IMPROVEMENT BY USING ANTIFOULING ON RETAINING WALL

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SCHOOL OF CIVIL ENGINEERING
UNIVERSITI SAINS MALAYSIA
2021

IMPROVEMENT BY USING ANTIFOULING ON RETAINING WALL

by

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This dissertation is submitted to

UNIVERSITI SAINS MALAYSIA

As partial fulfilment of requirement for the degree of

BACHELOR OF ENGINEERING (HONS.)
(CIVIL ENGINEERING)

School of Civil Engineering
Universiti Sains Malaysia

October 2021

Appendix A8

UNIVERSITI SAINS MALAYSIA

SCHOOL OF CIVIL ENGINEERING
ACADEMIC SESSION 2020/2021

FINAL YEAR PROJECT EAA492/6
DISSERTATION ENDORSEMENT FORM

Title: IMPROVEMENT BY USING ANTIFOULING ON RETAINING WALL

Name of Student: KAMAL KHAIRI BIN AHMAD MARZUKI

I hereby declare that all corrections and comments made by the supervisor(s)and examiner have been taken into consideration and rectified accordingly.

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Date: 4 / 8 / 2021

Approved by:

(Signature of Examiner)

Name of Examiner: Ts. Dr. Mastura Azmi

Date: 5/8/2021

(Important Note: This form can only be forwarded to examiners for his/her approval after endorsement has been obtained from supervisor)

ACKNOWLEDGEMENT

I would like to express my gratitude to Allah SWT for giving me the opportunity and help me throughout my research work in finishing the thesis of Improvement by Using Anti Fouling on Retaining Wall successfully.

I would want to convey my heartfelt appreciation to my research supervisor, Prof. Dr. Fauziah Ahmad, for allowing me to do my final year project study and for offering essential assistance throughout this research despite the unanticipated circumstances of COVID-19. Her energy, vision, passion, and honesty have all made an everlasting impression on me. As a final-year student, it was an honor to be led under her supervision.

Furthermore, I would want to convey my appreciation to Prof Ir. Dr. Srimala Sreekantan and Tuan Nur Farhah Binti Tuan Ismail for fabricating the superhydrophobic solution to be used in my final year project. I would also like to express my special gratitude to my supervisor's research assistant, Mohamad Syazwan Bin Mohd Roslee, for helping me throughout my final year project in the amidst of COVID-19.

Last but not least, I would like to express my gratitude and thank you to my parents and friends for their unending assistance in assisting me psychologically and physically in finishing this research, without which the final year project would not

Prof Dr Fauziah Ahmad

come to fruition. Throughout the study, there have been many ups and downs; however, I am glad for all of the wonderful love and encouragement I have received from those around me.

ABSTRAK

Mikroorganisma hadir dalam hampir setiap situasi alam sekitar. Mikroorganisma menghasilkan metabolit agresif seperti asid, karbon dioksida, dan sebatian sulfur yang boleh menyebabkan kerosakan yang tidak dapat dipulihkan. Lapisan superhidrofobik adalah lapisan permukaan tenaga yang rendah yang mudah menangkis air. Topografi permukaan dan kimia adalah kritikal untuk permukaan untuk memperolehi sifat hidrofobik. Objektif kajian ini adalah untuk menentukan ciri-ciri anti lumut dan menilai prestasi anti lumut pada grout, mortar dan kiub mortar bertetulang .Ujian yang dijalankan adalah '*water contact angle*' (WCA), '*sliding angle*' (SA), '*peel off*' dan '*fungi resistance*'. Keputusan untuk WCA untuk grout adalah 123.0°, mortar adalah 138.6° dan mortar diperkukuhkan adalah 131.4° iaitu lebih rendah daripada 150°. Keputusan untuk SA untuk grout adalah 70 ± 5°, mortar adalah 50 ± 5° dan mortar diperkukuhkan adalah 15 ± 5° iaitu lebih tinggi daripada 10°. Oleh itu, lapisan tersebut tidak mempunyai sifat superhidrofobik. Ujian '*peel off*' dijalankan untuk mensimulasikan kesan calar mekanikal. Semua sampel mengalami penurunan prestasi kerana grout mengalami penurunan WCA kepada 124.6° kepada 102.8° kepada 87.4° manakala WCA mortar menurun kepada 120.8° kepada 104.5° kepada 83.4° dan WCA mortar bertetulang menurun kepada 122.2° kepada 112.0° kepada 83.2°.Ujian '*fungi resistance*' menunjukkan bahawa kedua-dua sampel yang tidak bersalut dan bersalut untuk semua jenis sampel telah ditumbuhi oleh kulat selepas pemerhatian selama 90 hari .Kajian ini boleh diringkaskan bahawa lapisan tersebut tidak memperolehi sifat superhidrofobik.

ABSTRACT

Microorganisms are recognized to be present in nearly every environmental situation. Microorganisms create aggressive metabolites such as acids, carbon dioxide, and sulfur compounds, which can cause irreversible damage. A superhydrophobic coating is a low-energy surface layer that easily repels water. The surface topography and chemistry are critical for a surface to acquire the hydrophobic property. The objective of this study is to determine the characteristic of antifouling and to evaluate the performance of antifouling on grout, mortar, and reinforced mortar cubes. Tests conducted were water contact angle (WCA), sliding angle (SA), peel-off test, and fungi resistance test. The results for WCA for grout was 123.0°, the mortar was 138.6°, and reinforced mortar was 131.4° which were lower than 150°. The results for SA for grout was 70 ± 5°, the mortar was 50 ± 5°, and reinforced mortar was 15 ± 5° which were higher than 10°. Therefore, the coating does not possess superhydrophobicity behavior. Peel off test was conducted to replicate the effect of mechanical scratch. All of the samples experienced decreased performance as the WCA of grout decrease into 124.6° to 102.8° to 87.4° while WCA of mortar decrease to 120.8° to 104.5° to 83.4° and the WCA of reinforced mortar decrease to 122.2° to 112.0° to 83.2°. The fungi resistance test shows that fungi colonized both uncoated and coated samples for all types of samples after 90 days of observation. This study can be summarised that the coating does not achieve superhydrophobicity.

