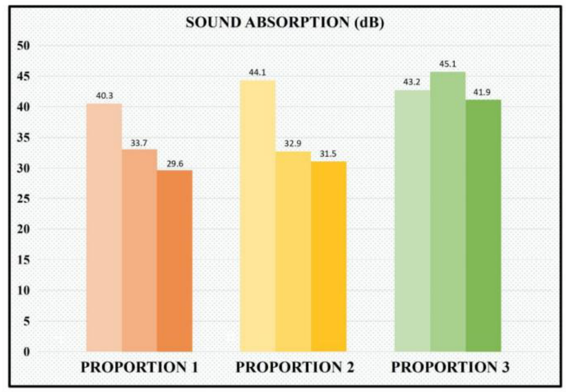


Figure 9. Sound Absorption Test Results

Figure No. 9 flaunts the graph of the 9 sample specimens recorded decibels when a 90 decibels white noise was being played on the other side of the PVC pipe.

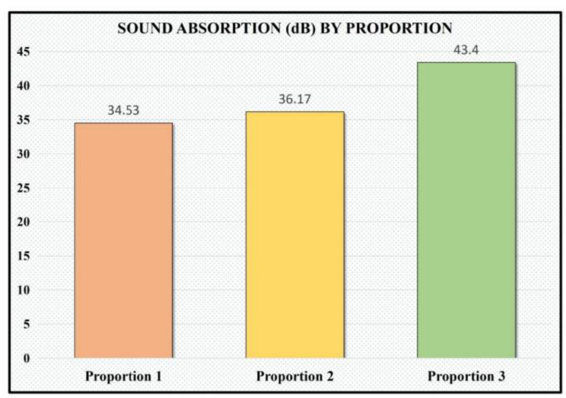


Figure 10. Average Sound Absorption Test Results Based on Proportion

Figure No. 10, exhibits the graph of the average decibel recorded on the three different proportions (P1, P2, P3), accumulated through the sound absorption testing.

P1 accumulated an average of 34.53 dB from the three different thicknesses, while P2 recorded an average of 36.17 dB, and subsequently, P3 logged an average of 43.4 dB.

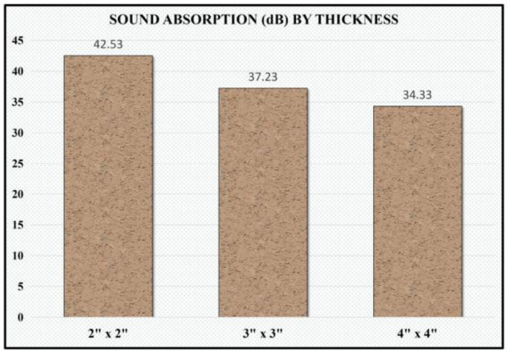


*Figure 11.*Average Sound Absorption TestResults Based onThickness

Figure 11 demonstrates the graph of the average decibel recorded based on the three different thicknesses gathered through sound absorption testing. A 2-inch thickness collected an average of 42.53 dB, P2 amassed an average of 37.23 dB, and P3 accumulated an average of 34.33 dB.

The three proportions and thicknesses achieved commendable results, satisfying the prescribed decibel standard for acoustic partitions. However, Proportions 1- and 4-inches thickness emerged as the most notable performer. This observation underscores the importance of design considerations and technical precision in acoustics, highlighting superior performance relative to its counterparts within this specific context of acoustic partitioning.

3.2.2. Compressive Strength

The Compressive Strength Test (TCT) is a mechanical procedure utilized in research to ascertain a material's maximum compressive load capacity before it fractures. This method involves applying a gradually increasing load to compress the test specimen between the base plate of a compression-testing apparatus. Specifically, ASTM D3501 - Standard Test Methods for Wood-Based Structural Panels in a Compression test fixture, designed to exert a compressive load on the central portion of the specimen.

TABLE VI.
Test Result for Standard Test Methods for Wood-Based Structural Panels in aCompression (ASTM D3501)

Sample Identification	**Actual Dimensions (mm)**			**Maximum Load (N)**	**Compressive Strength**			
	Length	**Width**	**Height**		**psi**	**Average**	**MPa**	**Average**
P1 – 1	47.1	46.12	47.52	8996	600		4.14	
P1 – 2	61.01	61.12	67.8	8983	350	364	2.41	2.51
P1 – 3	97.12	94.7	94.3	8971	142		0.98	
P2 – 1	48.21	46.2	51.8	6710	437		3.01	
P2 – 2	62.14	63.47	70.1	6690	247	262	1.7	1.80
P2 – 3	98.7	95.9	95.7	6615	102		0.7	
P3 – 1	47.13	46.9	48.12	6621	334		2.30	
P3 – 2	63.44	65.8	69.7	7751	270	234	1.86	1.61
P3 – 3	101.1	99.7	98.1	6871	99		0.68	

The findings regarding the compressive strength of the composite mixture are presented in Table 4. This table outlines data for three distinct proportions (P1, P2, and P3), each comprising three samples designated as 1, 2, and 3. The table details the actual dimensions, maximum load, and compressive strength determined for each specimen.

