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Abaca Fiber (*Musa textilis* Nee) and Plastic Post-Consumer Wastes (A/PCW) as Potential Building Material

ABSTRACT

This study presents the utilization of flexible plastic post-consumer wastes combined with abaca (A/PCW) as a potential composite board for building industry. Employing a simple physico-mechanical process using S2 grade abaca fiber and flexible plastic PCW which produced composite board potential for building materials. Hence, the study investigated the best performing formulation of A/PCW composite based on its physical and mechanical properties. Three types of A/PCW samples with six specimen were prepared for each type. These are Sample 1, 2 and, 3 which has 50:50, 60:40, and 70:30 wt:wt ratio, respectively. Abaca fiber grade S2 with PCW made of polyethylene terephthalate (PET), and PET with metalized aluminium bonded with R10-103 agent were used to form a composite board. Sample 2 performed best among the samples by recording the most improved physical and mechanical properties. Analysis of Variance (ANOVA) in Statistical Package for the Social Sciences (SPSS) statistics tool was applied., The results supported and confirmed the experimental analyses.

Keywords: *abaca, composite board, flexible plastics, wastes utilization*

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INTRODUCTION

The Philippines is in the stage of development and is experiencing high demand of construction materials according to the Philippine Statistics Authority (PSA). This is due to the annual population growth rate of 1.73% for the period of 2010-2015 (*PSA 2015*), and the annual population growth rate projection of 1.59% for 2015 -2020. Housing backlog is among the challenges, being experienced by the Philippine Government. It was publicly announced in October 2017 that the country has 5.7 million housing backlogs. This is expected to increase to 7 million in 2020 if housing backlog will not be given attention soon. The average family monthly income in the Philippines is about twenty two thousand pesos (*PSA 2015*). Hence, this becomes a challenge for every family to buy or build a house. As a result, the construction industry, academe and research institutes continuously conduct research and develop new building materials focusing on local resources. Among the local resources available within reach of the researchers are the natural fibers from abaca (*Musa textilis* Nee). Another resource, which could be a potential building material when mixed with abaca is the post-consumer plastic waste. Flexible and general plastic wastes form 17% (*Senoro 2006*) and 20% by weight (*Sapuay 2016*), respectively in Philippine typical landfill. The combination of abaca with PCWs when its potential is proven effective could be a solution not only in housing problem but also to the plastic waste management problem of the society. The mechanical property of the abaca has been recognized as potential replacement for conventional reinforcement materials (*Dancel 2018; Kumar and Roy 2018*), such as metal, plastic, and wood. Impregnating into, or reinforcing a material with another will produce composite material that has enhanced or improved property (*Delicano 2018*) (**Table 1**).

Abaca, globally known as Manila hemp (*Musa textilis* Nee), is considered as one of the strongest fibers in the world. The abaca plantation in Marinduque island province started with 8-10 ha in Barangay Tugos wherein a cooperative was put up to capacitate farmers. Consequently, the Philippine Fiber Development Authority reported an increase of abaca production in 2010 (*DOST-MIMAROPA 2017*) to 2017 (*Arcalas 2017*). Albay Province, the biggest producer of abaca in the Philippines, acknowledged that the quality of the fiber produced in Marinduque have better quality compared to their region. However, Marinduque lacks the infrastructure in mass-producing abaca fibers as compared to Albay. Abaca Grade S2 produced in Marinduque offered extremely long (201-245 cm) fibers with superior tensile strength (*Moreno et al. 2010*), i.e., 27.67-32.08 kg $(gm\text{-}m)^{-1}$, compared to other natural fibers. The fiber yield and recovery range are 131.5-347.9 g per plant and 1.06-1.40%, respectively (*Moreno et al. 2010*). These properties created the abaca fiber a potentially effective reinforcement to polymer matrix and become a composite material for building industry.

The PCW flexible plastics are made of polymer, i.e., polyethylene terephthalate (PET) and some are made of a combination of PET and metalized aluminum. PET is a strong material that absorbs minimal moisture with melting temperature range of 250-260°C (*Mustafa 1993; ANS 1992*). PET with metallized aluminum flexible plastic is used extensively due to its durability, lightness, and strength property. These types of materials are used in food and health care industries. The work of *Grino* (*2012*) demonstrated that the rate of burning of PET laminate with metallized aluminum was about 52 mm in^{-1}. With the above mentioned characteristics of abaca and flexible plastics. This study conducted in 2017, utilized combined abaca and PCW with the binding agent to generate new composite product for the building industry. In building industry, the composite materials are made by combining two or more materials that become a homogenous or heterogeneous materials to maximize useful properties, minimize weaknesses and optimize usefulness. By choosing an appropriate combination of matrix and reinforcement material, a new material can be made, which exactly meets the requirements of a particular application. Examples of these types of works have been illustrated by some researchers/scientists in the Philippines (*Senoro et al. 2018; Senoro et al. 2014; Aspiras and Manalo 1995; Acda 2009; ITDI 2018; and Macatangay et al. 2012*) (**Table 1**).

