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Natural Hydrophobic Coating: Application of Agricultural Waste for Re-engineering (AWARE)

Harold H. Calendatas [a], Katrine Joyce M. Cambaya [a,1,*], Ronna May M. Jose [a], Estela P. Pulga [a], Cian Maxine V. Roa [a], Teodoro A. Amatosa, Jr. [a]

[a] College of Engineering and Architecture, Northwest Samar State University, Calbayog City, Samar, 6710 Philippines
[1]cambaya.katrinejoyce@nwssu.edu.ph*

* corresponding author

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ABSTRACT

Concrete is a hard, dense, and porous substance. It is particularly vulnerable to deterioration and damage from chemical and water intrusion. The purpose of this study was to determine the use of sugarcane bagasse and rice husk ashes to produce a natural hydrophobic coating over concrete. The sugarcane bagasse and rice husk waste ashes were disseminated in an ethanol/stearic solution to create the hydrophobic coating. Solution 2 with 3g rice husk ash, 2g sugarcane bagasse ash, and 50 ml ethanol/stearic solution showed the highest water contact angles of 117.818° and 110.005°. The Capillary Water Absorption Test showed that specimens coated with solution 2 experienced an average weight gain of 1.63%, much less than specimens coated with solution 1 and 3, which were 2.08% and 4.22%, respectively. Water uptake was decreased by as much as 68.52%. This natural hydrophobic coating material is promising in the construction field.

1. INTRODUCTION

One of the most often utilized building materials is concrete. It is used to construct water treatment facilities, high-rise commercial structures, and homes. It is a material that is dense, rigid, and porous, making it especially susceptible to deterioration and damage from chemical and water incursion. The unprotected structures can be subjected to water penetration and moisture that may cause deterioration and corrosion. Water penetration and moisture can result in the rusting and expanding of the reinforcement bars which may cause hampering the load-bearing capacity of building structures. Concrete surfaces and reinforcements attached to them can be protected by applying hydrophobic coating material. That is why most concrete projects specify some waterproofing system. Concrete constructions must be waterproofed in order to prevent moisture from entering the area, safeguard the structural elements of the concrete, and preserve embedded reinforcing steel. A building that is not waterproofed may result in costly and hassle repair work in the future (Staff, 2006).

The incorporation of natural fiber residues derived from agricultural waste—such as jute, sisal, banana stalks, vegetable residues, cotton stalks, and wheat straw husks—has been explored as reinforcement materials in the development of particleboards, wall panels, fibrous construction panels, and coir fiber-reinforced composites (A. D. Laksono et al., 2022; Laksono, Ismail, Ningrum, & Ernawati, 2021; Andromeda Dwi Laksono et al., 2022). Rice husk is recognized as an agro-waste material and is generated in the Philippines in around 2 million tons per year. During the milling process, the hard protective coverings of rice grains are stripped off the grains, which are the rice husk (Shira, 2017). According to research, each kilo of milled white rice yields 0.28 kilograms of rice husk. Organic and inorganic remains, such as amorphous silica, can be found in rice husks. Rice husk ash (RHA) is produced when rice husks are burned. Silicon oxide is the predominant component of RHA, accounting for 90–98% of the ash. RHA has been widely employed in producing various silicates, cement, lightweight building materials, insulators, and adsorbents over the last two decades (Hossain et al., 2018; Setyawan et al., 2019). Agricultural waste from sugarcane can be used to make natural silica resources. Sugarcane bagasse ash (SCBA) is a by-product of a sugarcane factory. An agricultural waste resource that could be exploited to produce natural silica resources is sugarcane bagasse. It is asserted that natural silica is inexpensive, easy to handle, and may be produced from low-cost materials. SCBA has high silica content (53.1%) (Norsuraya et al., 2016).

As previously mentioned, the ash from sugarcane bagasse and rice husks contains a lot of amorphous silica. Silica is an adsorbent component that can be used for different waterproofing systems. Natural silica is regarded as safe to handle and can be produced from inexpensive resources, particularly agro-waste materials. In order to determine the viability of these agro-waste materials, natural processes (Amatosa et al., 2019) can replace this, as a sample in the creation of a hydrophobic coating on concrete; this study looks at that possibility.