In the case of P1, comprised of 70% sawdust and 30% CFH (Coconut Husk Fiber)sawdust, two samples exhibited notably high compressive strength within this proportion, measuring 4.14 MPa and 2.41 MPa, with corresponding maximum loads of 8996 N and 8963 N. For P2, consisting of 60% sawdust and 40% CFH sawdust, an average compressive strength of 1.80 MPa or 262 psi was achieved. Similarly, P3, with an equal ratio of both substrates, attained an average compressive strength of 1.61 MPa or 234 psi.

According to the Standard Test Methods for Wood-Based Structural Panels in Compression (ASTM D3501), this method assesses compressive strength properties and evaluates the maximum compressive strength [34]. Concerning thisstudy, the P1 exceeded the required minimum for a composite board that could be used asa partition wall, which was 2.5 MPa [35].

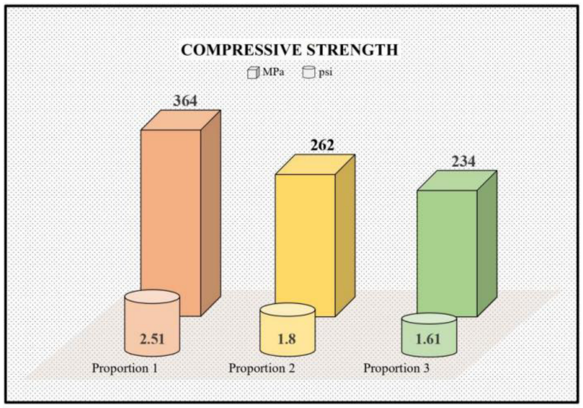


Figure 12. Compressive Strength Test Results

In Figure 12, the graph depicts the average compressive strength of the three distinct proportions as determined through testing. Notably, the graph illustrates that P1 achieved the highest level of compressive strength among the tested proportions.

P1 attained an average compressive strength of 2.51 MPa or 364 psi, which was 39.44% higher than P2 and 55.55% higher than P3. Additionally, the compressive strength of P1 developed from this study was recorded at 2.51 MPa or 364 psi, which performed satisfactorily based on the required minimum for a composite board that couldbe used as a partition wall, which had 2.5 MPa [35]. However, P2 and P3 failed to pass by lacking 28% and 35.6%, respectively, from the minimum.

Based on the findings, the composition consisting of 60% sawdust and 40% CFH did not meet the standard for compressive strength in partition walls. However, the mixture comprising 70% sawdust and 30% CFH (designated as P1) exhibited the highest compressive strength among the three ratios tested, meeting the maximum standard for partition walls; furthermore, it indicates that an equal ratio of substrates does not surpass the prescribed minimum compressive strength.

3.2.3 Moisture Content

ASTM D4442 outlines moisture content tests for various materials like wood and veneer, including those with adhesives and additives. Moisture content refers to the total water in a material, expressed as a percentage of water to solids in a sample volume. Wood-based materials' moisture content can be indicated as a percentage of the oven-dried weight (oven-dry basis) or its initial mass (wet basis), with the former being the standard in this standard.

TABLE VII.
Result for Direct Moisture Content of Wood And Wood-Base Materials(ASTM D4442) – Method A – Oven-Drying (Primary)

Sample Identification	Initial Weight, Wi (g)	Oven-dried Weight, Wd (g)	Moisture Content (ώ%)	Average
P1 – 1	126	109	15.60	11.32
P1 – 2	440	398	10.55	
P1 – 3	995	923	7.80	
P2 – 1	113.5	101.5	11.82	8.19
P2 – 2	424	394	7.61	
P2 - 3	970	922.5	5.15	
P3 - 1	117.5	102	15.20	8.89
P3 - 2	433.5	404	7.30	
P3 - 3	1060.5	1018	4.17	

Three different proportions (P1, P2, and P3) have three samples labeled 1, 2, and 3. Table 7 determines the initial weight of sample specimens for each proportion, oven-dried weight, and moisture content.

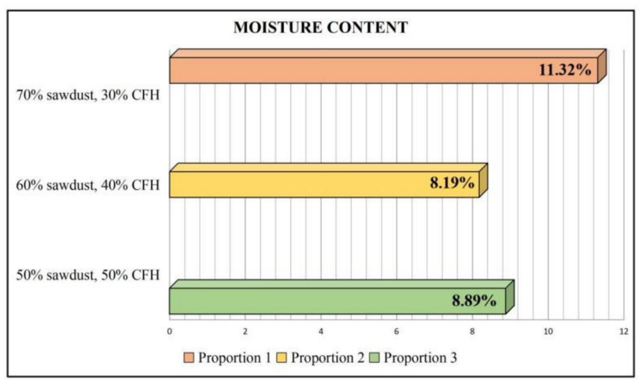


Figure 13. Moisture Content Results Based on Proportion

The moisture absorption rate of fiberboards was notably affected by the composition of the substrate. As shown in Figure 13, Proportion 1, which was the 70% sawdust and 30% coconut fiber husk, recorded an average of 11.32%, while Proportion 2, which was the 60% sawdust and 40% coconut fiber husk, and Proportion 3, which was the 50% sawdust and 50% coconut fiber husk accumulated a moisture content of 8.19% and 8.89%, respectively. As the amount of sawdust in composite increases, moisture absorption also increases. This was because sawdust has high water porosity and hydrophilic properties [36].

