Journal of Engineering, Architecture, and Informatics (JEAI)
Volume 1, Series 2021

Coconut Fiber and Pineapple Leaf Fiber Wall Panel Board

Bryan Joseph Guzman, Charls John Lee Sumer, Jerico Pader, Lance Stephen Domingo, Lyka Louise Torrado, Matthew Peter Uy, Darrel Jay Balbin

Civil Engineering Program
School of Engineering, Architecture, and Information Technology Education, University of Saint Louis
Tuguegarao City, Cagayan

***Abstract*— In recent years, the widespread use of wall panels in construction has underscored their industrial convenience. However, various panels exhibit weaknesses in practical applications, including significant dead weight, poor seismic performance, high water absorption, susceptibility to cracking, and failure to meet stringent energy-saving standards for thermal insulation. While gypsum boards have emerged as popular choices due to their economy, quality, and ease of use, their vulnerability to water damage remains a significant drawback. Consequently, this study aimed to produce 12 wall panel boards using coconut fiber (coir) and pineapple leaf fiber (PALF), comprising four distinct mixtures (GP, GPCP10, GPCP15, and GPCP20). The objective was to identify the optimal mix ratio through assessments of water absorption capacity and bulk density. Dry weight, wet weight, and volume measurements were obtained for each sample, enabling calculation of water absorption capacity and bulk density using prescribed formulas. These metrics were then compared to control samples (GP). Results revealed that GPCP10 exhibited the lowest water absorption, averaging 46.05%, and the highest bulk density, averaging 1.17%. This suggests that the composition of GPCP10 may offer the desired properties, demonstrating minimal water absorption and potentially superior flexural strength.**

Keywords*— *wall panels, coconut fiber, pineapple leaf fiber, building materials, water absorption

I. INTRODUCTION

A wall panel board, typically a flat, rectangular construction component, is commonly prefabricated offsite and transported as a fully assembled unit for installation or as a precast structure [1]. These boards are traditionally crafted from materials like concrete, fiberglass, timber, masonry, and gypsum. Gypsum boards, for instance, utilize gypsum as their primary constituent, distinguishing them from conventional fiberglass and concrete wall panels. Comprising gypsum, paper, and additives, gypsum boards find widespread use in covering interior walls, ceilings, and partitioning systems due to their cost-effectiveness and convenience [2]. However, their susceptibility to water, owing to their porous nature, poses a significant vulnerability, particularly in scenarios involving flooding or plumbing leaks.

To mitigate the construction industry's reliance on conventional materials like concrete and fiberglass, eco-friendly alternatives, known as eco-materials, have emerged. These materials, often derived from agricultural sources and featuring natural fibers, offer promising characteristics while minimizing environmental impact [3, 4]. Notably, coconut fiber or coir, extracted from coconut husks, presents remarkable attributes such as durability, acoustic resistance, non-toxicity, and resistance to moisture and degradation [5]. Similarly, pineapple leaf fiber (PALF), with its high cellulosic content, boasts excellent mechanical properties, finding applications in automotive and building sectors [6]. Despite these strengths, both coir and PALF exhibit weaknesses in moisture resistance, thermal stability, and dimensional stability, necessitating chemical treatment for enhancement [7].

In this study, the incorporation of coir and PALF, treated with sodium hydroxide (NaOH) solution, as reinforcements for gypsum boards is proposed. By maintaining a consistent composition ratio with traditional gypsum boards, the aim is to evaluate the water absorption capacity and bulk density of the resultant products. Through systematic testing, the goal is to identify the optimal mix ratio for coir and PALF in reinforcing wall panel boards, thus contributing to the advancement of eco-friendly construction materials.

II. RELATED WORKS

Natural fibers have been integral to human endeavors for centuries and have found diverse applications across various sectors such as automobiles, furniture, packaging, and construction [8, 9]. Compared to synthetic counterparts, natural fibers offer numerous advantages including favorable mechanical properties, cost-effectiveness, weight reduction, abundance, and sustainability [8, 9]. They have been utilized in a wide array of applications including building materials, particle boards, insulation boards, human and animal food, cosmetics, medicine, and other biopolymers and fine chemicals [10]. Researchers have extensively studied the use of natural fibers as reinforcements in composites, including cement paste, cement sand mortar, and concrete, with fibers such as coir, sisal, jute, eucalyptus grandis pulp, malva, ramie bast, pineapple leaf, kenaf bast, sansevieria leaf, abaca leaf, bamboo, palm, banana, hemp, flax, cotton, and sugarcane [10].