Further, this is the first study, which generates new and usable composite material made of abaca fiber and PCW of plastic shampoo sachet. There are other related studies on wastes utilization, and abaca fiber (**Table 1 and 2**). However, this study is the first to combine both abaca fiber and PCW and harness its potential as a building material. Hence, this study addresses environmental sustainability, provides localized job opportunities and helps discover potential solution to the housing backlog problem in the country.

Various studies (*Elanchezhian 2018; Kalagi et al.2018; Sanjay and Yogesha 2017; Sanjay et al. 2018;*

Table 1. Various studies in wastes utilization in the Philippines on composites for building materials.

No.	Title of the Study	Outputs	Source
1	Effects of impregnation of organoclay in the thermo-physico-mechanical properties of recycled composite aluminates as barrier material	Barrier material for environmental protection	*Senoro et al. 2018*
2	Resistance factors and reliability index of recycled plastic aluminates as roofing shingles using LRFD and FORM methods.	Roofing shingles	*Senoro et al. 2014*
3	Utilization of textile waste cuttings as building materials	Building materials	*Aspiras and Manalo 1995*
4	Sustainable use of waste chicken feather for durable and low cost building materials for tropical climates	Low cost building materials	*Acda 2009*
5	Processing of polyester fiber from recycled polyethylene terephthalate (RPET)	Carpet fibers	*ITDI 2018*
6	Recycling/processing of foamed PS from food and electronic packaging into lightweight concrete and secondary products	Light weight construction products	*ITDI 2018*
7	Utilization of agricultural wastes in the manufacture of composite boards	Composite boards	*Macatangay et al. 2012*

Rahimi and Garcia 2017) used abaca fiber as component for building materials (**Table 2**). It was noted that plastics have various codes called SPI – RIC (Society of the Plastic Industry– Resin Identification Code) 7. This specific code was given attention in this study as properties, uses and recyclability of plastics vary with the code assignments (*Rahimi and Garcia 2017*). Plastics under SPI-RIC 7 are categorized as 'other plastics'. It contains multi-layer barrier films and is considered non-recyclable. However, this type of plastic was considered "recyclable" (*Senoro et al. 2018*) using simple physico-mechanical process; i.e., by using simple mixing process and equipment. The Australian/New Zealand Standards (*AS/NZS 1859 2017*) presented properties of various building boards, (i.e., commercial market and product development) as reference for composite board properties (**Table 3**). The typical physical and mechanical properties include thickness, density, morphology, tensile, bending, compression, modulus of elasticity, modulus of rupture, water absorption, and swelling (*AS/NZS 1859 2017; Freire et al. 2017; Marinho 2013; Wu 2018; Salari et al. 2013; Hiziroglu 2009; and PNS 230 1989*).

Table 2. Various studies using abaca fibers as a component of building materials.

No.	Title of the Study	Materials	Study Objective/s and/or Output/s	Source
1	Mechanical behaviour of plaster reinforced with abaca fibers	Abaca fibers, Gyproc Saint Goabain gypsum	As fiber-reinforced plasterboards with enhanced toughness	*Elanchezhian 2018*
2	Review of mechanical properties of natural fiber composites	Abaca, jute, sisal, banana, cotton coir, hemp	Mechanical properties of abaca, jute, sisal	*Kalagi et al. 2018*
3	Experimental study on mechanical properties of natural fiber reinforced polymer composite materials for wind turbine blades	Fabrics made up of multiple plies of parallel fibers stitched bonded with polyester thread	Alternative material for wind turbine blades	*Sanjay and Yogesha 2017*
4	Characterization and properties of natural fiber polymer composites: A comprehensive review	Natural fibers, synthetic fiber	Fabrication techniques for composite production, properties characterization techniques	*Sanjay et al. 2018*
5	Studies on natural/glass fiber reinforced polymer hybrid composites: An evolution	Two different natural fibers, glass fiber	Hybrid (natural/glass fiber polymer) composites	*Rahimi and Garcia 2017*

Table 3. Physical and mechanical properties of different boards as building materials.