3.2.4 Water Absorption

TABLE VIII.
Results for Water Absorption of Wood and Wood-Base Material(ASTM D1037) – 24-Hour Soaked in Water

Sample Identification	Sample Size (in)	Proportion (%)		Oven-dried Weight, W (g)	Weight after soaked, W' (g)	Water Absorption (%)	Average (%)
		S	CFH				
P1 - 1	2x2	70	30	109	116	6.42	20.67
P1 - 2	3x3			398	492	23.62	
P1 - 3	4x4			923	1218	31.96	
P2 - 1	2x2	60	40	92	116	26.09	18.72
P2 - 2	3x3			394	463	17.51	
P2 - 3	4x4			922	1037	12.47	
P3 - 1	2x2	50	50	91	105	15.38	12.40
P3 - 2	3x3			404	456	12.87	
P3 - 3	4x4			1018	1109	8.94	

Table 8 shows the composite mixture's water absorption results. Three different proportions (P1, P2, and P3) with three sample thicknesses are labeled as 1, 2, and 3. The table also determines the oven-dried weight, the weight after being soaked for 24 hours, and the water absorption.

As shown in Table No. 8, P1 recorded an average of 20.67%, while P2 and P3 achieved 18.72% and 12.40%, respectively. Some sources cited that 5–12% is considered normal, and up to 17% is acceptable. When the moisture content of wood reaches 35 to 50%, it begins to rot and becomes prone to mold growth. Generally, wood can withstand up to 25% without degrading [37]. This indicates that the samples from this study showed better moisture absorption.

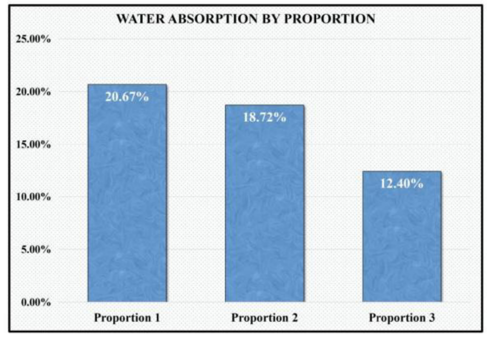


Figure 14. Water Absorption Results Based on Proportion

As shown in Figure No.14, water absorption increases as the amount of sawdust in the sample increases compared to the coconut husk fiber. Sawdust's high water porosity and hydrophilic properties caused this finding [38]. The structure of the samples also increased water absorption.

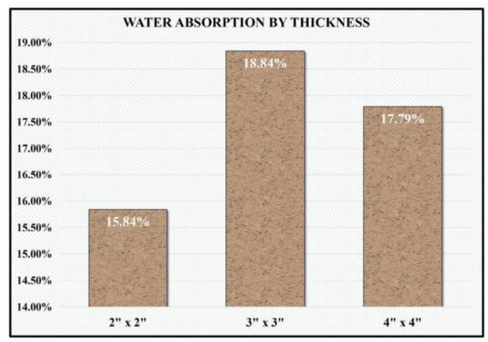


FIGURE 15. WATER ABSORPTION RESULTS BASED ON THICKNESS

As shown in Figure No.15, as the thickness of the samples increases, their ability to absorb water also increases. The results of a study that was carried out indicate that there is a significant relationship between the thickness of the specimen and its ability to absorb water, which calls for more investigation in this area of study [39].

3.2.5. Fire Resistance

The test determines the ignitability of a horizontally oriented test specimen when exposed to a small flame. This evaluation involves closely observing how the flame spreads across the specimen and measuring the time it takes for the entire specimen to be fully ignited. To ensure the accuracy of the results, a closed metal chamber was utilized to shield the test environment from any external factors that could interfere with the ignition process, such as wind or fluctuations in temperature.

TABLE 9.
Fiberboard Composite Fire Test Result

Sample	Time before getting ignited
Proportion 1	17:25 s
Proportion 2	15:43 s
Proportion 3	16:55 s

Table 9 shows the fire test results for the composite mixture, three separate proportions (P1, P2, and P3.)

TABLE 10.
Conventional Wood-Based Panel Board Fire Test Result

Sample	Time
Sample 1	10:46 s
Sample 2	11:14 s
Sample 3	11:03 s
Average time:	11:01 s

Table 10 presents the fire test results for conventional wood-based panel board, three separate samples (S1, S2, and S3), and their average time.