In a study by [14], coconut fiber and polyethylene terephthalate (PET) bottles were investigated as potential primary raw materials for panel boards. Coconut fiber replaced wood fiber as the panel filler, while recycled PET bottles served as the panel cover. Tests conducted on the coconut fiber panel board revealed superior properties, particularly in terms of swelling, water absorption, rupture modulus, and elasticity modulus, suggesting its suitability for applications such as closets, cabinets, and tables. Similarly, [15] examined wall panels reinforced with coconut fiber alongside gypsum and cement binders. While coconut fibers didn't significantly contribute to bending strength, they enhanced compressive strength and density while maintaining moisture content and water absorption levels. Additionally, [16] evaluated the suitability of bark-free oil palm trunk (OPT) in gypsum composites, demonstrating its thermal stability and mechanical performance.

Moreover, coconut husk fiber-reinforced composite wall panels [17] for heat insulation and soundproofing, reveals good trends in compressive strength, water absorption, and density with varying fiber content and curing age. Another study [18] explored coir fiber-reinforced composites for sound absorption panels, indicating promising acoustic properties. Furthermore, [19] demonstrated the mechanical and sound absorption enhancements achieved by adding coir fibers to wood particle debris, suggesting their applicability in automotive inner walls. Studies [20][21] also highlighted the noise absorption capabilities of kenaf and date palm fibers in insulation and plaster composites, respectively.

Regarding coconut fiber's application in partition walls, a study [22] reported its superior load-carrying capacity, bending, and compression strength compared to plywood, along with waterproof and economic advantages. Another study [23] investigated the use of rice husk and red clay-based geopolymer in wall panel board fabrication, revealing insights into flexural strength, bulk density, and thermal conductivity. Similarly, a study [24] explored the mechanical properties and moisture absorption behavior of polystyrene foam PALF fiberboard composites, emphasizing the influence of fiber percentage on tensile strength and moisture absorption.

III. METHODS

A. *Preparation of Materials*

Coconut husks and pineapple leaves were sourced from Iguig, Cagayan, and Gonzaga, Cagayan, respectively, and transported to Tuguegarao City for preparation. The husks and leaves underwent thorough washing to remove impurities before extraction. Table 1 presents the characteristics of the collected materials.

Coconut fibers (coir) were manually extracted by separating the hair-like fibers from the husks. Pineapple leaf fibers (PALF) were obtained by scratching the surface of the leaves before undergoing the chemical retting process, as depicted in Figure 1. Chemical retting involves dissolving much of the cellular tissues of the fibers, such as lignin, hemicellulose, and cellulose, with the aid of a chemical solution. The extracted fibers were immersed in a 6% sodium hydroxide (NaOH) solution for 24 hours. This concentration ensures better adhesion and yields optimum mechanical properties of the fibers [25-27]. NaOH pellets were procured from the market.

TABLE I. CHARACTERISTICS OF COCONUT HUSK AND PINEAPPLE LEAF

Characteristic	Coconut	Pineapple
Variety	Tall	Smooth Cayenne
Classification	Seed fiber	Leaf fiber
Color	Brown	Green
Length (cm)	100-200	300-500

Fig. 1. Preparation of the husks and leaves (left) before extraction (right)

The NaOH solution was prepared by dissolving NaOH pellets in tap water using a wooden pole as a stirrer. A 240-gram quantity of NaOH pellets was dissolved in tap water to achieve a 6% concentration.

Fig. 2. Dried coir (left) and PALF (right) after the chemical retting process

Figure 2 illustrates the appearance of coir and PALF after the chemical retting process. The fibers were then washed thoroughly with tap water until neutralized and sun-dried for an additional 24 hours.

B. Fabrication of Wall Panel Board

Table 2 outlines the batch compositions of gypsum powder (GP) and additives incorporated with varying amounts of coir and PALF (CP), ranging from 10% to 20% by weight based on the mass of gypsum powder.

TABLE II. BATCH COMPOSITIONS OF THE SAMPLE COMPOSITES BASED ON [23]

Batch Composition	Gypsum powder (g)	Coir and PALF % added (g)	Additives (g)	Water (g)
GP	336	0	96	500
GPCP10	336	33.6	96	500
GPCP15	336	50.4	96	500
GPCP20	336	67.2	96	500

The gypsum powder (GP) mixture served as the control sample without fiber content. Gypsum powder with 10% CP (GPCP10) contained 33.6 grams of fiber content, GPCP15 contained 50.4 grams, and GPCP20 contained the highest fiber content with 67.2 grams.

