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RESEARCH ARTICLE

Quaternary Ammonium Based Compound Improves Interfacial Bond and Hydrophobicity of Coirpith-Cement Composite

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Abstract

Coir pith is a coconut waste derived from the extraction of coconut fiber that accounts for 70% of total husk. With an estimated 6.7 million husks produced in the Philippines annually, a large fraction of waste known as coir pith is left to rot, thrown or burned. Coir pith in cement board composite is applicable as insulation and a light indoor construction material due to its high-water absorption properties and less strength. The study sought to solve the high-water absorption problem while aiming at improving the strength and durability of the composite that will meet the needs for indoor and outdoor construction materials. According to the study's findings, QUAC increases the hydrophobicity of coir pith-cement composites, improves interfacial bonds, and has the potential for light indoor and outdoor construction.

KEYWORDS:
coconut waste, coir pith, composite, QUAC, waste disposal.

1 | INTRODUCTION

Coconut husk is considered one of the largest farm wastes in the Philippines. The Philippines' average coconut production accounted for 14.6 million metric tons of coconut annually (PCA, 2015). The heaviest husk (dry weight) recorded was 0.46 kg (Pogosa et al., 2018). This leads to an estimated coconut husk generation of 6.7 million metric tons per year. Seventy (70) percent of the estimated husk volume is coir dust, otherwise termed coco pith, while the remaining thirty (30) percent are fibers. A projected volume of approximately 1.8 million metric tons is available for fiber production; however, only approximately 30% is converted into commercial coir. A large portion, including 70% of coco pith, is left to rot, thrown away, or burned (Niro, 2012). This waste, if not properly managed, could add to the problem of carbon emissions by becoming a breeding place for insects and other organisms that could be a vector of diseases.

Coir and its associated coir pith have gained popularity in cement composites in recent years as the industry shifts to alternative uses of renewable energy to reduce environmental impact and production costs (Brasileiro et al., 2013). The use of coir fiber in concrete reinforcement is deemed to increase tensile and flexural strength (Ferro G et al., 2015). When mixed into concrete, this helps control the growth of tensile cracking (Hamood et al., 2015). Natural fibers are used in the development of environmentally friendly construction materials to replace synthetic fibers. Natural fibers are cheap, biodegradable materials (Al-Masoodi et al., 2015) that can be explored for incorporation into cement in the production of low-cost building materials (Olurunnisola, 2008). A dearth of literature on the use of coir pith in cement composites still exists (Brasileiro et al., 2013).

The mechanical performance, however, of natural fiber in cement composites is influenced largely by the cement-fiber matrix interaction (Pereira et al., 2013). Interfacial bonding between these two materials is improved using chemical pre-treatment treatments such as alkaline treatment. This results in poor composite durability (Rao and Goud, 2010) and environmental issues.

Compatibility can be improved by coating lignocellulosic material (Frybort et al., 2008), forming a blocking layer (Simatupang et al., 1987) on the natural fiber surface using environmentally friendly technology.

Little is known about the effect of QUAC on raw fiber and related by-products. Sufficient studies point to the attributes of QUAC-based compounds in maintaining the durability and strength of fiber in fabric. Usually, QUAC-based compounds have a positive charge from the long alkyl chain that clings to the negative charge particles of the fiber that ensure the adsorption and soft feel of the fabric. It also has an anti-static agent to prevent the fiber from becoming entangled (Saraiva et al. 2008). QuAC-based compounds work by crosslinking interaction (ionic interaction) (Zia et al., 2011), thereby maintaining the natural mechanical properties of the fiber. Hydrophobic properties of the silicon content increase concentration around the yarn particle and create a film coating, which results in a decreased absorbency of the fiber. (Parvinzadeh and Hajiraissi, 2008). This property may improve the fiber-cement interfacial and solve the problem of the high moisture absorbency of coir pith.

2 | MATERIALS AND METHODS

2.1 | Coir pith and Cement Preparation

Coir pith was prepared by cutting the coconut husk into smaller sizes of approximately 5 cm and retted for 24 hours in tap water and allowed to drain for 12 hours to obtain sufficient moisture to ease the shredding process. The prepared coir husk was shredded using a shredder and run twice to obtain optimum production of coir and fiber. Thereafter, the long fiber was manually separated from the coir pith. The produced coir pith was sundried for 3 days under full sunlight as set by the researcher. This activity was done at DEBESMSCAT, Masbate. Portland cement was procured in Munoz, Nueva Ecija together with a QUAC-based compound. The moisture content of the prepared coir pith was taken using the oven drying method at the CLSU chemistry laboratory after soaking and drying for 3 days under full sunlight.

The quartering method was performed to secure the required sample materials for casting, wherein dried samples were divided into four quarters and two opposite sides were taken and mixed thoroughly. For coir dust-cement composite production, blended cement type IP of Portland cement with fly ash was utilized.