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LIST OF ABBREVIATIONS

AFM	Atomic Force Microscopy
FESEM	Field Emission Scanning Electron Microscopy
HFDS	1H,1H,2H,2H-Perfluorodecyltriethoxysilane
OPC	Ordinary Portland Cement
PDMS	Non-Fluoro Polydimethylsiloxane
POFA	Palm Oil Fuel Ash
SA	Sliding Angle
SHC	Superhydrophobic Coating
SS	Silica Solution
UV	Ultraviolet
WCA	Water Contact Angle

CHAPTER 1

INTRODUCTION

1.1 Project Background

Over the last few years, the development of an area has undergone an upsurge due to the world's population increases exponentially (Yan, et al., 2021). The area suitable for development, such as a flat area and an area with a sturdy subsurface profile, will be reduced. Therefore, the development for an area that is not favorable will be unavoidable.

The areas that are not favorable are hilly areas, weak and unstable soil, unfavorable subsurface profile, seafrontt and waterfront areas. Any development in these types of areas possessed very dangerous. The use of geotechnical structures such as retaining walls can strengthen the slope in hilly areas and piles can be used to support any building in that area.

However, these geotechnical structures such as retaining wall usually abandoned and hardly any maintenances are done afterward. As a result, the geotechnical structure is exposed to weathering effects, groundwater attacks, and fungi attacks. These will affect the performance and aesthetic value of the geotechnical structure. The superhydrophobic coating can avert these problems.

The superhydrophobic coating will act as a barrier that can prevent water intrusion into the geotechnical structure. Without water, any fungi and bacteria cannot grow and live at the surface of the geotechnical structure. Moreover, the superhydrophobic coating acting as a barrier, chloride, and sodium present in the saltwater in seafront development cannot penetrate the geotechnical structure.

Therefore, the use of superhydrophobic can enhance the durability of a geotechnical structure. For a surface coating to achieve superhydrophobic, the Water Contact Angle (WCA) needs to be higher than 150° and the Sliding Angle (SA) less than 10°. Husni et al. (Husni, et al., 2017) state that compounds frequently used in construction to act as water repellent agents is silicon-based compounds such as silanes, siloxanes, and silicons.

Zarina (Zarina, et al., 2013) , in her article, states that silica (Si) is the by-product of palm oil fuel ash (POFA), and in palm oil industries, the waste that was produced was 3 million metric tons. The production of superhydrophobic coating for geotechnical structure by utilizing POFA waste can reduce the waste disposal problems.

In this project, POFA and non-fluoro polydimethylsiloxane (PDMS) was used to fabricate superhydrophobic solution and three types of cement are used: grout, mortar, reinforced mortar.

1.2 Problem Statement

Fungi or bacteria can inhabit the geotechnical structure because they are ubiquitous in almost every environmental condition. These microorganisms produce aggressive metabolites such as acids, carbon dioxide, and the sulfur compound, which can cause destructive destruction to geotechnical structures such as erosion, spalling, and corrosion of rebars. (Miron & D., 2017). The deterioration caused by the microorganism can be slowed down by continuous maintenance can cost a lot of overtime.

Besides microorganisms, the harsh environment also contributes to the deterioration of building structures such as seafront and waterfront. The Pacific Ocean and the South China Sea surround Malaysia; therefore, the development at the seafront is unavoidable. The seawater contains dissolved salt such as chloride and sodium can cause corrosion to the reinforcement bar of piles. The physical attack caused by chloride and sulfate ions will weaken the concrete surface (Manap, et al., 2017). Thus, the strength of the building structure will be weakened.

Furthermore, the usage of antifouling or antifungals on building structures is still not widely used. A few studies show that the use of antifouling can preserve the quality of the building structure. A rigorous research study about the benefit of antifouling in improving the building structure is needed to create a long-lasting solution for preserving the building structure other than maintenance.

1.3 Objectives

The objectives of this study are as follows:

i. Determine the characteristic of the antifouling

ii. To evaluate the performance of antifouling on mortar cube

iii. To analyze the resistance of the coating

1.4 Scope of study

This study mainly focuses on the geotechnical structure durability improvement by applying antifouling or superhydrophobic coating on the surface of the geotechnical structure. The surface of the geotechnical structure is represented by cubes of grout, mortar, and reinforced mortar. Series of tests will be conducted to evaluate the performance of antifouling on the cubes, such as water contact angle (WCA), sliding angle (SA), fungal resistance, self-cleaning, pencil hardness, atomic force microscopy (AFM), and field emission scanning electron microscopy (FESEM).

1.5 Thesis Layout

This thesis is divided into five chapters. Chapter 1 provides the background study, problem statement, objectives, and scope of the study. Chapter 2 describes the literature review regarding the research related to the application of superhydrophobic on mortar. While Chapter 3 discloses the research methodology, which consists of experiment preparation and data collection procedure. Next, Chapter 4 shows the analysis of data and discussion on the achievement of research objectives. Last but not least, Chapter 5 will represent the conclusion of this research, and some recommendations for future research are proposed.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter would include analysis of studies on the superhydrophobic coating that have been applied. Aside from that, the findings of previous studies will be described in detail in this part.