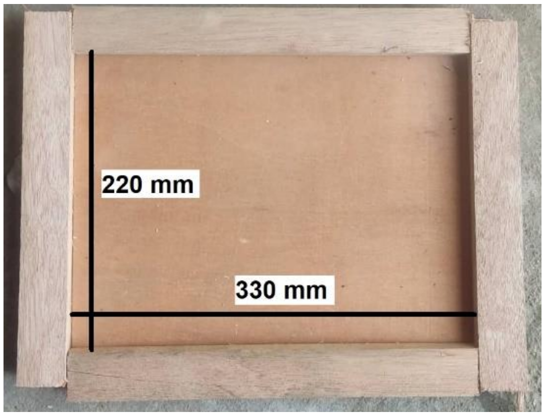

Fig. 3. Rectangular wooden mold for GPCP composites

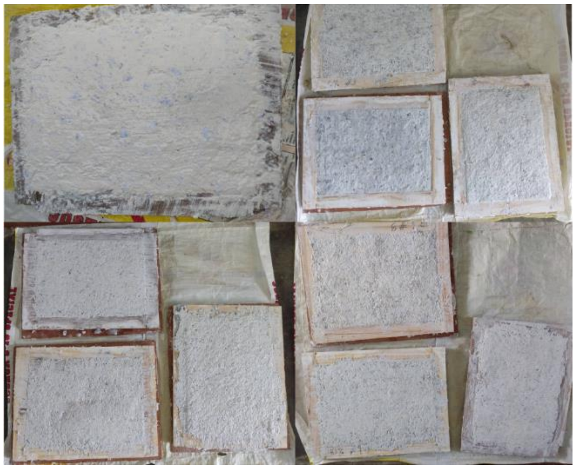

Fig. 4. Cast GPCP composites

These batch compositions were selected to achieve optimal water absorption, density, and mechanical strength properties [28]. The ratios facilitated sufficient fluidity for easy wetting of coir and PALF, enabling convenient mixing with the gypsum powder. Excessive solid ratios can lead to mixing difficulties due to high viscosity [29].

The homogenized composite slurries were cast into rectangular wooden molds with dimensions of 330mm by 220mm by 15mm, as depicted in Figure 3. This mold design offered optimal mechanical properties [23].

Figure 4 illustrates the casting of composite slurries into rectangular wooden molds. Three samples were produced for each batch composition to ensure data reliability. The composite samples were then sun-dried for 3 days.

C. Testing and Evaluation

To determine the water absorption capacity (WAC) of the composites, Equation 1 was applied following the method outlined by [30]. After sun-drying for 3 days and cooling, specimens were weighed (mdry), submerged in water for 24 hours, removed, patted dry, and reweighed (mwet).

$$\boldsymbol{WAC = \frac{m_{wet} - m_{dry}}{m_{dry}} \times 100} \quad (1)$$

Figure 5 depicts the weighing of dry GPCP composites before submerging in water. Surface irregularities observed were attributed to trapped air bubbles during casting, with the whitish color indicating the presence of coir and PALF particles.

Fig. 5. Weighing of dry GPCP composites with 10 (top), 15 (mid) and 20 (bottom) wt%

Figure 6 shows the submerged GPCP composites after dry weighing, displaying protruding fibers due to the casting method.

Fig. 6. GPCP composites with 10 (left), 15 (mid) and 20 (right) wt% submerged in water for 24 hours

Figure 7 presents the weighing of wet GPCP composites after submersion, indicating slight swelling due to remaining water content.

Fig. 7. GPCP composites with 10 (top), 15 (mid) and 20 (bottom) wt% after patted dry

Bulk density (ρ) was determined using equation (2) by dry weighing the samples and measuring their volume in cubic centimeters.

$$\boldsymbol{\rho} = \frac{\boldsymbol{Mg}}{\boldsymbol{Vg}} \qquad (2)$$

IV. RESULTS AND DISCUSSION

A. Water Absorption Capacity Test

Figure 8 shows the appearance of the GPCP composites after being patted dry with clean cloth. It can be observed that a little bit of their edges has been removed. This is due to not having a protective filament on both surfaces sandwiching the core or the homogenized composite slurry.

Fig. 8. GPCP composites with 10 (top), 15 (mid) and 20 (bottom) wt%

TABLE III. DRY AND WET WEIGHT OF THE GPCP COMPOSITES FOR WATER ABSORPTION TEST

Batch Composition	**Sample No.**		
	1	*2*	*3*
GP, mdry (g)	1210	1210	1220
GP, mwet (g)	1810	1800	1840
GPCP10, mdry (g)	1270	1280	1250
GPCP10, mwet (g)	1850	1870	1830
GPCP15, mdry (g)	1180	1150	1170
GPCP15, mwet (g)	1890	1820	1870
GPCP20, mdry (g)	1140	1150	1150
GPCP20, mwet (g)	1910	1900	1890

Table III outlines the dry and wet weights of various gypsum powder composite panels (GPCP) and pure gypsum powder (GP) composites used for water absorption testing. Each sample, categorized by batch composition and sample number, demonstrates varying weights in both dry and wet states. For instance, GP composites exhibit higher dry and wet weights compared to GPCP variants, suggesting a greater water absorption capacity with increased graphene content. Notably, as the fiber percentage in GPCP increases from 10% to 20%, there is a trend of decreasing dry weights alongside fluctuating wet weights. This data underscores the significance of fiber content in determining the water absorption properties of polymer composites, crucial for applications requiring moisture resistance and durability.