2. METHODS

2.1 Materials

Ordinary Portland Cement (Type – 1) which complies with the requirements of ASTM specification C150 was employed as the primary binder in each sample of concrete $(100mm \times 100mm \times 100mm)$. The fine aggregates and coarse aggregates used comply with the ASTM specifications C33. All extraction and treatment procedures used in this investigation used tap water. Stores that sell rice milling products supplied the raw rice husk in the nearby barangays of Calbayog City, while the sugarcane bagasse was sourced from a factory of sugarcane farmers in San Miguel, Gandara. Both raw materials have undergone acid and thermal treatment to obtain silica (Husni, 2017). NaOH, citric acid, stearic acid, ethanol, and commercial adhesive spray were acquired from local online stores. Oven/Furnace, Weighing Scale, Sieve no. 100 (0.150mm), thermometer, stirring rod, and beaker are the tools and equipment used in making the coating material.

2.2 Production

About 3 g sugarcane bagasse ash and rice husk ash (1g/2g/3g) were dispersed in 8 mM of stearic acid in 50 ml of ethanol to make the hydrophobic coating solution. Before spraying the coating, the solution was stirred at room temperature for an hour. On the adhesive-coated

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surface of the concrete cube, the hydrophobic coating solution was physically brushed on. After the primary coating layer dried, another top layer was brushed on. To fully cover the concrete surfaces in ash particles, these brushing procedures have to be done at least three times. The specimens were subjected to a capillary water absorption test and water contact angle test. Coating morphology was studied through optical micrographs in Advanced Device and Materials Testing Laboratory (ADMATEL). The results were then evaluated after conducting the tests required for this study.

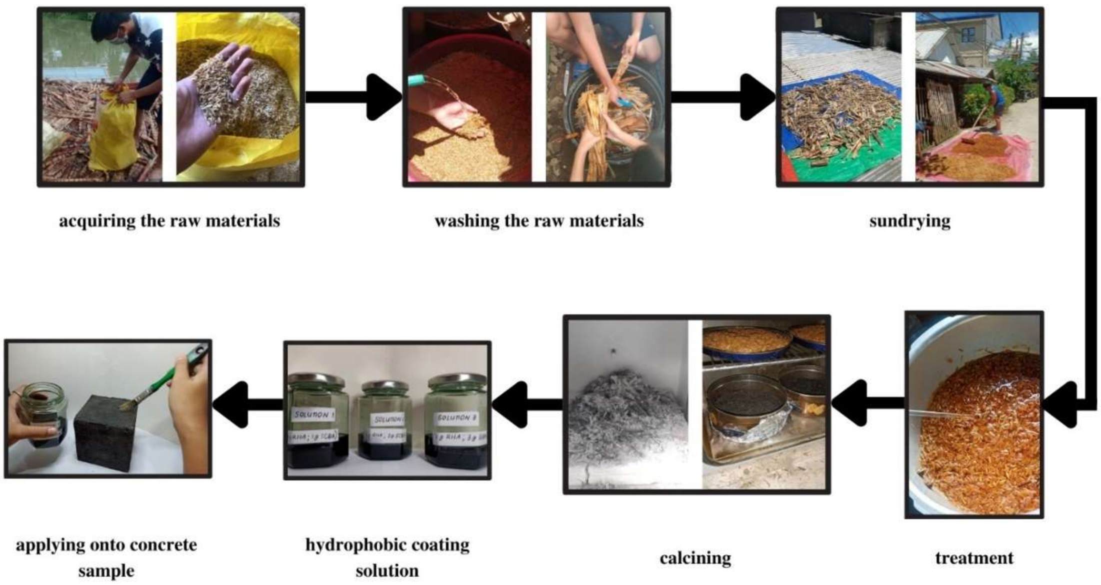

Figure 1. Distribution flow of hydrophobic coating solution

3. RESULTS AND DISCUSSION

3.1 Concrete Hydrophobicity

Table 1. Water Contact Angle of Coated and Uncoated Concrete Specimens

		Trial 1	Trial 2	Trial 3	Average
Solution 1	with adhesive	92.456°	95.957°	91.445°	93.286°
	without adhesive	98.116°	109.699°	106.04°	104.618°
Solution 2	with adhesive	107.719°	108.126°	110.005°	108.617°
	without adhesive	107.92°	112.688°	117.818°	112.809°
Solution 3	with adhesive	91.637°	92.032°	96.978°	93.549°
	without adhesive	92.123°	101.668°	106.518°	100.103°
Uncoated		61.15°	79.095°	63.969°	68.071°