Thickness Type	Thickness, mm	Density, kg m^{-3}	Water Absorption, % Wt	Swelling, % Thickness	Tensile Strength, MPa	Modulus of Elasticity, MPa	Modulus of Rupture, MPa	Source
A] Fiberboard and OSB								*AS/NZS 1859 2017, Freire et al. 2017, Marinho 2013*
Thin	2.5 – 5	800 - 850	ND*	ND	ND	3,450	34.5	
	6 - 9	775						
Medium	10 - 12 13 - 22	725	4.57 - 28	4.87 – 21.74	0.10 – 0.26	877.45 – 1297.51	8.94 – 11.10	
Thick	23 – 32.8	620 -650				2,400 – 3,450	24 – 34.5	
B] Hardboard (Fiberboard)								*Wu 2018*
	2.1		40	30				
	2.5		35	25				
	3.2		35	25				
	4.8		35	25	0.62 ⊥ to surface; 15.2 for // to surface	ND	31.0	
	6.4		25	20				
	7.9		20	15				
	9.5		15	10				
C] Composite								
OSB with nano SiO_2 (1 – 5%) with adhesive			52.85 – 122.32	31.3 – 95.38	ND	2,385 – 2,599	18.12 – 21.73	*Salari et al. 2013*
OSB with phenol formalehyde adhesive			ND	6.32 – 18.42	ND	2,845 – 3,331	17.5 – 21.3	*Hiziroglu 2009*
D] MDF in Philippines								
Standards			$\leq$30	$\leq$ 10	ND	ND	$\geq$ 13.7	*PNS 230:1989*

* ND = no data

MATERIALS AND METHODS

The study was conducted in Boac, Marinduque, Philippines from April to October 2017. Raw materials included were PCW plastic shampoo sachets (**Figure 1a**), untreated dried S2 grade abaca fibers (**Figure 1b**), and R10-103 binding agent (**Figure 1c**). The PCWs, classified as SPI-RIC 7, were collected from several households at five Barangays of Boac Municipality. These barangays were Mangyan-Mababad, Mogpog, Bantad, Mainit and Binunga, Boac. The sachets of shampoo were made of polyethylene terephthalate (PET) and most often combined with aluminum and laminate material. Other sachets do not have aluminum component. The untreated dried S2 grade abaca fibers about 0.5 mm in diameter and 3.0 m in length were purchased from Tumagabok, Boac, Marinduque. The binding agent, R10-103, was manufactured by Polymer Products (Phil) Inc., and was purchased in Manila, Philippines. The binding agent was composed of 40 mL resin and 15 mL hardener.

The devices/equipment (**Figure 3**) used were: cutter and scissors to produce plastic strips with size similar to the abaca fibers; digital balance weighing scale to measure the weight of the samples and determining the weight proportions; measuring tape to prepare samples with the same width and length; calliper to measure the thickness of the sample; three GI ga.26 moulders with size 51 mm x 80 mm x 15 mm for the formation of the new composite board; and 6 mm thick steel compactor to compress the raw materials with adhesive to obtain/produce the desired shape of the composite board.

The fabrication process and physico-mechanical property analyses

The PCW, primarily composed of PET and PET with aluminum, without defect, were collected and selected to be used in the study. The plastic wastes were cut into strips with a width of 3 mm and length of 50 mm and 80 mm, and the abaca, with a typical length of 3 m, was cut with length equal to the length of the plastic strips. Three types of samples, with six specimen each type, were prepared. These three types of samples were (1) 50:50, (2) 60:40, and (3) 70:30 wt:wt ratio proportion. The abaca ratio to plastic by weight was based on previous studies (**Table 1** and **2**). The PCW strips were placed in a transverse direction sandwiched by abaca fiber placed on a longitudinal direction (**Figure 4**). This means that the layer of PCW strips were placed in between of abaca fibers. The combined raw samples were placed in a Ga. 26 galvanized iron moulder layer by layer and spreading thin film layer of R10-103 binding agent between PCWs and abaca fibers. The amount of R10-103 binding agent was the same for all samples. Compaction followed, using a fabricated 6 mm thick steel compactor with vice grips. The desired thickness was 15 mm and drying was conducted at ambient air for 15-30 min while sample is in the mould. Physical and mechanical properties were analysed employing Philippine National Standards (PNS) 230: 1989 and its standards as the controlling variables. PNS 230:1989 is known as Specifications for Particle Boards (**Table 4**).

Physical tests were conducted to determine the mass (m), volume (V), specific gravity (SG), water absorption (WA), and thickness swelling (TS). The mechanical

Figure 3. Digital weighing scale and calliper used in the weighing and mesurements in the study.

Figure 2. The raw materials (a) post-consumer wastes; (b) Abaca S2 Grade; (c) Binding Agent.