TABLE IV. WATER ABSORPTION CAPACITY OF GPCP COMPOSITES

Batch Composition	**Sample No.**		
	1	*2*	*3*
GP (%)	49.59	48.76	50.82
GPCP10 (%)	45.67	46.09	46.40
GPCP15 (%)	60.17	58.26	59.83
GPCP20 (%)	67.22	65.22	64.35

Table IV provides crucial insights into the water absorption capacities of GPCP (Gypsum Powder Composite

Panels) composites, essential for assessing their suitability in various applications. The results demonstrate a notable trend wherein higher percentages of fiber reinforcement correlate with increased water absorption resistance. Specifically, while pure gypsum powder exhibits relatively high water absorption percentages, GPCP formulations with 15% and 20% fiber content showcase significantly lower absorption rates, suggesting enhanced moisture resistance and durability. These findings underscore the pivotal role of fiber reinforcement in improving the water resistance properties of gypsum powder composites, informing material selection and design considerations in fields such as construction, where moisture management is paramount.

B. Bulk Density Test

Table V presents the dry weight and volume measurements of GPCP (Gypsum Powder Composite Panels) composites, essential for determining bulk density. Through categorization by batch composition and sample number, the table illustrates variations in both weight and volume across different composite formulations. Notably, while the dry weights exhibit differences reflecting the composition of each batch, the volume remains consistent at 1089 cubic centimeters for all samples. These findings provide valuable insights into the material characteristics, aiding in assessing the structural integrity and density variations of GPCP composites, crucial considerations in applications such as construction and material engineering.

TABLE V. DRY WEIGHT AND VOLUME OF THE GPCP COMPOSITES FOR BULK DENSITY TEST

Batch Composition	**Sample No.**		
	1	*2*	*3*
GP (g)	1210	1210	1220
GPCP10 (g)	1270	1280	1250
GPCP15 (g)	1180	1150	1170
GPCP20 (g)	1140	1150	1150
Volume (cm3)	1089	1089	1089

TABLE VI. WATER ABSORPTION CAPACITY OF GPCP COMPOSITES

Batch Composition	**Sample No.**		
	1	2	3
GP (g/cm3)	1.11	1.11	1.12
GPCP10 (g/cm3)	1.17	1.18	1.15
GPCP15 (g/cm3)	1.08	1.06	1.07
GPCP20 (g/cm3)	1.02	1.01	1.07

Table VI delineates the water absorption capacities of GPCP (Gypsum Powder Composite Panels) composites, categorized by batch composition and sample number, with measurements presented in grams per cubic centimeter (g/cm^3). Each entry signifies the density of the composite material, with GP (Gypsum Powder) serving as the baseline for comparison. The data highlights varying water absorption capacities among different composite formulations, with trends suggesting that higher percentages of fiber reinforcement result in lower densities and, consequently, enhanced water resistance. Notably, GPCP20 exhibits the lowest density across all samples, indicating its potential suitability for applications requiring superior moisture resistance. These findings emphasize the critical role of composite composition in determining material density and water absorption characteristics, crucial considerations for industries such as construction and material science.

V. CONCLUSION

The fabrication of a wall panel board was successfully demonstrated by the solidification of gypsum powder with coir and PALF. Specifically, the GPCP10 provided the lowest water absorption capacity. It has a lower water absorption capacity than the control samples, thus, implying suitability for indoor applications such as wall and ceiling claddings where moisture accumulation is kept at a minimum. On the other hand, increasing fiber content decreases the bulk density and, hypothetically, the gypsum composite flexural. It is best to go for GPCP10 as it shows more advantages than the other batch compositions to attain the desired mix ratio, as shown in the results.

The study tested the water absorption and bulk density of the core of a gypsum board; hence, it is not yet the finished product as the material's flexural strength is not yet tested. It is then recommended to sandwich the core between a layer of protective filament on both surfaces to determine whether it reduces the material's water absorption capacity and bulk density. For further research, it is good to attempt to modify the batch compositions (addition and substitution of materials used) to cater to and expand to other applications of wall panel boards. Conduct a flexural test (ASTM C78) using an unconfined compressive machine (AASHTO T208) to validate further the relationship between bulk density and flexural (mechanical) strength. Determine if oven drying the samples can shorten the solidification time and ensure a more accurate dry weight.

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