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Concrete hydrophobicity was determined using a water contact angle. On coated (with or without adhesive) concrete surfaces as well as on uncoated concrete surfaces, water contact angles (WCA) were measured using the software ImageJ. As shown in figure 3, the uncoated concrete blocks were penetrated by water droplets, whereas the droplets on the coated concrete remain on the surfaces. On the uncoated concrete, the average measured water contact angle was 68.071°. It is lower than 90°, which is considered to be hydrophilic. WCA on coated surfaces ranged from 91.637° to 117.818°. The coated samples' water contact angles are all greater than 90°; therefore, the coated concrete surfaces were considered hydrophobic. Concrete surfaces coated with solution 2 (3g RHA; 2g SCBA; 50 ml ethanol/stearic solution) showed the highest water contact angle with an average of 112.742° (with 117.818° as the highest). The data presented Table 1 also shows that coated concrete without adhesive showed higher WCA than coated concrete with adhesive. However, through the researchers' observation throughout the experiment, coated concrete with adhesive is still more effective than coated concrete without adhesive. Adhesive lets the ash particles be firmly attached to the concrete surfaces prolonging the effect of the coating solution on concrete surfaces.

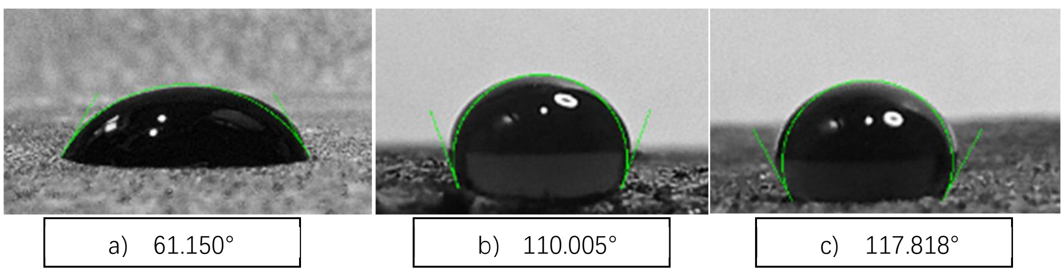

Figure 2. Water Contact Angle on Concrete Surfaces**:** (a) uncoated concrete, (b) hydrophobic coated concrete with adhesive, and (c) hydrophobic coated concrete without adhesive.

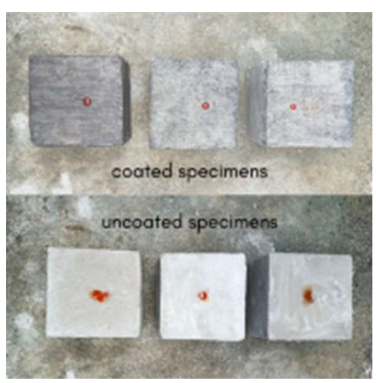

Figure 3. Visual presentation of the hydrophobicity of coated and uncoated concrete

3.2 Capillary Water Absorption

Table 2. Water Absorption of Coated and Uncoated Concrete Specimens

Days	Solution 1 Sample (grams)			Solution 2 Sample (grams)			Solution 3 Sample (grams)			Uncoated Sample (grams)
	1	2	3	1	2	3	1	2	3	
Initial	**2048**	**2018**	**2064**	**2073**	**2024**	**2053**	**2066**	**2009**	**2062**	**2043**
1	2052	2021	2071	2076	2027	2059	2078	2026	2079	2110
2	2061	2034	2077	2079	2032	2065	2086	2031	2099	2141
3	2066	2037	2078	2084	2036	2066	2095	2043	2104	2143
4	2070	2039	2081	2087	2040	2069	2107	2059	2110	2146
5	2073	2041	2088	2090	2044	2072	2114	2067	2116	2146
6	2077	2042	2090	2092	2046	2073	2118	2073	2120	2147
7	2080	2043	2091	2095	2049	2075	2123	2078	2124	2147
8	2083	2044	2093	2097	2053	2076	2127	2083	2129	2148
9	2085	2046	2094	2099	2054	2077	2129	2087	2133	2148
10	2087	2047	2095	2101	2055	2078	2136	2093	2135	2149
11	2089	2049	2097	2103	2056	2079	2141	2098	2137	2149
12	2091	2052	2099	2104	2057	2081	2145	2101	2139	2149
13	2093	2055	2102	2105	2058	2083	2149	2103	2140	2150
14	2094	2057	2103	2106	2059	2084	2151	2104	2146	2150
15	**2095**	**2059**	**2105**	**2107**	**2060**	**2085**	**2153**	**2105**	**2149**	**2151**