2.2 | QUAC based Solution Preparation and Soaking

The control (0), 25, 50, and 75 ml/l QUAC-based solutions were prepared in four separate containers properly labeled as T0, T1, T2, and T3 respectively. The solution was blended by paddling manually until a uniform mixture was attained. The prepared coir weight in accordance with the needed ratio for cement and composite (1:.11 by weight of cement adopted from Olurunnisola, 2008) was soaked and properly mixed. This was allowed to rest for 15 minutes and thereafter filtered with a net to drain solution and retain soaked material. As mentioned above, the retained material was sundried for 3 days.

2.3 | Production of the Composites.

The study produced two composites:

- Cement paste (CP): 100% cement with a water-cement ratio of .30 (control); Coir pith cement composite (CCC): 100% cement with 11% pith dry weight (1:.11 cement: coir pith), water ratio of .75 in 0, 25, 50, and 75 ml/l treatments. Mixing of water was adjusted to attain workability and compaction without pressing. Wooden moulds were used to produce composites, and a mould size of 50x50x100mm was prepared for compression tests.

- Coir pith and cement were dry mixed manually in a plastic container in a 1:.11 ratio, and water was added to create composites. This was placed in a prepared moulder and kept at an ambient room temperature of $28 \pm 2°C$ for 24 hours, then demoulded and cured at the same ambient temperature for 28 days. Compression test specimens were cured in distilled water for 28 days prior to testing.

2.4 | Physical and Mechanical Properties Test

Compressive strength was tested at DOST laboratory testing using the Matest Servotronic Compression Machine (UTM) with a rate of load of 1.80 kN/sec (August 05, 2016). Determination of the composites' physical properties such as bulk density, water absorption, and apparent porosity was done by adopting the method used by Brasileiro et al. (2013). The specimens were placed in an oven for 24 hours at 100 $\pm$ 5°C and their dry weight (Wd) was obtained. They were thereafter immersed in water for 24 hours. The immersed weight was determined using a hydrostatic balance (Wi). Saturated weight (Ws) was evaluated after the specimen was dried using absorbent paper. The following formula is used in the calculation of the physical properties.

- BD (g/cm3)=Wd/(Ws-Wi)
- WA (%)=(Ws-Wd).100/Wd
- AP (%)=(Ws-Wd).100/(Ws-Wi)

2.5 | Statistical Analysis

Four treatments (levels of concentration) of QUAC-based solutions have been replicated three times following CRD. The physical and mechanical properties tests were analyzed using one-way analysis of variance at a 5% level of significance after the Shapiro-Wilk test confirmed the normal distribution of samples (p >.05). Post hoc multiple comparisons of means were done using Tukey's test. All analyses were carried out using IBM SPSS Statistical Software version 22.

3 | RESULTS AND DISCUSSIONS

3.1 | Bulk density and Compressive strength

Data on bulk density and compressive strength are presented in a chart Figure 1 with error bars that represent means (homogenous group). The results of the study indicated a lower bulk density of cement composite with an increasing trend in the treated coir pith or coir fiber. A related study of Orunnisola (2009) indicates that lower bulk density is correlated with the presence of void and high porosity of the fiber particles. The same study by Brasileiro (2013) indicated that vegetal-aggregate cement composites showed low bulk density. There was no observed statistical difference among the treatment means as reflected in the one-way analysis of variance at a 5% significance level as indicated in Table 1. Moreover, compressive strength showed the same trend with no significant difference among the treatment means. The results indicated low compressive strength ranging from 4.86 for the untreated to 5.03 for the treated composites. The result is relatively higher compared to the studies of Orunnisola (2009) and Brasileiro (2013), where compressive strength is lower than 5 MPa but comparatively lower than sand-cement composites and cement paste composites, as cement paste is a ceramic material and sand is a hard-rigid aggregate, while fiber is soft and pliable with low loading capacity. Compressive strength is typical of a light weight construction material with a range of 3.5 to 4.5 MPa (Brasileiro, Veira, Barreto, 2013).

TABLE 1 Analysis of variance (F cal. Test) of the influence of QUAC based on the mechanical and physical properties of the composite.

Source of variation	BD	CS	WA	AP
Between groups	001	.418	1959.735	1728.852
Within groups	.001	.593	18.772	15.723
Total	.001	1.011	1978.508	1744.575
Fcalc	3.074	1.881	278.385*	293.217*
Sig.	.091	.211	0.00	0.00

3.2 | Water absorption and apparent porosity

Water absorption and apparent porosity are interdependent properties and are shown in Table 1 and the bar graph in Figure 2. The average water absorption ranges from 8.67–18.6 (treated) and 40.88% (untreated), relatively lower than in the study of Olurunnisola (2009) where absorption is less than 36%, excluding untreated composite. Xie et al. (2015) found 24.3–139.0%

water absorption after 28 days of curing. The same trend can be observed in apparent porosity. Treated composites have lower porosity than untreated composites. Table 2 presents the results of the analysis on water absorption and apparent porosity.