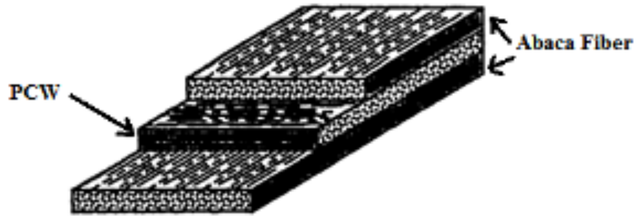

Figure 4. Stacking sequence of abaca fiber and plastic post-consumer wastes.

property tests were modulus of rupture (MOR), and nail head pull through (NHPT). The mean value per parameter for the six specimens collected for each type of samples were analyzed by quantitative analysis using equation 1 in which M represents the mean, n as the number of samples, and W represents the mechanical test of the new composite product. The dimension of all specimen were 50 mm x 80 mm x 15 mm for all properties tested (**Table 5**).

$$\text{Mean (M)} = \left(\frac{1}{n}\right)\left(\sum_{i=1}^{n} \text{Wi}\right) \tag{1}$$

The MOR is a flexural strength analysis of the material that could provide information on its maximum or yield strength before rupture occurs. This is a required test under PNS 230:1989. It determines the application of the product for structural components. The property result depends on the board density. A concentrated bending load was applied at the center with a span of 15 times the thickness of the specimen. Then, *MOR* can be calculated by load deflection curves using equation 2 with *P* as the maximum breaking load, *L* as the effective length in *cm*, *w* as the width in *cm* and *t* as the thickness of the specimen (sample).

$$MOR = \frac{3PL}{2wt^2} \tag{2}$$

The NHPT used both common and finishing nail. This is an important analysis in board material development as this material is installed using nails and/or screws. Integrity of installation such as the type of nails and distances between nails/screw could also be determined by the result of the NHPT analysis. The test was conducted using common and finishing nail, compression machine and PNS (**Table 4**). Standard deviations (SD) of the acquired data were also calculated and presented.

The water absorption (WA) test used a sample size and procedure prescribed by PNS 230:1989. The specimen was immersed in a distilled water for an initial 2 and 24 hours. After water immersion, weighing and calculation followed using equation 3 where A_w is equal to percent of

Table 4. Analyses of the physical and mechanical properties of the new composite product (board).

Test Conducted	Standard/s	Equipment/ Tool	Specifications	Brand
Static Bending	Philippine National Standards (PNS) 230:1989	Compression Machine	Proving Ring Constant: 500 kgf Capacity: 2.109696046 L: 65 mm	Tanfuji
Nail-head Pull Through	Philippine National Standards (PNS) 230:1989	Compression Machine	Proving Ring Constant: 500 kgf Capacity: 2.109696046 L: 65 mm	Tanfuji
Thickness Swelling	Philippine National Standards (PNS) 230:1989	Digital Scale	Capacity: 30 kg Division: 1 g Rechargeable Battery / Adaptor LCD Display with 3 changeable LED backlight (HIGH/OK/ LOW) Stainless Steel Top Plate - Size: 265 x 204 mm	n/a*
		Vernier Calliper	Accuracy: ±0.03 mm Graduation: 0.02 mm (0.001”)	n/a
Water Absorption	Philippine National Standards (PNS) 230:1989	Digital Scale	Capacity: 30 kg Division: 1g Rechargeable Battery / Adaptor LCD Display with 3 changeable LED backlight (HIGH/OK/ LOW) Stainless Steel Top Plate - Size: 265 x 204 mm	n/a
		Vernier Calliper	Accuracy: ±0.03mm Graduation: 0.02mm (0.001”)	n/a

* n/a = not available

weight increased or decreased, W_i and W_f are the initial and final weight of the specimen, respectively. The result will provide information on the short term and longer term water absorption capability of the sample.

$$A_w = \frac{W_f - W_i}{W_i} x\ 100\% \quad (3)$$

The swelling test was carried out also following the PNS 230. The standard requires that the thickness swelling test result of the specimen should be PNS compliant and not be more than 10%. Hence, the thickness swelling used the calliper and equation 4 where S_T is the swelling effect based on the specimen thickness; T_i and T_f are the initial and final thickness, respectively. Whereas, the specific gravity (*SG*) determination used the equation 5 where *F* is the final weight of the specimen, *K* is equal to 1 (SI units used) or 0.061 (inch-pound used), *L* is the length, *w* is the width, t as the thickness of the specimen,

$$S_T = \frac{T_f - T_i}{T_i} x\ 100\% \quad (4)$$

$$SG = \frac{KF}{Lwt} \quad (5)$$

Analysis of Variance (ANOVA) using statistical package for social sciences (SPSS) software was employed to analyze the results of WA, static bending for the MOR, NHPT, TS, SG. This is to determine the credibility of empirical data to help identify the most appropriate proportion of A/PCW composite. An F-statistic (Fs) greater than the F- critical (Fc) value is equivalent to a *p*-value less than alpha and both mean that you reject the null hypothesis which is represented by equation 6. The null hypothesis in this study means that there is “no significant difference between all established proportions which means no difference between Samples 1, 2 and 3.

$$F_s > F_c \approx p < \alpha \rightarrow reject\ null\ hypothesis \quad (6)$$

The properties of the material tested were compared with the prescribed properties of particleboard by Japan and other national standards of neighbouring countries. PNS 230:1989 was employed, as this is the appropriate standards for Philippine setting. PNS is equivalent to ISO, ASTM, JIS and similar standards of other countries. PNS was developed by Department of Trade and Industry-Bureau of Philippine Standards under Republic Act 4109 known as the Philippine Standardization Law (*Kojima and Atienza 2010*).