2.2 Common geotechnical structure problems

Nowadays, the use of geotechnical structures is more frequently used in development. The usage of retaining walls is to act as a partition, hold the backfill soil, and prevent soil erosion. However, retaining walls are usually left untreated after the project is finished. The properties and the appearance of the retaining wall can deteriorate due to exposure to the outdoor environment. (Goffredo, et al., 2017).

Many factors can deteriorate the properties and the appearance of the retaining wall, such as fungi growth, environmental conditions such as humidity, weathering effect, and bird droppings. (Goffredo, et al., 2017). The growth of microorganisms can cause cracking, powdering, and staining. These visual damages can affect the surface's chemical and mechanical properties, which will affect the surface textures and colors (Farooq, et al., 2015).

However, these problems can be averted by applying antifouling on the surface of the geotechnical structure. Antifouling can provide low surface energy to the surface of the retaining wall. Low surface energy can repel water droplets from entering into the geotechnical structure, which can prevent the growth of the fungi. Therefore, antifouling usage can mitigate the problem caused when the geotechnical structure is exposed to the outdoor environment and below ground environment.

2.3 Fungi growth

Microorganisms are ubiquitous in almost every environmental condition. However, the microorganism cannot directly concrete structure such as retaining wall, but microbial activity can reduce the protection of reinforcement steel by the deterioration of concrete cover. The reduction of the concrete cover will help the water and oxygen to migrate into the concrete cover and react with the reinforcement steel. The microbial activity reduced the weight of a cement sample up to 5.7% in three months, where without microbial, the reduction of weight of a cement sample is 0.3% (Noeiaghaei, et al., 2017).

Noeiaghaei (2017) states that the microbial activity at the concrete surface will significantly reduce the alkalinity of pore water and destroy the passive film surrounding the reinforcement steel. While carbonation reduces the alkalinity of the concrete's surface, acid rain or air pollution deposits, such as sulfur and nitrogen-containing compounds, can serve as nutrients for microorganism growth.

Figure 2.1 Wall covered in dark red growth (arrowed) of Trentepohliales. This alga is the primary colonizer in Singapore (Gaylarde, et al., 2011).

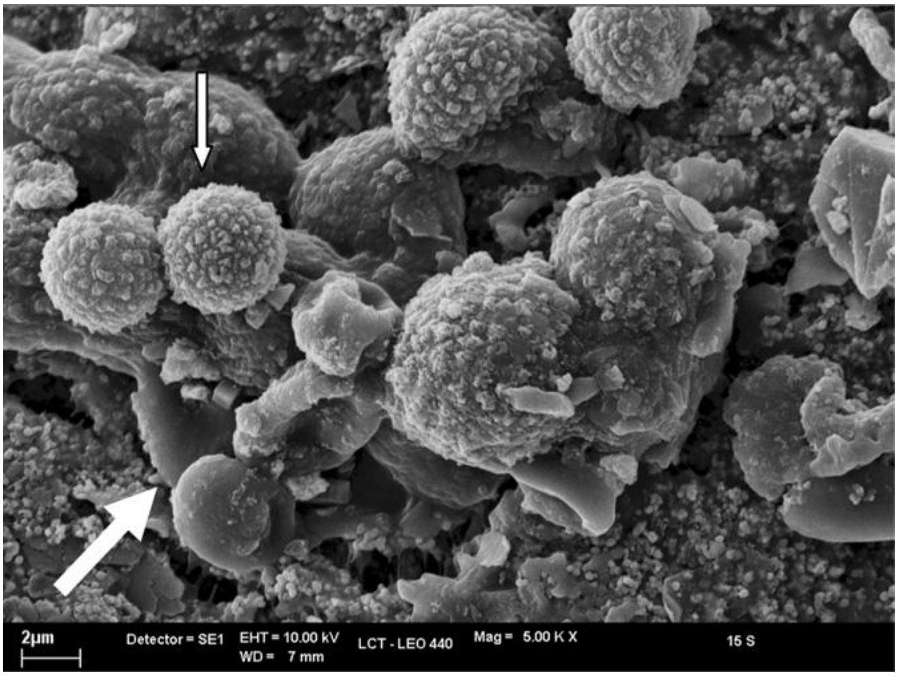


Figure 2.2 SEM of the microbial colony on the surface of an acrylic paint film exposed to the atmosphere for 19 months. The paint films underneath the colony can be seen to have deteriorated. Bar = 2 µm (Gaylarde, et al., 2011).

Furthermore, rain and wind bring a small portion of plants and animals such as spores and microbial cells, which allows the microorganisms to be deposited on the paint's surface. The growth rate of the microorganism relies on the environmental conditions, the substrate of the paint, and the nature of the paint films (Gaylarde, et al., 2011). High humidity or condensation and rise of temperature favor the growth of microorganisms. The constituent of the paint films can inhibit or stimulate the growth of microorganisms. The microbial cells blown by the wind may become unable to grow on the surface of the paint films; however, they may be consumed as nutrients by the microorganism on the surface of the paint films.

2.3.1 Environmental conditions

The environmental conditions are crucial for the microorganisms to grow, such as climates, temperature, humidity, air pollution, human activities, surrounding environments such as coastal and terrestrial environments, and vegetation nearby (Gaylarde, et al., 2011). The climates, temperature, and humidity are closely related. These factors create ideal conditions for the microorganism to grow as the rainy tropical climates provide humidity and ideal temperature for the microorganisms to grow. The growth of microorganisms is also affected by human activities. The presence of the algae on an exposed wall in a suburban area was significantly lower than in urban and rural areas in Latin America. This is due to frequent maintenance and repainting retarding the growth of the microorganisms (Gaylarde, et al., 2011).