It has been discovered that coconut husk has a sponge-like affinity for water and the ability to absorb eight (8) times its weight (Olurunnisola, 2009). However, lower porosity can be attributed to the treatment used. The lower the void, the lower the water absorption, the denser the composite (Asasujarit, Charoenvai, Hirunlabh, Khedari, 2009). Analysis of variance at a 5% level revealed that treatments have significant effects on water absorption and apparent porosity. Tukey's test showed that composites with higher QUAC treatments (treatments 3 and 4) have lower porosity than composites with treatments 1 and 2 of high porosity.

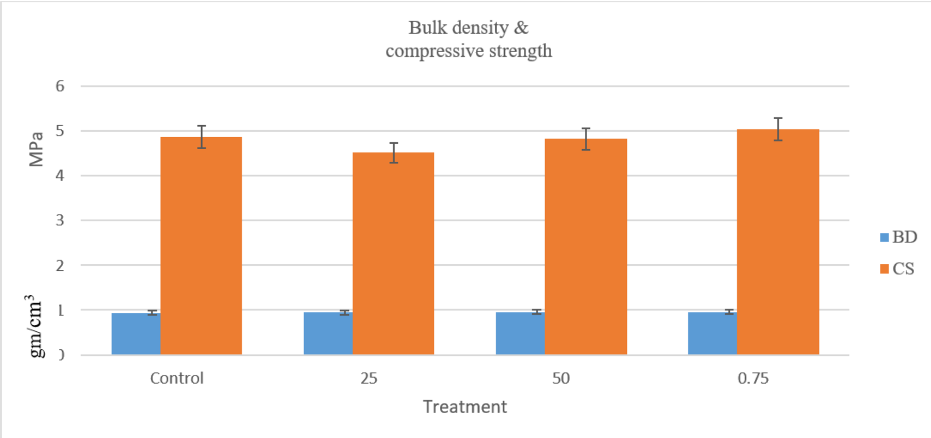

FIGURE 1 Results of analysis on Bulk density and compressive strength. Compressive strength tested at DOST Taguig, Manila, Philippines in August 2016.

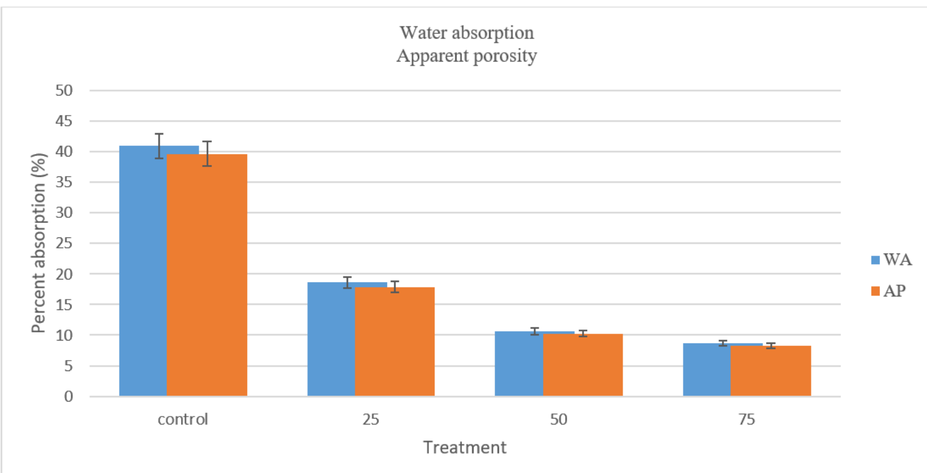

FIGURE 2 Results of analysis on water absorption and apparent porosity.

3.3 | Moisture content

At the CLSU chemistry laboratory, moisture content was determined from the different treatments, which were sundried for three days and oven dried to a constant weight.

TABLE 2 Moisture content variation in coir-pith.

Treatment	Moisture
C	9.99+0.07
T1	9.03+0.05
T2	8.71+0.03
T3	8.55+0.04

Data revealed a similar trend with density and water absorption. A decline in moisture was predominant in the treated coir dust. Treatment 3 has the least amount of moisture and ranges from 9.99 to 8.55, with control and treatment 3 having the lead. This observation contradicts Olurunnisola's study, in which treated coir particles had the highest moisture content while control particles had the lowest moisture content. It has been observed that treatment having the highest concentration dries faster than treatment with the lowest concentration. It can be deduced from the findings that the QUAC-based compound amino silicon does not only restrict water absorption but speeds up evaporation during the hydration process.

4 | CONCLUSION

The use of QUAC-based compounds has shown potential in addressing coir pith and cement matrix interaction. The interfacial bond between coir pith and the cement matrix was improved. An increased concentration of QUAC-based treatments has resulted in improved hydrophobic properties of coir cement composites with potential as outdoor and indoor light construction materials. While results can be promising, upscaling of the product composite needs further investigation for the product's industrial potential. Furthermore, the limited level of concentrations of QUAC-based compounds applied provides a wide room for further study.

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