Solid State Science and Technology, Vol. 31, No 1 (2023), 11-16
ISSN 0128-7389 | *http://myjms.mohe.gov.my/index.php/masshp*

EFFECTS OF RICE HUSK ASH FOR WATER RESILIENCE MATERIAL (HYDROPHOBIC COATING)

Nurjuhanah Juhari[1,*], Siti Nurain Mustafa Kamal[1], Norlizan Wahid[1], Hazrina Ahmad[1], Herda Balqis Ismail[2]

[1]*Center for Civil Engineering Studies*
Universiti Teknologi MARA, Cawangan Pulau Pinang
13500 Permatang Pauh, Pulau Pinang, Malaysia

[2]*Center for Civil Engineering Studies*
Universiti Teknologi MARA, Cawangan Johor, 81750 Masai, Johor, Malaysia

[*]*Corresponding author email: nurjuhanah@uitm.edu.my*

Received: 30 August 2022 ; Accepted: 15 March 2023

ABSTRACT

The agricultural waste recycling has drawn a great contribution to the environmental and economic growth of a nation. The formulation of hydrophobic surface coating using agricultural waste for water resilience material may solve the durability issues. However, formulation of eco-friendly water resilience material is still a challenging issue. The long chain flouro-silane in the hydrophobic formulations are expansive and hazardous to the human health and environment. Thus, non-toxic silica source using rice husk ash was used in this study. Two different sources of rice husk ash were compared to know the effect of hydrophobicity. Further testing on the surface wetting and water absorption were carried out on concrete surface for the water resilience performance. It was found that, the hydrophobicity was achieved at 142^o water contact angle for 3 g RHA and 5 g calcium carbonate incorporated in the formulation. The coating was found to reduce the water absorption but not fully prevented it. The outcome of this study may be beneficial to fabricate hydrophobic coating using non-toxic and environmentally friendly silica source materials and later diversify its application in water resilience material.

Keyword: Hydrophobic, rice husk ash, water resilience, coating

INTRODUCTION

A cementitious-based material which known as concrete has been utilized extensively in the construction industry. Despite the fact that concrete is famed for its durability, the performance may be compromised when exposed to water and severe environment. It could result in the concrete deteriorating, which further cause the structural failure. Sulfate, chloride, and carbon dioxide are examples of aggressive chemicals that can harm the concrete by reacting with hydrated cement components. In cases where the service life of a structure be the key concern, diminishing the transport qualities of the surface layer are seen as a possible approach. Thus, water resilience material such as hydrophobic coating in the surface treatment was introduced.

There are three different types of surface treatments, based on the functions, which are categorised by EN 1504-2:2004. The most widespread surface treatments are hydrophobic impregnation, pore blockage, and coating. Depending on how each treatment coating functions, the mechanism varies. Pore blocking or impregnation are used to reduce the porosity and reinforced the surface partially or completely. Hydrophobic impregnation is the treatment that produces a water repellant or water resilience surface by coating the pores and capillaries without filling the voids. The process of creating a continuous protective layer on the surface of concrete is known as the surface coating. Typically, the surface energy and microroughness play important role in the surface treatment properties. When the water contact angle (WCA) of the surface is greater than 90^o, it is considered as hydrophobic, whereas superhydrophobic if WCA reached 150^o.

Silica particles are necessary to create the roughness required by the hydrophobic coating. Carneiro et al. [1] introduced nanosilica in modifying the microstructure that has waterproofing effect. The hybrid nanosilica react with $Ca\ (OH)_2$ through pozzolanic reaction in the cement paste thus developed the super hydrophobicity. Zhao et al. [2], Subbiah et al. [3], and She et al. [4] incorporated different sources of nanosilica functionalized with low surface energy materials for the development of the superhydrophobic materials that able to remarkably behave as water resilience materials on concrete.