RESULTS AND DISCUSSION

The new composite product was cut into test sample size (**Figure 5**). The average mass was 60.06 g, 62.99 g, and 60.85 g for sample 1, 2 and 3, respectively (**Table 5**).

The overall best performing A/PCW composite board was Sample 2. This is the 60:40 A/PCW weight ratio. Sample 2 had the least mean WA rate of 2.62%, 0.04% TS, highest MOR 17.23 MPa, and 99.40 kgf NHPT. These properties made Sample 2 the best performing sample among the three types. However, all A/PCW composite boards have properties compliant to the PNS 230:1989. This standard requires WA of less than or equal to 30%, TS of less than or equal to 10%, and MOR of greater than or equal to 4.0 MPa. The results of the physical and mechanical strength of the composite board in this study were comparable with AS/NZS 1859 (*2017*), the works of *Marinho et al.* (*2013*) and *Wu* (*2018*) (**Table 3**). The physical and mechanical properties standard is a form of “range” and slightly varies between countries. Thus, it is important to follow the standards and properties of a specific country regarding the use of materials and compliance. Hence, the importance of following PNS standards in this study. The slight difference in range of property standards per parameter was associated with the climate differences (*Korai and Fujimito 1998*), especially the temperature which is a factor of swelling,and water absorption property. Japan, Australia and New Zealand have lower temperature than the Philippines; hence, absorption and swelling property standard upper limit of PNS 230:1989 is higher. This temperature association with the material strength was reported by the work of *Korai and Fujimoto* (*1998*). Abaca reinforcement to PCW composite increased the density. A sample of zero abaca

Figure 5. The new composite board cut into test sample size.

Table 5. Physical and mechanical properties of the new A/PCW product, *n* = 72.

Sample Type	Mean Dimension, mm			Mean Volume, cu. mm	Density, kg m^{-3}	Sp. Gr	Proportion of A/PCW, by % wt	Mean Water Absorption, % wt	Mean Swelling, % thickness	Mean Modulus of Rupture (MOR), MPa	Mean Nail Head Pull-Through (*PNS 230:1989*)	
	W	L	T								kgf	Gage Reading
1	50.98	79.32	14.93	60,373	995	0.99	50:50	6.07	2.47	10.74	63.10	18.87
2	50.44	79.99	15.71	63,385	994	1.03	60:40	2.62	0.04	17.23	99.40	31.22
3	50.35	79.44	14.77	59,054	1030	1.05	70:30	5.20	2.31	7.53	86.95	26.08
PNS								≤ 30	≤ 10	> 4.0	>45.89	
Result								PASSED	PASSED	PASSED	PASSED	

reinforcement was not included in the study because past studies (**Table 1** and **2**) showed that boards or any material with reinforcement of high tensile strength improved the mechanical properties of the material. Hence, this study focused on reinforced materials. All three types of samples are considered high-density board based on the acquired density range of 994-1030 kg m^{-3}.

The NHPT analysis on Sample 2, which used common nail, resisted the highest load of nail head pull through rather than the proportions 50:50 and 70:30. Comparing the obtained results to the PNS, the samples in all the proportions shown in the table passed the required NHPT capacity of greater than or equal to 450 N. Samples 1, 2, and 3 recorded an average NHPT capacity (using finishing nail) of 162.120 , 317.34, and 226.97 N respectively.

The NHPT analysis recorded was (using the common nail) 618.81, 974.79 and 852.68 N for Sample 1, 2, and 3, respectively. The NHPT analysis showed higher capacity by using common nail (**Figure 6**). The higher capacity using common nails was associated with its shaft design. However, the use of either common or finishing nail depends on the utilization area of the board. This result does not imply to use common nail but aid in making design using the A/PCW composite.

The result of MOR determined the load resistance capacity of each sample (**Table 6**). Samples 1, 2, and 3 recorded an average of about 109.53 kgf cm^{-2}, 175.67 kgf cm^{-2}, and 76.79 kg-f cm^{-2}, respectively. This result is similar to the results found by *Senoro et al.* (*2018*), *Macatangay et al.* (*2012*) and *Salari et al.* (*2013*) which showed that composite materials have higher mechanical property than the pristine product.

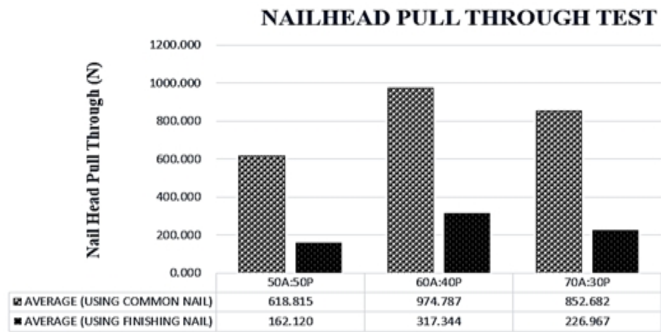

Figure 6. Result of nail head pull through analysis using common and finishing nail.