After completing the tests, researchers analyzed the data collected from three distinct fiberboard samples. These samples were subjected to the same testing conditions as the plyboard, with their ignition times carefully measured and recorded. By comparing the ignition times of the fiberboard samples to the established average ignition time of the plyboard, researchers gained valuable insights into the ignitability characteristics of the fiberboard composite mixture relative to this widely utilized material.

This comparative analysis provides a comprehensive understanding of how fiberboard composite mixture performs regarding fire resistance compared to plyboard, a material with known properties. By examining the differences in ignition times, researchers can identify potential strengths and weaknesses of fiberboard in fire-prone scenarios. These insights are crucial for making informed decisions about the suitability of fiberboard for various applications where fire safety is a concern.

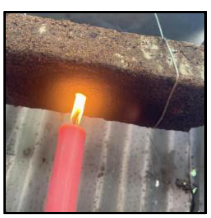


Figure 16. Fiberboard Composite Mixture Samples During Direct Heat

The setup shown in Figure 16 consists of fiberboard mixtures placed directly above the candle's flame. These mixtures were exposed to the heat and flame emitted by the candle.The purpose of this setup was to subject the fiberboard mixtures to the heat and flame of the candle in a controlled environment. By placing the samples directly above the fire source and enclosing them within the metal box, any external influences or disturbances that could affect the ignition process were minimized or eliminated.

The samples remained within the closed metal box until they were fully ignited, allowing for thorough observation and measurement of their burning behavior. This controlled environment ensured consistent testing conditions, enabling researchers to accurately assess the ignitability characteristics of the Fiberboard mixtures.

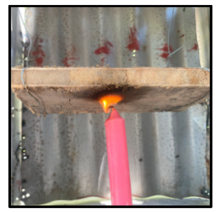


Figure 17. Plyboard Samples During Direct Heat

Figure 17 shows the replication of the same experimental process carried out with the fiberboard samples, mirroring the setup and procedures outlined in Figure 16. The primary objective of Figure 17 was to establish a basis for comparison between the recorded ignition times of the fiberboard samples.

By replicating the experimental setup and procedures, researchers ensured consistency and reliability in the testing methodology. This replication allowed for a direct comparison of the ignition times of the fiberboard samples tested in Figure 17 with those obtained from the original experiment depicted in Figure 16.

Figure 18. Fiberboard Composite Mixture and Plyboard Sample after Ignition

Following ignition, the recorded times for each test condition were carefully documented and compared. For plyboard composite mixtures, Proportion 1 exhibited an ignition time of 17 minutes and 25 seconds, Proportion 2 recorded 15 minutes and 43 seconds, and Proportion 3 registered 16 minutes and 55 seconds. Conversely, plyboard samples yielded ignition times of 10 minutes and 46 seconds for Sample 1, 11 minutes and 14 seconds for Sample 2, and 11 minutes and 3 seconds for Sample 3, with an average ignition time across samples of 11 minutes and 1 second.

Upon comparison, a noticeable trend emerged. It shows that fiberboard composite mixtures consistently displayed longer ignition times than plyboard samples. This observation suggests that Fiberboard may possess a higher resistance to ignition compared to plyboard. The extended ignition times of the Fiberboard composite mixtures indicate a slower rate of combustion or greater difficulty in initiating combustion compared to plyboard. This comparison underscores the potential for the Fiberboard composite mixture to offer improved fire resistance properties relative to plyboard.

3.3. Effectiveness of the Fiberboard

Acoustic fiberboard-based composite is a trailblazing engineering material that has many positive assets. The effectiveness of the acoustic fiberboard as a partition material in comparison to other conventional materials using standards and different research was shown in the following tables.

3. 3.1 Effectiveness of the Fiberboard Composites in Sound Absorption

4.

TABLE 11.
Sound Absorption Effectiveness of the Fiberboard Based on Proportion

Sound Absorption by Proportion	
Samples	**Sound Absorbed**
Proportion 1	45.47 dB - 55.47 dB
Proportion 2	43.83 dB - 53.83 dB
Proportion 3	36.6 dB - 46.6 dB
Standard: minimum of 40 db	

As indicated in the testing of the samples in their sound absorption capabilities a basis of 80 dB to 90 dB white noise was recorded in the absence of the products. The researchers aimed to get a minimum of 40 decibels less when the specimens were placed as it was the standard objective for the conventional acoustic materials.

Table 11 shows the three proportions and how much sound they absorbed in the unit of decibels. Satisfyingly, all of the three proportions competently satisfied the given standard. However, proportion 1 displays the most satisfactory data as it absorbed the most decibels with an amusing minimum of 45.47 dB and a maximum of 55.47 dB sound absorbed. Thus, based on the proportion in sound absorption, proportion 1 which was the 70% sawdust and 30% coconut fiber husk prevailed its acoustic excellence among the other proportions.