The development of a water-resilience coating has recently diverted on the synthetic silica to the natural silica source materials that can be obtained from the agricultural waste. For the superhydrophobic solution tested onto the concrete, Husni et al. [5] employed rice husk ash dispersed in ethanolic solution containing fluoroalkyl silane, 1H,1H,2H,2H-perfluorodecyl triethoxy silane. Saharudin et al. [6] created a superhydrophobic material using waste palm oil fuel ash (POFA) as a source of silica and non-fluoro polydimethylsiloxane (PDMS) as a surface functionalizing agent. RHA was previously combined with hydroxyl silicone oil (HSO) and vinyl triethoxysilane (VTS), respectively, for the fluorine-free superhydrophobic coating on substrate by Xu et al. [7] and Anitha et al. [8]. Natarajan et al. [9] incorporated sugarcane bagasse ash as silica source functionalized with dimethyldiethoxysilane (DMDEOS) for hydrophobic coating on tiles via drop casting process. Even though the results demonstrated the water resilience effectiveness, the use of high levels of chemical functionalizing agents necessitates longer preparation methods, expensive chemicals, and tedious process. Therefore, hydrophobic impregnation was selected as the surface treatment in this study by modifying the silica source obtained from the rice husk ash and calcium carbonate without the presence of any chemically functionalizing agent in the hydrophobic formulation for the water resilience material. Utilizing non-chemical eco-friendly materials and locally accessible agricultural waste in this study may help to mitigate environmental problems and address global sustainability difficulties.

EXPERIMENTAL DETAILS

The raw rice husk ashes were collected from rice mill of Padiberas Nasional Berhad (BERNAS), Simpang Ampat, Perlis and Kokopit Kedah. Concrete cubes of 150 mm ×

150 mm × 150 mm with the strength of 30 MPa were casted by MDC Plant Batu Kawan, Pulau Pinang. The homogenous ash solution was formulated by dispersing the 3 g RHA with 50 mL ethanol in an ultrasonic machine set at 350 rpm and 85 watts of power for at least 30 min. The 5 g calcium carbonate ($CaCO_3$) were slowly added into the solution and stirred by the magnetic stirrer at 80^o for at least 1 hour. The solution was then be applied onto the glass slide at 10 cm distance after coated with the adhesive sprayed until all area was wetted. The coated glass slide was then dried at room temperature for 24 h before the water contact angle be examined. The same procedures were followed to prepare the different formulation by varying the ethanol and calcium carbonate in the mix proportion. The water contact angle of a water droplet on the concrete surface was detected using ImageJ software to establish the concrete hydrophobicity. The water droplets were placed on both coated and uncoated concrete, and a microscope image of the water contact angle was acquired.

The water absorption test was carried out to determine the ability of concrete water in absorbing the water in accordance with BS 1881: PART 122: 1983. The uncoated and coated concrete cube was placed in the drying oven at a temperature of 105 ^oC for about 72 h. Then, the concrete cubes were weighted and recorded immediately after cooling. The cubes were then cooled and sprayed with the hydrophobic coating at distance of 10 cm apart on all surfaces. The samples were then weighted and immersed in the water at depth of 25 mm water on top of the surface. After 30 min, the concrete cubes were quickly dried with a cloth until all free water was removed from the surface. The water absorption was expressed as a percentage of the change in mass of the immersed specimen to the dry specimen.

RESULTS AND DISCUSSION

Water contact angle (WCA) for all solutions, demonstrated the surface wettability had values more than 74^o, indicating a hydrophilic and hydrophobic characteristic. The solutions were labeled according to the sources of RHA as silica particles in the formulation as in Table 1. RHA_KB01 to RHA_KB05 were the solutions incorporated RHA taken from Padiberas Nasional Berhad (BERNAS) whereas RHA_KK01 to RHA_KK05 were the solutions formulated by the RHA taken from Kokopit Kedah.

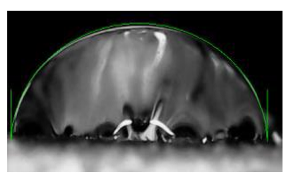
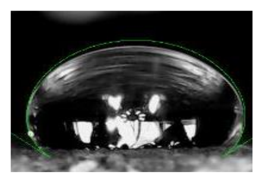
The rice husk ash from the Padiberas Nasional Berhad (BERNAS) exhibit hydrophobicity with higher WCA values up to 128^o. The raw rice hush ash dispersed in ethanol with the presence of calcium carbonate unable to form hydrophobicity characteristic as shown in Table 1 below. Adding more than 50 mL ethanol in the formulation lessen the WCA by 13 % for the RHA_KB but contradiction appeared towards RHA_KK. The WCA shown an incremental up to 24 % for the 60 mL ethanol, 3 g RHA and 5 g $CaCO_3$ in the RHA_KK05 formulation. For both sources of RHAs, the hydrophobicity characteristic was developed with the presence of 5 g $CaCO_3$ in the solution. The better characteristics was established by adding more ethanol in the hydrophobic coating preparation. It was found that the optimum dosage of ethanol was 50 mL. The RHA_KK01 revealed hydrophilic of the least WCA 74^o on the glass slide