Furthermore, concrete structures such as retaining walls closer to the coastal environment are susceptible to increased wind and salt sprays, making them perfect for developing microorganisms such as alga. Trentepohlia (Gaylarde, et al., 2011). Another factor affecting the growth of microorganisms is the presence of vegetation. The microbial spores and fragments on the vegetation can increase the chances of surface colonization due to the higher number of fungi in the air. The vegetation also provides shades for the microorganisms from UV irradiation and maintains humidity under the canopy (Gaylarde, et al., 2011).

2.3.2 Paint component

Paint consists of several components: fundamental paint component, biocides, pigment, and pigment volume content (PVC). Different fundamental paint components will have different resistance to fungi growth, such as low gloss paint will encourage microorganism growth. In contrast, oil-based alkyd paints can resist fungi growth. Bacteria and fungi tend to grow on gloss paint, while water-based and acrylic paint tends to grow alga and complex biofilms (Gaylarde, et al., 2011). However, some paint encourages the growth of fungi, such as cellulosic-based paint. The cellulosic component can be consumed as a nutrient by microorganisms that produce cellulose enzymes. Microbial colonization can produce aesthetic issues and deterioration such as spalling, blistering, and flaking of the paint film.

PVC is the volumetric ratio between resin and pigment which is used to determine the gloss and permeability of a paint. Gaylarde (2011) states that lower PVC can increase the waterproofing and decrease the permeability of the paint. The increase of waterproofing can reduce the growth of fungi; however, the reduction of permeability of the paint time of wetness after rainfall.

Biocide is a mixture of fungicides and algaecides which able to protect the paint from fouling. However, biocides need a specific water solubility to leach from the surface to act on the microbial cells. This can lead to rapid loss of activity and environmental pollution.

2.3.3 Surface substrate

Microbial adhesion and growth are greatly dependent on the surface substrate. The ability of a microorganism to grow on a surface depends on the surface roughness, porosity, pH, and the chemical nature of the surface. Fungal populations are more diverse on rough surfaces than smooth surfaces (Gaylarde, et al., 2011).

Heat absorption by the substrate may encourage the growth of fungi. The lower heat conductivity of the material underneath the painted surface will retain more heat but losing its heat more rapidly than the surrounding area at night. This cause condensation to occur which promote the growth of microorganism.

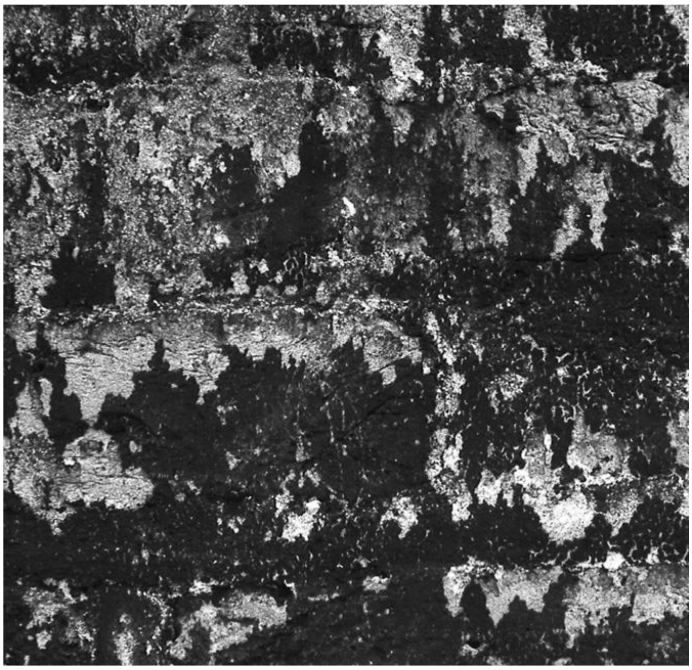


Figure 2.3 Thin, spalling black biofilm of cyanobacteria on a white painted wall. Some of the coatings have been removed, exposing the underlying substrate (Gaylarde, et al., 2011).

2.4 Antifouling

Cement-based composite has a variety of hydrophilic materials. Due to mesoporous properties and hydrophilic, water and aggressive ion can seep through easily into the porous microstructure, which can reduce the durability and service life. The physical and chemical degradation process is caused by water ingression because water can act as a transport medium for the aggressive ion to seep through. (Wang, et al., 2020)

For the past years, the number of research on the advantages of using antifouling on mortar has been rising. The usage of antifouling on mortar has shown a beneficial effect with a minimum side effect on the strength of the mortar. Although most of the antifouling use biocides, some of these compounds contain dangerous properties such as high toxicity, disruptive endocrine effect, or bioaccumulative potential (Trávníčková, et al., 2020).

Most antifouling has Cu and Zn, and the present these metals are dangerous to marine life. In his article, Turner et al. (2009) said that about 0.1% and 1.3% of Cu and Zn respectively are solvent-extractable, and the discharge of the leachate from the antifouling paint is toxic to marine low as 4mg/L.

Therefore, antifouling based on organic materials is needed as the compound is a biocide that does not harm the environment. The quantity of the waste can be reduced as the waste product from the industries increases. Furthermore, the fabrication of the antifouling based on organic material does not release harmful gasses as the fabrication of chemically synthesized antifouling would do.