TABLE 12.
Sound Absorption Effectiveness of the Fiberboard Based on Thickness

Sound Absorption by Thickness	
Thickness	**Sound Absorbed**
2 inches	37.47 dB - 47.47 dB
3 inches	42.77 dB - 52.77 dB
4 inches	45.57 dB - 55.67 dB
Standard: minimum of 40 db	

Table 12 exhibits the three thicknesses and how much sound they absorbed in the unit of decibels. Satisfactorily, all three proportions adequately satisfied the given standard. However, the sample with a 4-inch thickness exhibits the most satisfactory data as it absorbed the most decibels with an amusing minimum of 45.57 dB and a maximum of 55.67 dB. Therefore, based on thickness in sound absorption, the specimen with 4 inches of thickness triumphed in its acoustic excellence among the other thicknesses.

3.3.2. Effectiveness of the Fiberboard Composites in Compressive Strength

TABLE 13.
Compressive Strength of Various Materials (Based on Findings)

Compressive Strength		
Proportion 1	2.51 Mpa	ASTM D3501
Proportion 2	1.8 Mpa	
Proportion 3	1.61 Mpa	
Standard Partition Wall	2.5 Mpa	Ohijeagbon et al

Table 13 shows the compressive strength of the fiberboard composite compared to different studies. The compressive strength of P1 developed from this study was recorded to be 2.51 MPa, which performed satisfactorily based on the required minimum for a composite board that could be used as a partition wall with the standard of 2.5 MPa [35]. On this note, the proportion 1 fiberboard composite that was developed in this study had compressive strength that exceeded what variant analysis suggested and demonstrated.

3.3.3. Effectiveness of the FiberboardComposites in Moisture Content

TABLE 14.
Moisture Content of Various Materials (Based on Findings)

Moisture Content		
Proportion 1	11.32%	ASTM D4442
Proportion 2	8.19 %	
Proportion 3	8.89 %	
Standard Partition Wall	5-15%	IS3087

Table 14 shows the moisture content of the fiberboard composites compared to IS 3087 standards. The average moisture content for samples P1, P2, and P3 developed from this study was recorded to be 11.32%, 8.19%, and 8.89%, respectively, which performed satisfactorily based on the required minimum for a composite board that could be used as a partition wall, which was 5–15%, according to the IS 3087 standard.

Moreover, the moisture content percentages for Thickness 1, which was 2 inches, Thickness 2, which was 3 inches, and Thickness 3, which was 4 inches, exhibited 5.71%, 8.49%, and 14.21%, respectively. These outcomes also met the required standard for composite boards' moisture content, which was adequate for partition wall applications, aligning with the 5–15% standard established for wood-based partition walls.

3.3.4. Effectiveness of the Fiberboard Composites in Water Absorption

TABLE 15.
Water Absorption of Various Materials (Based on Findings)

Water Absorption		
Proportion 1	20.67 %	ASTM D1037-12
Proportion 2	18.72 %	
Proportion 3	12.40 %	
Standard Partition Wall	25%	InterNACHI®

Table 15 presents the water absorption percentages of the fiberboard composite in comparison to findings from various studies. In this study, based on ASTM D1037-12, the water absorption percentages of P1, P2, and P3 were determined to be 20.67%, 18.72%, and 12.40%, respectively. These values met the necessary standard for composite boards intended for use as partition walls, which is 25%, a benchmark comparable to wood-based partitions [37].

Furthermore, the water absorption percentages for Thickness 1, Thickness 2, and Thickness 3 were found to be 15.84%, 18.84%, and 17.79% respectively. These results also met the required standard for composite boards suitable for partition wall applications, aligning with the 25% threshold established for wood-based partition walls.

3.3.4. Effectiveness of the Fiberboard Composites in Fire Resistance

TABLE 16.
Fire Resistance Effectiveness of the Fiberboard

Fire Resistance	
Samples	**Time before getting ignited**
Proportion 1	17:25 s
Proportion 2	15:43 s
Proportion 3	16:55 s
Conventional Wood-Based Panel Board	11:01 s

Table 16 shows the fire test results. It reveals that the best time recorded for fiberboard composite was proportion 1, which contained 70% sawdust and 30% coconut fiber husk, which recorded 17:25 seconds, outperforming the average time recorded for conventional wood-based panel board with 11:01 seconds. This indicates that fiberboard composite offers superior fire resistance properties compared to plyboard. The longer ignition time recorded for the best-performing fiberboard composite sample underscores its ability to withstand ignition for an extended period, highlighting its suitability for applications where fire safety is critical. Overall, these findings demonstrate the clear advantage of fiberboard composite over conventional material in terms of fire resistance, making it a preferred choice for environments where fire safety is a primary concern.

In summary, the comparison between the two highlights the undeniable superiority of the proportion 1 mixture in terms of fire resistance. This superiority positions the researchers' composite board as a reliable and effective alternative to partition walls, offering enhanced safety and protection against fire hazards in various applications and environments.

IV. CONCLUSION AND RECOMMENDATIONS

4.2. Conclusion

Extensive testing on fiberboard composites made from sawdust and coconut husk fiber has provided detailed insights into their appropriateness for soundproofing applications. Rough testing that included soundproofing properties, compressive strength, moisture content, water absorption, and fire absorption obtained a comprehensive understanding of the material's performance.