The result of the physical tests is recorded as follows: the specific gravity of Sample 1, 2, and 3 were 0.99, 1.03, and 1.05 respectively. This shows that increasing abaca weight increases the specific gravity. The water absorption rate were 6.07, 5.2 and 2.6% for Samples 1, 2, and 3, respectively. This shows that increase in abaca weight decreased the water absorption rate. The moisture content were 8.3, 6.4, and 9.1% for Sample 1, 2 and 3, respectively. The decreasing water absorption rate of composite board with increasing amount of abaca fiber was attributed to the deposition of aluminum present in the PCW matrix and bind with the increasing amount of abaca fiber. Thus, decreasing opportunity of water to be absorbed by the composite material. The thickness swelling were 2.47, 0.04, and 2.31% for Sample 1, 2 and 3, respectively. Both moisture content and thickness swelling point to Sample 2 as the best performing sample.

During the statistical analysis using ANOVA, the results in NHPT using common nail showed an F_s (5.74) greater than the F_c (5.14). This means that the null hypothesis shall be rejected. This means that there are significant differences in terms of capability among

Table 6. The nail head pull through and modolus of rupture results with Standard Deviation, *n*=18.

Sample 1: 50% Abaca + 50% post-consumer wastes.

Specimen	Nail Head Pull Through		SD	Modulus of Rupture	SD
1	Finishing	15.401	2.134	6.343	
2	Nail	18.987		11.386	
3		15.19		10.541	2.316
4	Common	65.401	7.753	12.678	
5	Nail	54.43		7.983	
6		69.406		10.308	

Sample 2: 60% Abaca + 40% post-consumer wastes.

Specimen	Nail Head Pull Through		SD	Modulus of Rupture	SD
1	Finishing	17.089	13.841	9.406	
2	Nail	35.865		16.332	
3		44.093		20.751	5.502
4	Common	91.35	20.216	14.617	
5	Nail	84.388		22.844	
6		122.362		9.902	

Sample 3: 70% Abaca + 30% post-consumer wastes.

Specimen	Nail Head Pull Through		SD	Modulus of Rupture	SD
1	Finishing	27.637	4.536	14.405	
2	Nail	23.207		7.36	
3		18.565		8.223	4.236
4	Common	95.147	8.025	17.426	
5	Nail	79.114		7.017	
6		86.498		11.193	

Samples 1, 2, and 3 when common nail was used. However, the F_s (2.93) was lesser than the F_c (5.14) when finishing nail was used. This means that there are no significant difference in NHPT capability among samples if finishing nail was used. Also, the statistical analysis for static bending showed that F_s (20.49) is far higher than F_c (5.14) which means that there are significant differences in static bending property of Samples 1, 2, and 3 recording Sample 2 with the highest MOR equivalent to 17.23 MPa. Also, ANOVA showed differences between samples for moisture content recording F_s (5.5), greater than F_c (5.14). Other properties of three samples indicated that there were no significant differences between proportions (various samples). These properties were water absorption rate, thickness swelling, and specific gravity. The statistical analysis of ANOVA and SPSS supported and validated the credibility of gathered empirical data during data collection. The use of ANOVA and SPSS also contributed to the various successful works of *Obuka et al.* (*2012*), *Muhammad et al.* (*2015*), *Carpino et al.* (*2017*), *Lassila et al.* (*2018*), *Munari et al.* (*2018*) *and Amini and Imaninasab* (*2018*).

CONCLUSIONS AND RECOMMENDATIONS

The idea of utilizing A/PCW was built upon the perspective of environmental sustainability. Hence, the result of the investigation on the possibility of producing a new composite product useful to building industry has been promising. The empirical assessed data showed that the overall best performing specimen was Sample 2. This is the 60:40 wt:wt A/PCW ratio. Sample 2 had the least mean water absorption (WA) rate of 2.62%, 0.04% thickness swelling (TS), highest MOR 17.23 MPa, and 99.40 kgf NHPT. The ANOVA with SPSS results support that there were significant differences on its static bending (MOR), NHPT (using common nails) and moisture content between samples. However, all A/PCW composite boards have properties compliant to the PNS 230:1989.

With these findings, products from waste plastics such as this may be given special attention by the concerned agencies to help eradicate problems associated with solid wastes and other related concerns and to produce additional source of income for low-earning families. A deeper study may be conducted such as increasing ratio of PCW instead of increasing fiber weight, 100% PCWs and considering other aspects such as marketability and cost-benefit analysis.