2.4.1 Superhydrophobic coating

The superhydrophobic coating is a layer of low-energy surface that can repel water with ease. For a surface to gain the hydrophobic characteristic, the surface topography and chemistry are the main aspects to determine the degree of hydrophobicity. To achieve superhydrophobicity, the surface must have smooth surface topography in terms of both macro and nano-scale structure and the surface chemistry must have a proper design to achieve low energy surface (Dimitrakellis & Gogolides, 2018).

Both hydrophobic surfaces and superhydrophobic surfaces can repel water. However, superhydrophobic has more beneficial aspects such as anti-corrosion, anti-freezing, anti-biofouling, anti-fogging, and self-cleaning (Dimitrakellis & Gogolides, 2018). The superhydrophobic surfaces also possess a higher water contact angle (WCA) and lower sliding angle (SA) compared to hydrophobic surfaces.

For a superhydrophobic surface, the WCA must be more than 150°, and the SA needs to be lower than 10°. As for the hydrophobic surface, the WCA must be more than 90° but less than 150°, and the SA must be more than 10°. Moreover, the superhydrophobic can act as a sealant to prevent water from seeping into the concrete matrix through the micro-cracks developed.

Superhydrophobicity is a nature-inspired design of the lotus leaf. The surface of the lotus leaf has attained superhydrophobicity. Therefore, for a surface to achieve superhydrophobicity, the microstructure of the surface can imitate the microstructure of the lotus leaf. Peng Liu et al. (2017) have created a negative template of a lotus leaf that can be used to fabricate cement with a superhydrophobic surface. It was found out that the lotus leaf surface has micro papillae with a size of around 10 µm in diameter, and hydrophobic nanofibers that spread on the micro papillae enhance the hydrophobicity of lotus leaf.

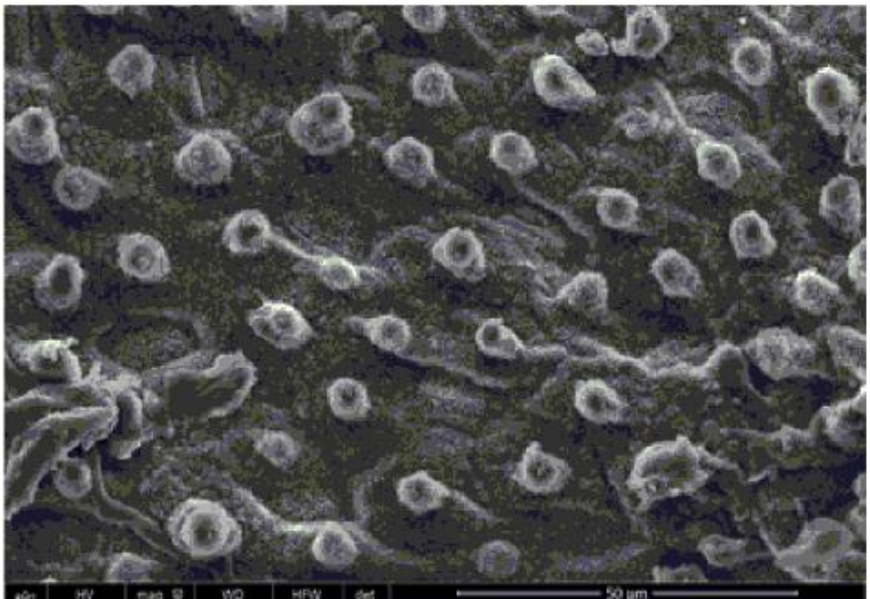


Figure 2.4 Microstructure of lotus leaf (Liu, et al., 2017)

2.4.1(a) Application

The superhydrophobic can be applied with two methods: admixing together with the cement during casting and coat the mortar surface with the superhydrophobic. For the admixing, the superhydrophobic can be added as an additional additive, not as cement replacement. The superhydrophobic will be mixed with water and cement during casting.

The superhydrophobic can be applied as a coating on the surface of the mortar. The application of superhydrophobic as the coating can make use of relevant technologies such as supersonic kinetic spraying, brushing coating, solvent casting, spin coating, and dip-coating (Wen & Guo, 2016).

Subbiah et al. (Subbiah, et al., 2018), in their article, found that both methods of application of the superhydrophobic do not have any significant difference between the method of application. In this project, the superhydrophobic will be applied as a coating by using dip-coating. Dip-coating was used because this method can coat every micro-cracks or pores efficiently.

2.4.1(b) Superhydrophobic compound

To achieve superhydrophobicity on a surface, the compound of the superhydrophobic solution is crucial to make sure that the surface is low energy surface. TiO_2 and SiO_2 are commonly used in the production of superhydrophobicity due to their properties. TiO_2 is widely used in industries because it has photocatalytic properties, meager cost, and very high stability (Zhang, et al., 2013). TiO_2 can withstand UV radiation due to its very high stability, which is the main problem for typical superhydrophobic coating (Subbiah, et al., 2018).

In the construction industry, silicon-based compounds are commonly used to act as water repellent agents. Silanes, siloxanes, and silicones are the widely used silicon-based compound (Husni, et al., 2017). Other than that, 1H,1H,1H,2H-perfluorodecyl-triethoxysilane (PFDTS), and non-fluoro polydimethylsiloxane (PDMS) can be used to act as surface functionalizing agents.

In this project, palm oil fuel ash (POFA) was used to extract silica. The silica was chosen because the interaction of concrete and water can be reduced due to the alkyl group of the silicon-based compound (Husni, et al., 2017). Meanwhile, PDMS will act as a functionalizing agent because it is low-cost, has high chemical resistance and UV resistance. (Mulroney & Gupta, 2017)

Table 2.1 Summary of the superhydrophobic compound that was used in the past study.