In this study, a fifteen-day capillary water absorption test was performed. With a total of 10 specimens; one for an uncoated specimen, three for specimens coated with solution 1, three for specimens coated with solution 2, and 3 for specimens coated with solution 3. The result obtained after fifteen days of immersion were shown in Table 2. the result in the table shows the increase in mass per gram of each specimen from day 1 up to day 15. The findings demonstrate that after 15 days of immersion, the uncoated specimen's cumulative water intake gradually increased and then stabilized thereafter, whereas the coated specimens absorbed less water than the uncoated specimens. Additionally, the result shows that after three days or 72 hours of immersion, the uncoated specimen is fully submerged in water resulting in almost maintaining its weight from day 3 up to day 15.

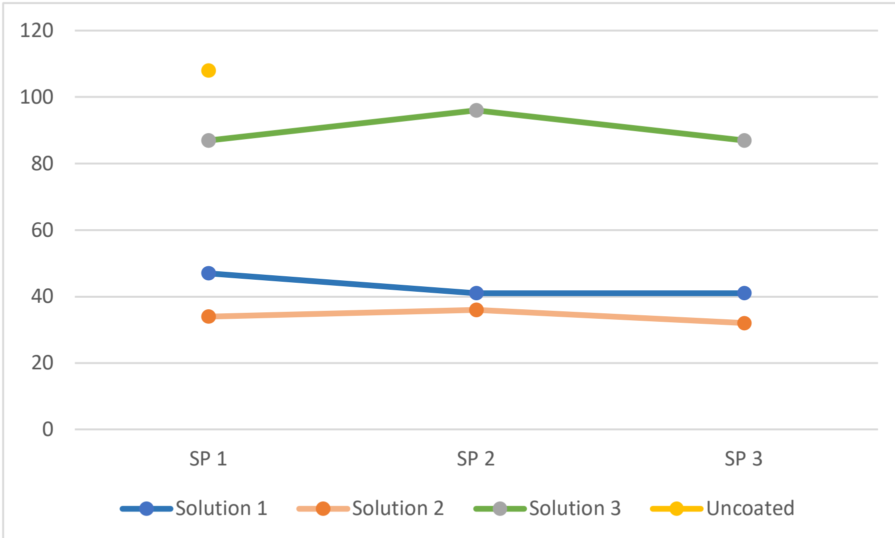

Figure 4. Graph of water absorbed by each concrete specimen after 15 days

According to the data in figure 4, the results show that the uncoated specimen has the highest water uptake compared to the coated specimen with 108 grams increase in its weight after 15 days. For the coated specimens, block 3 with solution 2 has the least water uptake among all specimens with only a 32g increase in weight after 15 days of immersion while block 2 with solution 3 has the highest water uptake with 96g weight increased after 15 days of immersion.

Table 3. Percentage of Water Absorption of Coated and Uncoated Concrete Specimens

Water Absorption									
Solution 1			**Solution 2**			**Solution 3**			**uncoated**
sp. 1	sp. 2	sp. 3	sp. 1	sp. 2	sp. 3	sp. 1	sp. 2	sp. 3	
2.24%	2.02%	2.00%	1.61%	1.75%	1.53%	4.04%	4.56%	4.05%	5.02%
Average Water Absorption									
2.08%			1.63%			4.89%			5.02%

In the Table 3, the results revealed that the concrete cube with solution 1 experienced an average weight increase of 2.08%, compared to 1.63% for solution 2 and 4.22% for solution 3. whereas, after 72 hours, the water had completely soaked into the uncoated concrete cube, making its weight had increased by up to 5.02% which is shown in the figure. Cumulative water uptake was reduced by 68.52%, 60.19%, and 16.67% when concrete was coated with hydrophobic coating solution 2, solution 1, and solution 3, respectively. The arrangement of

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least to highest value of water absorption are as follows: The uncoated specimen is the highest, followed by the specimens coated with solution 3 specifically Block 2, Block 3, and Block 1. It is then followed by specimens coated with solution 1 which are Block 1, Block 2, and Block 3; and the specimens coated with Solution 2 which are Block 2, Block 1, and Block 3.