The surface wettability upon concrete surfaces is as shown in Table 2. RHA_KB04 was chosen to be applied on concrete as it appeared as better performances of hydrophobicity on the glass surface. The comparison was carried out for different application process of coating. The concrete that not been coated with 3M adhesive unable to create bonding between the hydrophobic coating and the intact surface. The coating was not attached and remain coated on the soffit of concrete as the WCA unable to be seen once the water droplet been placed on the concrete. The WCA obtained on the concrete increased up to almost 10% from the glass slide substance once the concrete been treated with the coating. Thus, it indicated that more hydrophobicity characteristic was developed on the surface that has high silica content with rough surface rather than smooth surface.

Table 1: Surface wettability on the glass slide

Solutions	RHA (g)	$CaCO_3$ (g)	Ethanol (mL)	Water contact angle (^{o})
RHA_KB01	3	-	50	85
RHA_KB02	3	5	30	119
RHA_KB03	3	5	40	122
RHA_KB04	3	5	50	128
RHA_KB05	3	5	60	111
RHA_KK01	3	-	50	74
RHA_KK02	3	5	30	116
RHA_KK03	3	5	40	104
RHA_KK04	3	5	50	115
RHA_KK05	3	5	60	121

Table 2: Surface wettability on the concrete

Solution	Without 3M adhesive	Uncoated	Coated
	0^{o}	89^{o}	142^{o}
RHA_KB04			

Water absorption with the hydrophobic coating on the concrete surfaces gives lower value because it contains silica which give roughness to the concrete surface as well as prevent the water from ingress into the concrete. Thus, though the water absorption not fully prevented, but the coating able to hinder the penetration of excessive water intake to the concrete pores. Figure 1 showed the percentage of water absorption for uncoated concrete and coated concrete after 28 days of curing. The significant percentage of reduction was developed for the coated concrete with the hydrophobic coatings. The outcomes showed the reduction of water absorption of the coated concrete that been treated with the coating. Water uptake reduced more than 50 % for the treated concrete with hydrophobic coatings. The findings showed considerable outcomes for the surface functionalizing agent using raw rice husk from the rice mill rather than silane based hydrophobic formulation as carried out by Husni et al. [5].