Country	**Superhydrophobic compound**	**Author**
India	1H,1H,1H,2H-perfluorodecyltriethoxysilane (PFDTS) with nano TiO_2 and SiO_2 inclusions	(Subbiah, et al., 2018)
Malaysia	Silica from palm oil fuel ash (POFA) waste with non-fluoro polydimethylsiloxane (PDMS)	(Saharudin, et al., 2018)
China	Titanium dioxide nanowires with polydimethylsiloxane (PDMS).	(Zhang, et al., 2013)
Malaysia	Rice husk ash and 1H,1H,2H,2H-perfluorodecyl triethoxy silane	(Husni, et al., 2017)
China	SiO_2 and perfluorodecyltriethoxysilane (PFDTS)	(Wang, et al., 2020)

2.5 Test

Antifouling can be compared to the previous article on superhydrophobic coating. The following is the test that needs to be considered when conducting the test on superhydrophobic coating to verify the superhydrophobicity and suitability.

2.5.1 Water Contact Angle (WCA)

The water contact angle is a parameter that is used to differentiate the difference between hydrophilic, hydrophobic, and superhydrophobic. When the water contact angle of a surface is below 90˚, the surface is recognized as hydrophilic, and when the water contact angle is more than 90˚, the surface is considered hydrophobic. However, if the water contact angle is more than 150˚, the surface has achieved superhydrophobicity (Law, 2014).

When the water droplet comes in contact with the superhydrophobic surface, it will exhibit the lotus effect or Cassie Baxter state. The lotus leaf is the best example to represent the Cassie Baxter state. Cassis Baxter state occurs when the air is entrapped in between cavities which causes the water droplet to be suspended on top of the asperities of the surface (Saharudin, et al., 2018).

In past research by Saharudin et al. (2018) used POFA to extract silica, and PDMS was used as a surface functionalizing agent. The PDMS was mixed with the silica solution (SS) that was extracted from the POFA with the ratio of 1:1, 1:2, 1:3. 1:4, and 1:5. It was found out that the PDMS: SS ratio that achieves superhydrophobicity was 1:2 than 1:5 with the water contact angle was 156±1˚ and 138±1˚, respectively. This is because the top of the existing spikes is clumped with SiO_2.

The distance between each protrusion is higher for the PDMS: SS with the ratio of 1:5 compare to PDMS: SS with the ratio of 1:2. This leads to a reduction of air trapped in the spacing between the protrusion; hence the water droplet penetrates the microstructure. This causes the surface to lose superhydrophobicity.

Table 2.2 Summary of WCA results that were obtained in past studies.

Country	Method	WCA (°)	Author
India	Coating	162.3	(Subbiah, et al., 2018)
	Admixture	162.0	
Malaysia	PDMS:SS 1:2	156 ± 1	(Saharudin, et al., 2018)
	PDMS:SS 1:5	138 ± 1	
China	Coating	158 ± 2	(Zhang, et al., 2013)
Malaysia	Coating	152.3 ± 0.5	(Husni, et al., 2017)
China	Admixture	159± 0.8	(Wang, et al., 2020)

2.5.2 Sliding Angle (SA)

The sliding angle quantification of the roll-off ability of a surface. The sliding angle is the minimum angle of a surface that needs to be tilted to induced the water droplet to roll with respect to the horizontal plane. For a surface with superhydrophobicity, the SA needs to be lower than 10˚; meanwhile, for a hydrophobic surface, the sliding angle will be more than 10˚ (Dimitrakellis & Gogolides, 2018).

The sliding angle is affected by the topography of a surface. Smoother surface topography tends to have a lower sliding angle. Ideally, both macro and nano-scale surface structures must be smooth to achieve a sliding angle of below 10˚ (Dimitrakellis & Gogolides, 2018). When the sliding angle of a surface is lower than 10˚, it is in Cassie-Baxter state. This is due to the surface morphology nature promoted by the superhydrophobic compound (Saharudin, et al., 2018).

In the past study by Zhang et al. (Zhang, et al., 2013), the superhydrophobic surface can use the sliding angle to achieve self-cleaning. A self-cleaning surface will remove contaminants by letting the water droplet roll over and absorb the contaminants.

In the research, the sliding angle obtained was about 5°, which was possible by fabricating a superhydrophobic together with TiO_2 nanowires coating by using the dipping method.

Table 2.3 Summary of SA results that were obtained in past studies.

Country	Method	SA (°)	Author
India	Coating	5.7 ± 2.5	(Subbiah, et al., 2018)
	Admixture	5.9 ± 2.5°	
Malaysia	PDMS:SS 1:2	1 ± 1	(Saharudin, et al., 2018)
	PDMS:SS 1:5	15 ± 1	
China	Coating	5	(Zhang, et al., 2013)
Malaysia	Coating	NA	(Husni, et al., 2017)
China	Admixture	5 ± 0.5	(Wang, et al., 2020)

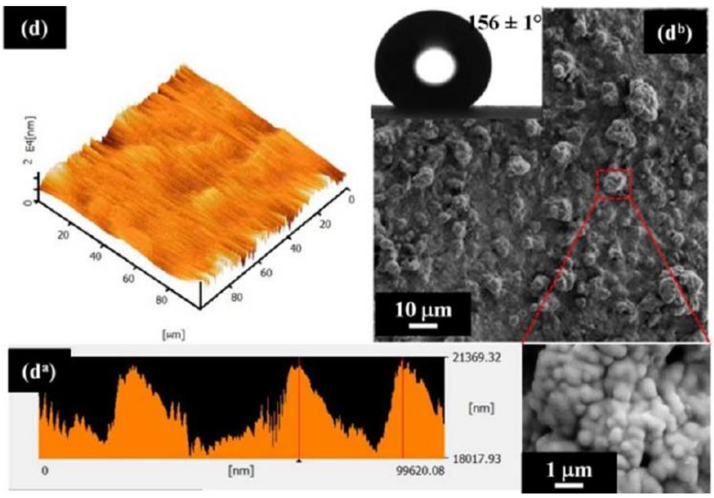
2.5.3 Characterization

The characterization is used to analyze the surface of the surface. It is crucial to determine the surface roughness of a surface. Characterization also helps to understand better how the surface will perform when water is dropped onto the surface. The morphology and topography of the surface can be examined using field emission scanning electron microscopy (FESEM) and atomic force microscopy (AFM).