With regard to soundproofing effectiveness, Proportion 1 emerged as a strong competitor, satisfying the minimum decibel criterion for acoustic partitioning. However, Proportion 3's performance differed substantially from the projected standard decibel level, indicating opportunities for improvement in soundproofing efficiency. This feature distinguished P1 as an attractive solution for locations requiring noise reduction, such as residential, commercial, or industrial settings.

Regarding compressive strength, P1 performed satisfactorily, satisfying the specifications for partition wall applications. Despite falling short of the minimum requirement, Proportions 2 and 3 demonstrated significant compressive strength, indicating their possible value in less demanding structural contexts.

Furthermore, this investigation of moisture content demonstrated that P1 could absorb more water than other mixes. While this may create worries about moisture management, it is essential to emphasize that moisture absorption levels are adequate. Furthermore, the relationship between sample thickness and moisture content shows that thickness modifications indicate fine-tuning moisture management capabilities.

This study also investigated fiberboard composite materials' water absorption properties, incorporating varying proportions of sawdust and coconut husk fiber. Notably, the sample with a composition of 70% sawdust and 30% coconut husk fiber (P1) exhibited the highest water absorption capacity, indicating a direct relationship between sawdust content and moisture absorption. Moreover, the study revealed a correlation between sample thickness and water absorption, with thicker samples generally displaying higher water absorption rates.

In terms of fire absorption, fiberboard composites outperformed typical plyboard. Proportion 1 showed excellent resistance to ignition, with an ignition duration of more than 17 minutes. Proportions 2 and 3 likewise demonstrated significant fire resistance but with significantly shorter igniting periods, establishing them as viable options for fire-safe soundproofing solutions.

After thoroughly examining the outcomes obtained, it became evident that Proportion 1 emerged as the most successful candidate across all tests conducted. Specifically, the fiberboard composite comprising 70% sawdust and 30% coconut husk fiber demonstrated superior performance compared to other compositions. This observation highlights the effectiveness of this particular blend in enhancing the desired properties of the fiberboard.

4.3. Recommendations

The study took a full academic year to complete. By concentrating on the findings from relevant studies, the researchers were able to determine what needed to be changed or upgraded to develop a successful process for creating the soundproof panel board. Numerous unfavorable elements were seen and experienced, which made it difficult for the researchers to carry out their findings smoothly. The recommendations that follow were made to use the observations that have been gathered in future studies.

1. Employ another method for testing the sound absorption capability of the fiberboard. The researchers recommend utilizing an impedance tube based on the ASTM standards to ensure the acquisition of more precise and accurate findings. This approach ensures that the data collected is reliable and can be confidently used for further analysis and interpretation.

2. Continue research into the utilization of various binding agents to assess potential impacts on the compressive strength and other mechanical properties of the final product when alternative resins are employed. The researchers ponder whether this investigation holds significance as it offers insights into optimizing material selection, ensuring structural integrity, and enhancing product performance.

3. Conduct a comparative analysis between the cost of fiberboard composites and traditional plyboards, commonly utilized in partition walls, for informed decision-making in construction projects. This assessment provides valuable insights into the economic feasibility and efficiency of different materials.

4. Investigate if incorporating supplemental sodium borate has a direct impact on the mechanical properties of the fiberboard, like compressive strength, moisture content, water absorption, and fire resistance.

5. Investigate the application of a single plant species for sawdust and evaluate its distinct characteristics when combined in different ratios. With this method, it is possible to concentrate on examining how the special qualities and properties of the selected species enhance the features of panel boards.

6. Seek out accredited testing facilities to increase accuracy and give one access to advanced equipment and knowledge, both of which are necessary for reliable outcomes.

7. Utilize a standardized testing method for analyzing the fire resistance of the fiberboard composite with the guidance of ISO 11925-2.
8. Explore various variable usages of the fiberboard composite following its mechanical and physical properties.

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REFERENCES

[1]. D. N. B. Tawasil, E. Aminudin, N. H. Abdul Shukor Lim, N. M. Z. Nik Soh, P. C. Leng, G. H. T. Ling, and M. H. Ahmad, “Coconut fibre and sawdust as green building materials: A laboratory assessment on physical and mechanical properties of particleboards,” Buildings, vol. 11, no. 6, Jun. 2021.

[2]. O.S. Chathurangani, W. J. M. K. Perera, H. M. N. S. Kumari, G. H. M. J. S. De Silva, and G. S. Y. De Silva, “Utilization of Sawdust and Coconut Coir Fiber for producing Noise reducing Wall Tile.”

[3]. C. H. Huang, J. H. Lin, C. W. Lou, and Y. T. Tsai, “The efficacy of coconut fibers on the sound-absorbing and thermal-insulating nonwoven composite board,” Fibers Polym., vol. 14, no. 8, pp. 1378–1385, Aug. 2013.

[4]. F. Maharlika and Aida, “Utilization of Sawdust as Interior Acoustic,” in IOP Conference Series: Materials Science and Engineering, 2020, vol. 879, no. 1.