REFERENCES

Abesamis, J., Campos, J.C. and Castell C. 2013. "Estimating the effects of urbanization on carbon emissions: Evidence in the Philippines". Policy Brief; VII (1). ISSN#2094-3342.

Acda, M.N. 2009. "Sustainable use of waste chicken feather for durable and low cost building materials for tropical climates". Sustainable Agriculture: Technology, Planning and Management. Nova Science Publishers, Inc. ISBN:978-1-60876-269-9.

Acosta, V., Paul, J., Lao, C., Aguinaldo E. and Valdez M.D.C. 2012. "Development of the Philippines National Solid Waste Management Strategy 2012-2016". *Procedia Environmental Sciences* 16:9-16.

Amir Amini and Reza Imaninasab 2018. "Investigating the Effectiveness of Vacuum Tower Bottoms for Asphalt Rubber Binder Based on Performance Properties and Statistical Analysis". *Journal of Cleaner Production* 171: 1101 – 1110.

ANS, 1992. An American National Standard: Standard Test

Methods for Impact Resistance of Plastics and Electrical Insulating Materials. ASTM Headquarters, December 1992.

Arcalas, J. 2017. Abaca output up 5.3 percent in January – August. PhilFIDA; November 7, 2017

AS/NZS 1859. 2017. Reconstituted Wood-Based Panels Specifications. Australian/New Zealand Standards. AS/NZS 1859; 3: 2017.

Aspiras, F.F. and Manalo JRI. 1995. “Utilization of Textile Waste Cuttings as Building Materials”. *Journal of Materials Processing Technology* 48: 379 – 384.

Carpino, C., Bruno, R. and Arcuri, N. 2017. “Statistical analysis of the heating demand in residential buildings located in Mediterranean climate and proposals for refurbishment”. *Energy Procedia* 133: 16-27.

Cuevas, L.A. 2016. “Water pollution control and enforcement status and challenges in the Philippines”. Strategies and Practices for Water Pollution Enforcement Workshop. Taipei, Taiwan; 2016 November 8-10.

Dancel, R. 2018. “Abaca Fiber as Retrofitting Material.” Proceedings of Research for an International Conference, Manila, Philippines, 27-28 August 2018.

Delicano J.A., 2018. “A Review on Abaca Fiber Reinforced Composites.” *Journal of Composite Interfaces* 25 (12)

Department of Science and Technology-MIMAROPA 2017. 2010 Annual Report of DOST – MIMAROPA, Region 4b; 2017

Elanchezhian, C,, Rammath, B,V., Ramakrishnan, G., Rajendrakumar, M., Naveenkumar,,V. and Saravanakumar, M.K. 2018. “Review on Mechanical Properties of Natural Fiber Composites”. Materials today: Proceedings 5 (1): 1785 – 1790.

Freire, A.L.F., de Araujo, J.P., de Freitas, R.M., de Almeida, N.J.A. and de Figueiredo, M.C.B. 2017. “Environmental Assessment of Bioproducts in Development Stage: The Case of Fiberboards Made from Coconut Residues”. *Journal of Cleaner Production* 153:230-241

Grino, A. Jr. 2012. Investigation of Recycled Plastic Aluminates (RPA) with Organoclay: A Potential Construction Material as a Thermal Insulation and Water Vapor Barrier. MS Thesis. Mapua Institute of Technology, Manila Philippines

Hiziroglu, S. 2009. “Properties of Strandboard Panels Manufactured from Eastern Red cedar”. *Martials* 2:926-933; DOI:10.3390/ma2030926.

Israel, D.C. 2003. “The Quest for Better Environment: Past Experiences and Challenges”. Philippine Institute for Development Studies. ISBN 971-564-070-2: RP 12-03-500

ITDI 2018. Processing of Polyester Fiber from Recycled Polyethylene Terephthalate (RPET). Industrial Technology Development Institute Department of Science and Technology.

Iucolano, F., Caputo, D., Leboffe, F. and Liguori, B. 2015. “Mechanical Behaviour of Plaster Reinforced with Abaca Fibers of Plaster Reinforced with Abaca Fibers”. *Construction and Building Materials* 99: 184 – 191.

Kalagi, G.R., Patil, R., Nayak, N. 2018. “Experimental Study on Mechanical Properties of Natural Fiber Reinforced Polymer Composite Materials for Wind Turbine Blades”. *Materialstoday: Proceedings* 5: 2588 – 2596.

Korai, H. and Fujimito, Y. 1998. “Nail-Head Pull-Through Strength and Lateral Nail Resistance Strength of Wood-Based Boards Subjected to Various Climatic Conditions in Japan [2015]”. *Journal of Wood Science* ISSN: 1435-0211.

Kumar, P. and Roy. 2018. “Study and Experimental Investigation of Flow and Flexural Properties of Natural Fiber Reinforced Self Compacting Concrete.” *Procedia Computer Science* 125 [2018] 598 – 608.