According to the data presented above, specimens coated with solution 2 consistently showed the lowest percentage of water absorption compared to the other coated and uncoated specimens, making it more effective hydrophobic solution.

3.3 Characterization of the Coated Concrete Sample

This report provided the images to characterize the surface morphology of the coated concrete sample coated with Solution 2 submitted to Advanced Device and Materials Testing Laboratory (ADMATEL). As-received concrete sample, labeled as Hydrophobic Coated Concrete Sample, was submitted for optical microscopy as shown in Figure 5 below. The surface morphology of the sample was carefully observed using Carl Zeiss High Power Microscope via ZEN software at 50x and 200x magnifications. Enclosed in yellow boxes indicate the location of the areas of inspection taken (See Areas 1 – 5).

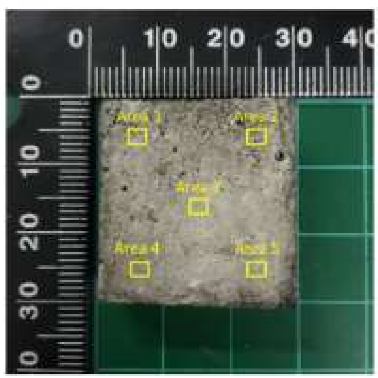

Figure 5. As-received Hydrophobic Coated Concrete Sample showing the areas of inspection.

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The Figure 6 below shows the photomicrographs obtained from Areas 1 at 50x and 200x magnification. Two (2) optical images with different depth of field at 200x magnification were taken to distinguish the hydrophobic coating and concrete surfaces.

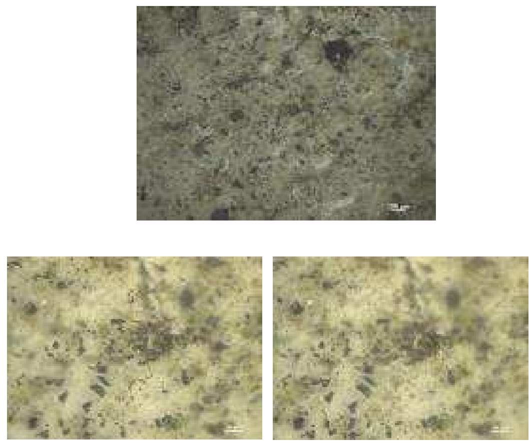

Figure 6. Photomicrographs obtained from Area 1 taken at 50x & 200x magnification

According to Husni et al. (2017), one requirement of hydrophobic coating is to create roughness on concrete surfaces. The images shown characterize the presence of ash particles on the hydrophobic-coated concrete surface. However, per the report given by ADMATEL, this is not enough to give interpretations on the roughness of the concrete surface. Thus, it is recommended to analyze the surface morphology using SEM Imaging to further characterize the morphology of the hydrophobic coating on concrete surfaces.

4. CONCLUSION

Hydrophobic concrete was successfully achieved using silica from sugarcane bagasse and rice husk waste ashes dispersed in an ethanol solution with stearic acid as the surface functionalizing agent. All water contact angles measured on all specimens were above 90°, considering the coated concrete specimen as hydrophobic. Solution 2, containing 3g rice husk ash, 2 g sugarcane bagasse ash, and 50 ml of ethanol/stearic acid solution, showed the greatest variations in water contact angle and water absorption. It has the highest water contact angle of 117.818° on coated concrete without adhesive and 110.005° on coated concrete with adhesive. Capillary Water Absorption Test also revealed an average weight increase of 1.63% for specimens coated with solution 2, which is significantly lower than specimens coated with solution 1 and specimens coated with solution 3, having an average weight increase of 2.08% and 4.22%, respectively. Cumulative water uptake was reduced by 68.52%, 60.19%, and 16.67% when concrete was coated with hydrophobic coating solution 2, solution 1, and solution 3, respectively. In terms of the coating morphology characterization, the results from the optical micrographs only showed the presence of ash particles on the concrete surfaces. This could further be analyzed and given detailed interpretations through SEM Imaging.

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