[5]. J. Singh, R. Laurenti, R. Sinha, and B. Frostell, “Progress and challenges to the global waste management system,” Waste Manag. Res., vol. 32, no. 9, pp. 800–812, Sep. 2014.

[6]. P. M. Macatangay, E. C. Magndayao, and C. A. M. Rosales, "Utilization of Agricultural Waste in the Manufacture of Composite Boards,".

[7]. V.P. Arida, A.L. Gonzales, O.G. Atienz, D.L. Pugal, “THE PHILIPPINE JOURNAL OF SCIENCE.” VOL. 116, No. 2, 1987.

[8]. Philippine Statistics Authority. "Coconut Production," PSA, 2022. [Online]. Available: https://psa.gov.ph/major-non-food-industrial crops/coconut#:~:text=The%20coconut%20(with%20husk)%20production,the%20same%20quarter%20of%202022.

[9]. C. W. Kang, S. W. Oh, T. B. Lee, W. Kang, and J. Matsumura, “Sound absorption capability and mechanical properties of a composite rice hull and sawdust board,” J. Wood Sci., vol. 58, no. 3, pp. 273–278, 2012.

[10]. RS Components. "Soundproofing Guide." RS Online,https://ph.rsonline.com/web/content/discovery/ideas-and-advice/soundproofing-guide.

[11]. J. Nyumutsu, A. Agyei-Agyemang, Y. Andoh, P. O. Tawiah, and B. A. Asaaga, “THE POTENTIAL OF SAWDUST AND COCONUT FIBER AS SOUND-REDUCTION MATERIALS.”

[12]. F. Maharlika and Aida, “Utilization of Sawdust as Interior Acoustic,” in IOP Conference Series: Materials Science and Engineering, IOP Publishing Ltd, Aug. 2020. doi: 10.1088/1757-899X/879/1/012157.

[13]. W. Ahmed, R. A. Khushnood, S. A. Memon, S. Ahmad, W. L. Baloch, and M. Usman, “Effective use of sawdust for the production of eco-friendly and thermal-energy efficient normal weight and lightweight concretes with tailored fracture properties,” J Clean Prod, vol. 184, pp. 1016–1027, May 2018, doi: 10.1016/j.jclepro.2018.03.009.

[14]. P. Paramasivam and Y. O. Loke, “Study of sawdust concrete,” 1980.

[15]. R. P. Memon, A. Rahman, M. Sam, A. S. M. A. Awal, and L. Achekzai, “Jurnal Teknologi Full Paper MECHANICAL AND THERMAL PROPERTIES OF SAWDUST CONCRETE,” 2017. [Online]. Available: www.jurnalteknologi.utm.my

[16]. T. N. Storodubtseva, A. Aksomitny, and V. A. Saldaev, “The study of soundproofing properties of wood polymer-sand composite,” in Solid State Phenomena, Trans Tech Publications Ltd, 2018, pp. 993–998. doi: 10.4028/www.scientific.net/SSP.284.993.

[17]. S. Sengupta and G. Basu, “Properties of Coconut Fiber,” in Encyclopedia of Renewable and Sustainable Materials: Volume 1-5, vol. 1–5, Elsevier, 2020, pp. 263–281. doi: 10.1016/B978-0-12-803581-8.04122-9.

[18]. J. E. G. Van Dam, M. J. A. Van Den Oever, and E. R. P. Keijsers, “Production process for high density high performance binderless boards from whole coconut husk,” in Industrial Crops and Products, Jul. 2004, pp. 97–101. doi: 10.1016/j.indcrop.2003.12.017.

[19]. S. Panyakaew and S. Fotios, “New thermal insulation boards made from coconut husk and bagasse,” Energy Build, vol. 43, no. 7, pp. 1732–1739, Jul. 2011, doi: 10.1016/j.enbuild.2011.03.015.

[20]. N. Ngadiman et al., “Panel Board from Coconut Fibre and Pet Bottle,” in E3S Web of Conferences, EDP Sciences, Mar. 2018. doi: 10.1051/e3sconf/20183401014.

[21]. M. F. Omar, M. A. H. Abdullah, N. A. Rashid, A. L. Abdul Rani, and N. A. Illias, “The Application of Coconut Fiber as Insulation Ceiling Board in Building Construction,” in IOP Conference Series: Materials Science and Engineering, IOP Publishing Ltd, Jul. 2020. doi: 10.1088/1757-899X/864/1/012196.

[22]. C. P. Araújo Junior et al., “Binderless Fiberboards Made from Unripe Coconut Husks,” Waste Biomass Valorization, vol. 9, no. 11, pp. 2245–2254, Nov. 2018, doi: 10.1007/s12649-017-9979-9.

[23]. C. H. Huang, J. H. Lin, C. W. Lou, and Y. T. Tsai, “The efficacy of coconut fibers on the sound-absorbing and thermal-insulating nonwoven composite board,” Fibers and Polymers, vol. 14, no. 8, pp. 1378–1385, Aug. 2013, doi: 10.1007/s12221-013-1378-7.