The lotus leaf-inspired the superhydrophobic surface; therefore, the microstructure of the superhydrophobic can imitate the microstructure of the lotus leaf. The lotus leaf has micro papillae with a diameter of around 10 μm. The microstructure of the lotus leaf correlates with the Cassie-Baxter state. The Cassie-Baxter state proposed that the infiltration properties of droplets on a rough surface can be regarded as a composite interaction. As liquids infiltrate the heterogeneous surface, they do not thoroughly wet the spaces between the protrusions on the uneven surface. Under the liquid drop, the air is confined, and the droplet is in contact with a complex interface of vapor and solid

In the past research by Subbiah et al. (Subbiah, et al., 2018), the PDMS: SS weight ratio of 1:2 was able to achieve superhydrophobicity while PDMS: SS weight ratio of 1:5 only achieve hydrophobicity. The FESEM image (Figure 2.5 d^b) shows that the surface has hills and valleys resulting from the micro papillae structure. The AFM line profile (Figure 2.5 d^a) shows the topography of the surface. The AFM line profile for PDMS: SS with a weight ratio of 1:2 shows an average distance between spikes of approximately 25.94 µm. The higher magnification of the image shows that the spike has the formation of a hierarchical structure to achieve high roughness, increasing the number of air pockets and air-liquid contact area.

Figure 2.5 3D AFM topographical images of PDMS: SS with a weight ratio of



1:2. The image at the right side shows the FESEM (d^b), and the image at the bottom shows the line profile of AFM (d^a) (Saharudin, et al., 2018).

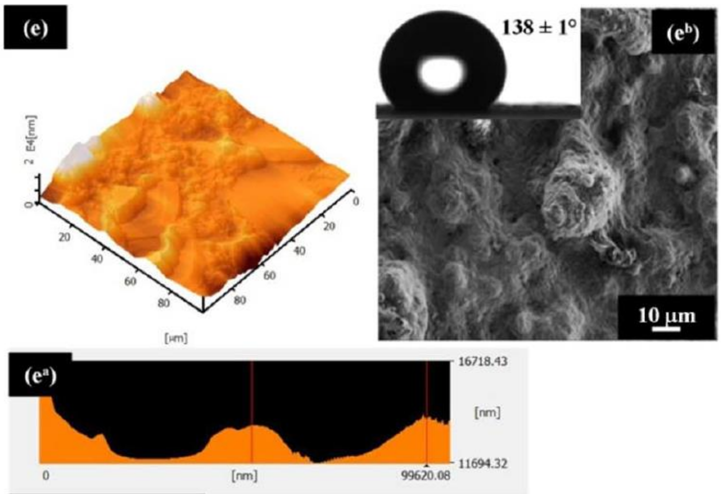


Figure 2.6 3D AFM topographical images of PDMS: SS with a weight ratio of 1:5. The image at the right side shows the FESEM (e^b), and the image at the bottom shows the line profile of AFM (e^a) (Saharudin, et al., 2018).

2.5.4 Fungal resistance

The geotechnical structure that is exposed to the aggressive environment such as groundwater, seawater, and extreme climates is susceptible to deterioration. The presence of moisture will encourage the growth of fungi and microorganisms since they are ubiquitous in most habitats. This can lead to biodeterioration that will change undesirable changes in material properties of the geotechnical structure (Miron & D., 2017). Biodeterioration is a global problem caused by various microorganisms that will lead to distinct damage to the structure, such as physically, chemically, and aesthetically (Carrillo-González, et al., 2016).

Fungi are ubiquitous; therefore, they can grow on the surface and inside cracks and pores, and they contribute to the degradation of the aesthetic value of the geotechnical structure. It was reported that *Cladosporium, Penicillium,* and *Aspergillus* are the common fungi that exist in the atmosphere, and humidity of the local environment affects the concentration of the fungi (Er, et al., 2018). The growth of fungi does not only deteriorates the aesthetic value of the geotechnical structure but can also cause respiratory problems. Symptoms are rhinitis, cough, and sore throats (Jerónimo, et al., 2019).

Mold is one of the fungi families that grow on the surface of mortar, whether indoor or outdoor. Within the mold is mycelia, which releases tiny spores into the air to reproduce and fungi also produce biologically active substances such as mycotoxins to ensure the persistent existence of the fungi. These can cause problems related to health such as allergy, Allergic fungal sinusitis, immune suppression diseases, asthma, skin allergies, etc. Children and senior citizens are especially vulnerable to these health problems (Chuduri, 2014).

2.6 Past Research

A few types of research were done to evaluate the performances of superhydrophobicity on several surfaces such as glasses, grout, and mortar. In the past study, several approaches were used to utilize the advantages of superhydrophobicity properties, such as the coating on the surface and admixture in the mortar or grout.