Lais S. Munari, Alberto NG Antunes, Debora DH Monteiro, Allyson N. Moreira, Hugo H. Alvim and Claudia S. Magalhaes. 2018. “Microtensile Bond Strength of Composite Resin and Glass Ionomer Cement with Total-Etching or Self-Etching Universal Adhesive”. International *Journal of Adhesion and Adhesives* 82:36–40.

Lippo, L., Filip, K., Eija S., Pekka, K.V. and Sufyan, G. 2018. “Mechanical Properties and Fracture Behavior of Flowable Fiber Reinforced Composite Restorations”. *Dental Materials* 34: 598 – 606.

Macatangay, P.M., Magundayao, E.C., and Rosales C.A.M. 2012. “Utilization of Agricultural Wastes in the Manufacture of Composite Boards”. *ASEAN Journal Science and Technology for Development* 29 (2): 129 – 140.

Marinho N.P., do Nascimento, E.M., Nisgoski, S. and de Demenico, V.I. 2016. “Some Physical and Mechanical Properties of Medium-Density Fibreboard Made from Giant Bamboo”. *Materials Research* 16 (6): 1387 - 1392

Moreno, L.O., Parac, A.A., Ocon, F.L. and Gapasin, R.M. 2010. Fiber Characteristics of Promising Abaca (*Musa textilis* Nee) Accessions in NARC [National Abaca Research Center] Germplasm Suited for Specific Industry End Uses [2010]. Food and Agriculture Organization of the United Nations.

Muhammad, A.A., Alawi, S., Che Mohd, S.S., Ayub, M.S., and Meisam T. 2015. "Enhanced Rigidity of Natural Polymer Composite Developed from Oil Palm Decanter Cake". *Bioresources* 10 (1): 932-942.

Mustafa, N. 1993. Plastic Waste Management: Disposal, Recycling, and Reuse. Canadian Plastics Institute, Toronto, Ontario, Canada.

Obuka Nnaemeka Sylvester P., Ihueze, C.C., Okoli N.C. and Ikwu Gracefield, O.R. 2012. "Experimental Investigation and Statistical Analysis of Creep Properties of a Hybridized Epoxy-Alumina-Calcium Silicate Nanocomposite Material Operating at Elevated Temperatures". *International Journal of Scientific & Technology Research* 1 (6): ISSN 2277-8616.

Philippine National Standards 230. 1989. Standard Requirements for Medium Density Fiberboard (MDF). Philippine National Standards (PNS) 230: 1989.

Philippine Statistics Authority. 2015. Average Annual Population Growth Rates (PGR), by Five-Calendar Year Intervals, Philippines: 2010-2045. Philippine Statistics Authority, Philippines.

Rahimi, A. and Garcia, J.M. 2017. "Chemical Recycling of Waste Plastics for Ne.w Materials Production". *Nature Reviews Chemistry* 46: DOI:10.1038/s41570-017-0046.

Salari, A., Tabarsa, T., Khazaeian, A. and Saraeian A. 2013. "Improving Some of Applied Properties of Oriented Strand Board (OSB) Made from Underutilized Low Quality Paulownia (*Paulownia fortunie*) Wood Employing Nano-SiO2". *Industrial Crops and Products* 42:1-9.

Sanjay, M.R., Madhu, P., Jawaid, M., Senthamaraikannan, P., and Senthil, S. 2018. "Characterization and Properties of Natural Fiber Polymer Composites: A Comprehensive Review". *Journal of Cleaner Production* 172: 566 – 581.

Sanjay, M.R. and Yogesha, B.Y. 2017. "Studies on Natural/ Glass Fiber Reinforced Polymer Hybrid Composites: An Evolution". *Materials today: Proceedings* 4: 2739 – 2747.

Sapuay, G. 2016. "Resource Recovery Through RDF: Current Trends in Solid Wastes Management in the Philippines". *Procedia Environmental Sciences* 35:464 – 473.

Senoro, D.B., Grino, A. and Chan, E. 2018. "Effects of Impregnation of Organoclay in the Thermo-Physicomechanical Properties of Recycled Composite Aluminates as Barrier Material". *Defect and Diffusion Forum* 382: 12 – 20.

Senoro, D.B., Pourbeheshtiansabet, M., Cruz, E.S. and Basilia BA. 2014. "Resistance Factors and Reliability Index of Recycled Plastic Aluminates as Roofing Shingles using LRFD and FORM Methods". *Sustainable Environment Research* 4; 24 (5): 357 – 364

Senoro, D.B. 2006. Processing and Characterization of Recycled Plastic Aluminum Laminates Impregnated with Organoclay as Potential Landfill Liner. MS Thesis University of the Philippines Diliman, Philippines.

Wu, J.H. 2018. "Fiberboard". Lectures, Department of Forestry, Bio-based Composite Laboratory, National Chung Hsing University, Taiwan 2018.