[24]. N. H. Bhingare and S. Prakash, “An experimental and theoretical investigation of coconut coir material for sound absorption characteristics,” in Materials Today: Proceedings, Elsevier Ltd, 2020, pp. 1545–1551. doi: 10.1016/j.matpr.2020.09.401.

[25]. M. Hosseini Fouladi, M. J. M. Nor, M. Ayub, and Z. A. Leman, “Utilization of coir fiber in multilayer acoustic absorption panel,” Applied Acoustics, vol. 71, no. 3, pp. 241–249, Mar. 2010, doi: 10.1016/j.apacoust.2009.09.003.

[26]. M. Hosseini Fouladi, M. Ayub, and M. Jailani Mohd Nor, “Analysis of coir fiber acoustical characteristics,” Applied Acoustics, vol. 72, no. 1, pp. 35–42, Jan. 2011, doi: 10.1016/j.apacoust.2010.09.007

[27]. C. Author, R. Zulkifli, and M. Jailani Mohd Nor, “Noise Control Using Coconut Coir Fiber Sound Absorber with Porous Layer Backing and Perforated Panel,” Am J Appl Sci, vol. 7, no. 2, pp. 260–264, 2010.

[28]. M. Hosseini Fouladi, M. J. M. Nor, M. Ayub, and M. Ghassem, "Enhancement of coir fiber normal incidence sound absorption coefficient," Journal of Computational Acoustics, vol. 20, no. 1, Mar. 2012, doi: 10.1142/S0218396X11004493.

[29]. M. Dunky, "Urea-formaldehyde (UF) adhesive resins for wood," 1998.

[30]. Yang, I., Han, G. S., Ahn, S. H., Choi, I. G., Kim, Y. H., & Oh, S. C. (2014). Adhesive Properties of Medium-Density Fiberboards Fabricated with Rapeseed Flour-Based Adhesive Resins. The Journal of Adhesion, 90(4), 279–295. Retrieved from: https://doi.org/10.1080/00218464.2013.793161

[31]. A. Moubarik, H. R. Mansouri, A. P., Ahmed, A. F. Charrier, M. A. Badia, & B. C. (2013). Evaluation of mechanical and physical properties of industrial particleboard bonded with a corn flour–urea formaldehyde adhesive.Retrievedfrom: https://doi.org/10.1016/j.compositesb.2012.07.041

[32]. Acoustical Surfaces, "Sound Transmission Class (STC) Rating," Acoustical Surfaces Blog. [Online]. Available: https://www.acousticalsurfaces.com/blog/acoustics-education/sound-transmission-class-stc-rating/?fbclid=IwAR3_FAePnFssJTA-JHywfokcH-E9fYvx6_pl3mfg-DWNkVQ9qrx1uQHm5mw

[33]. I. O. Ohijeagbon, A. A. Adeleke, V. T. Mustapha, J. A. Olorunmaiye, I. P. Okokpujie, and P. P. Ikubanni, "Development and characterization of wood-polypropylene plastic-cement composite board," Case Studies in Construction Materials, vol. 13, Dec. 2020, doi: 10.1016/j.cscm.2020.e00365.

[34]. Test Methods for Wood-Based Structural Panels in Compression," doi: https://doi.org/10.1520/d3501-05ar11.

[35]. Ohijeagbon, I., Adeleke, A., Mustapha, V., Olorunmaiye, J., Okokpujie, I., and Ikubanni, P. (2020). Development and characterization of wood polypropylene plastic-cement composite board. Case Studies in Construction Materials. 13. Retrieved from: doi: 10.1016/j.cscm.2020.e00365 (Accessed April 21, 2023)

[36]. Burlacu, A., Gavril, S., Abid, C., Barbuta, M., Verdes, M., Vizitiu, R., and Branoaea, M. (2022). Experimental Investigation on Mechanical and Thermal Properties of Concrete Using Waste Materials as an Aggregate Substitution. Retrieved from:https://www.researchgate.net/publication/369094517_Experimental_Investigation_on_Mechanical_and_Thermal_Properties_of_Concrete_Using_Waste_Materials_as_an_Aggregate_Substitution

[37]. "Moisture Meters for Home Inspectors," www.nachi.org.https://www.nachi.org/moisture- meters-home-inspectors.htm#:~:text=Readings%20of%205%20to%2012

[38]. G. Sosoi et al., "Experimental Investigation on Mechanical and Thermal Properties of Concrete Using Waste Materials as an Aggregate Substitution," Materials, vol. 15, no. 5, p. 1728, Jan. 2022, doi: https://doi.org/10.3390/ma15051728

[39]. X. Zhang, Y. Wang, B. Wan, G. Cai, and Y. Qu, "Effect of specimen thicknesses on water absorption and flexural strength of CFRP laminates subjected to water or alkaline solution immersion," Construction and Building Materials, vol. 208, pp. 314–325, May 2019, doi: https://doi.org/10.1016/j.conbuildmat.2019.03