Subbiah et al. (2018) did both methods of applying superhydrophobic coating on cement mortar and admixing during the cement casting. The superhydrophobicity was achieved by using synthesized TiO_2 and SiO_2 nanomaterials and 1H,1H,1H,2H-perfluorodecyltriethoxysilane (PFDTS). The coating was prepared by adding 1.5g of nano-TiO_2 and 1.5g of nano-SiO_2 into PFDTS/ethanol mixture. The admixture was prepared by adding 1.5g of nano-TiO_2 and 1.5g nano-SiO_2, and 1mL of PFDTS into the 100g of OPC.

In the research, the water contact angle (WCA) that was obtained for the coating method and admixture method was 162.3° and 162°, respectively. From the result, it can be concluded that the different approaches do not affect the performance of the superhydrophobic since the WCA for both methods is the same. In conclusion, the PFDTS and the nanomaterials were successfully grafted into the cement matrix and achieved superhydrophobicity. However, the use of TiO_2 and SiO_2 was not sustainable as the nanomaterial was made chemically.

Husni et al. (2017) researched evaluating the feasibility of superhydrophobic ash coating on concrete to reduce the water absorption of concrete. The superhydrophobic coating utilizes the water repellent properties from the rice husk ash. The homogenous ash solution was manually sprayed onto the layered adhesive on the concrete cube surface. The spraying method was fixed at a consistent distance of 10 cm until the surface was wetted, and the usage of the solution must be at least 278 ml/m^2.

The rice husk was dried at 110˚C for 24 hours, and 20g of dried rice husk was stirred in citric acid for 2 hours at 50˚C. The dried rice husk was treated with citric acid to start the hydrolysis of celluloses and hemicelluloses. The rice husk was filtered, rinse, and dried. The rice husk was then calcined in a muffle furnace at 800˚C for 30 minutes under the atmospheric condition to obtain silica from the rice husk. Silica reduced the interaction between concrete and water because of the alkyl group of the silicon-based compound. 3g of rice husk ash was then dispersed into 50 ml of 1H,1H,2H,2H-perfluorodecyltriethoxysilane (HFDS)/ethanol mixture.

As a result of using rice husk to synthesized superhydrophobic coating, the water contact angle achieved was 152.3 ± 0.5˚C, which satisfies the superhydrophobicity properties. In conclusion, using the ethanolic solution with rice husk ash and fluoroalkyl silane, a superhydrophobic surface was successfully formed on the surface of the concrete. However, the bond between the superhydrophobic and the surface of the concrete was not sufficient as a layer of adhesive was needed to make sure that the superhydrophobic coating does not wear down during its expected service life.

2.7 Summary

In order to overcome problems faced by cement-based structure, a lot of researches on superhydrophobicity have been accomplished that can be utilized to improve the quality and durability of the structure in the actual case scenario.

As a result, all researchers successfully fabricated the superhydrophobic coating on each sample surface and were able to satisfy the superhydrophobicity properties, which are water contact angle more than 150° and sliding angle of less than 10°. However, most of the superhydrophobic coatings used are synthesized chemically, and some researchers used glass surfaces as a sample.

In this research, the superhydrophobic coating was synthesized using an organic compound that was extracted from palm oil fuel ash (POFA) waste which is environmentally friendly and reduces the amount of waste produced from the industry. Moreover, a cement-based surface was used in this research to replicate the surfaces of the geotechnical structure. To verify that the coating was superhydrophobic, water contact angle and sliding angle were determined, and the characterization of the coating was done to find out further how the coating performs.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter would explain the workflow representing how the study was conducted. Desk study on hydrophobicity surface has been done to conduct the experiment. Silica which is a silicon-based compound was used to act as a water repellent agent for the surface to achieve superhydrophobicity. The silica was extracted from palm oil fuel ash (POFA) waste. The superhydrophobic solution is then applied to the surface of the sample by the dip-coating method. Characterization was conducted to identify the surface as a superhydrophobic surface, such as FESEM and water contact angle. Other than that, a fungal resistance test was also conducted to guarantee that any fungal and microorganism cannot grow on the superhydrophobic surface to avoid deterioration and aesthetic damage caused by the fungal. Further details are shown in Figure 3.1.

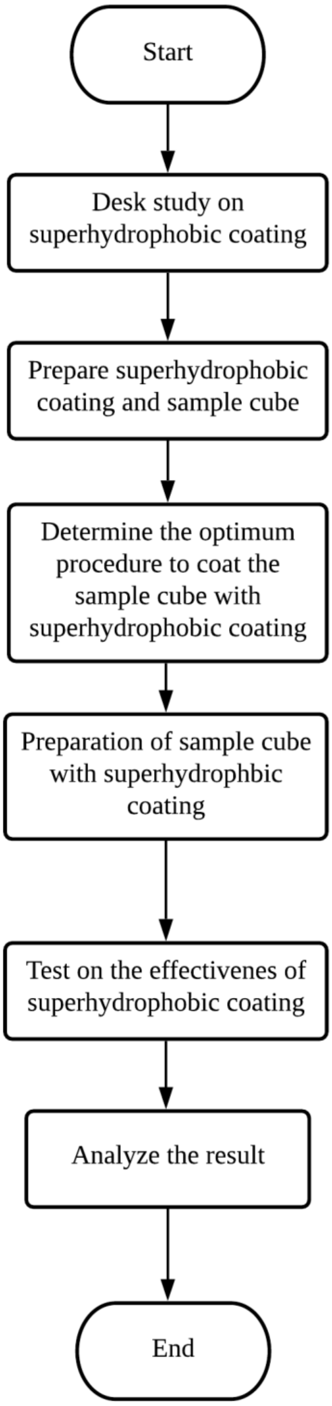


Figure 3.1 Flowchart for methodology.