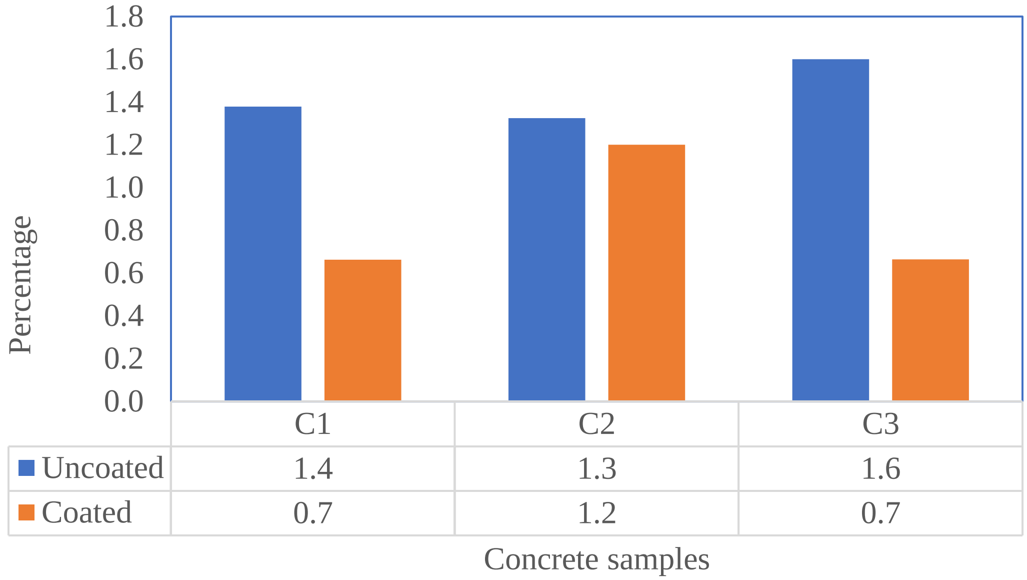


Figure 1: Percentage of water absorption for hydrophobic coatings

CONCLUSIONS

RHA obtained from the rice mill plant successfully converted into the hydrophobic coating via spraying method on the glass and concrete substrate. An eco-friendly hydrophobic coating is developed in this present works via simple, and convenient method without the presence of any functionalizing agent to develop the coating. The surface roughness of the treated substances showed substantial influence on the hydrophobic characteristic. The concrete with roughed surface gave higher water contact angle rather than smooth surface on the glass slide. The formulation of 3 g RHA, 5 g $CaCO_3$ and 50 mL ethanol gave significant hydrophobic characteristic with water contact angle of 142^o. However, without the presence of $CaCO_3$ in the mixture, the hydrophobic characteristic was not developed. The calcium carbonate provides more silica content to provide better hierarchical linkages between -Si-CH in the formation of hydrophobic coating. More than 50 % of the water absorption was reduced once the concrete been treated with hydrophobic coating. The hydrophobic coating should be further improved by applying multiple layers of coating on the substrate. This research findings may be beneficial for the development of the water resilience coating for the surface treatment that be applied in the building and construction.

ACKNOWLEDGEMENTS

The authors would like to express acknowledgement to Padiberas Nasional Berhad (BERNAS), Simpang Ampat, Perlis and MDC Plant Batu Kawan, Pulau Pinang for providing the raw rice husk and concrete cubes for this study. The authors would also like to convey great gratitude to the Center of Civil Engineering Studies, Universiti Teknologi MARA, Pulau Pinang for providing the facilities and support in the completion of the research.

REFERENCES

[1] L. do R. S. Carneiro, M. Houmard, V.V. Rocha, P. Ludvig (2021). *The Open Construction & Building Technology Journal*, **14**(1), 400.

[2] Y. Zhao, Y. Liu, Q. Liu, W. Guo, D. Yang, D. Ge (2018). *Materials Lett*ers **233**, 263.

[3] K. Subbiah, D.J. Park, Y.S. Lee, S. Velu, H.S. Lee, H.O. Jang, H.J. Choi (2018). *Progress in Organic Coating* **125**, 48.

[4] W. She, X. Wang, C. Miao, Q. Zhang, Y. Zhang, J. Yang, J. Hong (2018). *Construction Building Materials,* **181**, 347.

[5] H. Husni, M. Nazari, H. Yee, R. Rohim, A. Yusuff, M.A.M. Ariff, N. Ahmad, C. Leo, M. Junaidi (2017). *Construction Building Materials,* **144**, 385.

[6] K.A. Saharudin, S. Sreekantan, N. Basiron, Y.L. Khor, N.H. Harun, R.B.S.M.N. Mydin, K. Vignesh (2018). *Polymers*, **10**(8), 878.

[7] K. Xu, Q. Sun, Y. Guo, S. Dong (2013). *Applied Surface Science,* **276**, 796.

[8] C. Anitha, S.S. Azim, S. Mayavan (2017). *Journal of Alloys Compounds,* **711**, 197.

[9] S. Natarajan, S.T. Subramaniyam, V. Kumaravel (2019). *Applied Sciences*, **9**(1), 190.

[10] British Standard BS 1881: Part 122:1983 *Testing Concrete Part 122 Method for determination of water absorption*, British Standard Institution: London, UK, 1983.

[11] British Standard BS EN 1504-2:2004 *Products and systems for the protection and repair of concrete structures, Definitions, requirements, quality control and evaluation of conformity Surface protection systems for concrete*, British Standard Institution: London, UK, 2004.