SEMARAK ILMU PUBLISHING

Journal of Advanced Research in Applied Mechanics

Journal homepage:
https://semarakilmu.com.my/journals/index.php/appl_mech/index
ISSN: 2289-7895

Exploring the Feasibility of Utilizing Palm Tree Texture for a Self-Cleaning Architectural Design of Building Envelopes

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ARTICLE INFO

Article history:
Received 13 June 2023
Received in revised form 15 August 2023
Accepted 31 August 2023
Available online 9 October 2023

Keywords:
Self-cleaning; surface and texture; building envelope cleanliness

ABSTRACT

The passion of self-cleaning potential on palm tree species contributing to building envelope design maintenance through biomimetic architecture is the notion of this exploration. The greediness of property investors that are more concerned on building design to strive the sustainability rather than the maintenance strategic on their building. However, the uniqueness on building shapes and patterns of this envelope confronts with main complications on surface maintenance in associates with pollution such as air-bone, water-bone and grease-born pollution that also trap in air moisture. Furthermore, the selection of material is the important fragment in building envelope cleanliness to design the sustainable maintenance. In conjunction, the palm tree foreseen as self-cleaning building envelope that has the potential to develop the resilience maintenance based on its characteristics. Therefore, the exploration on surface and texture of selected specimen of palm tree is main contributor to this research in finding the self-cleaning characteristics on building envelope materials. The selective specimen will be monitored under Light-microscope and Scanning Electron Microscope (SEM) based on environmental experiment. The outcome of this exploration will discover the nature mechanism through its nature course and develop the self-cleaning conceptual on building envelop materials to overcome the problems in every building envelope design.

1. Introduction

Palm trees known as low maintenance landscape category characteristics is explored by Nuzaihan Aras *et al.,* [1]. Spennemann Drik [2] in his research claimed that palm trees had largely organismal life span. Gurupranes *et al.,* [3] found there are total numbers of 32 species of palm trees mentioned and the population in tropical country as proven by Barry Tomlinson and Brett Hugget [4]. The

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https://doi.org/10.37934/aram.110.1.3751

pattern, form and structure of the palm trees are explored to find the most suitable pattern and form of palm trees for building envelope maintenance in tropical country. The special characteristic of the palm trees and the special texture had made them survived in tropical climate investigated by Nuzaihan Aras *et al.,* [1] and also through the form of the leaves to prevent it from dehydrated by Gurupranes *et al.,* [3]. It is believed that these characteristics had bring palm trees and palm leaves into architectural styles and modification of the forms and patterns on building envelope or building skin design.

Abdullah Badawy [5] in his journal seen that biomimetic in architecture is the way of finding solutions to approach sustainability in between building and nature support from theoretical statement written Barry Tomlinson and Brett Hugget [4]. Biomimicry does not exploit nature by extracting material goods from nature but implement the nature value and characteristic of the palm leaves. Concept of biomimicry is to learn and explore the characteristic from nature environment and implement or involve it into building design or material maintenance such as self-cleaning characteristic from lotus plant and palm tree. Biomimetic technologies are offer a technology that offer multi-functions as referred from Abdullah Badawy [5]. This can result in cost saving benefit in building envelope maintenance in future and it is environmentally friendly to the global.

The challenges in selecting the best material for building envelope contributes to exploration on materials innovation. Most of skyscrapers design using curtain wall as its building envelope. The external wall surface using tempered glass, insulating glass, laminated glass or coated glass are exposed to the high content of dirt, debris, and other harmful mineral deposits in the air. Oh Seungtae *et al.,* [6] in his research found that this materials in not exception trapping the impurities in the air that is exposed to air contamination. The management has to allow the cleaning maintenance at least 12% of the total cost of the maintenance expenditure for a building and it leads to high cost consume support from Kim and Lau [7].

Building envelope required maintenance to increase the lifespan and also maintain the building function and operation especially building envelope. Building envelope as building façade forms the external layer of weatherproof envelope to a building. This is explored by Sommese Francesco [8] that it protected the building skin from environment disaster. There are many different types of materials can be use in design building envelope such as cladding panels, aluminium or glass curtain walling and profiled metal sheets. Sommese Francesco [8] in his research found that every different type of building envelope material requires various type of maintenance and building maintenance always facing the problem to maintain the building envelope for skyscraper and the maintenance cost is more expensive than normal building supported from Christino *et al.,* [9]. Proactive maintenance is required for every property with annual maintenance budget, regular building condition assessments, and annual proactive maintenance. Regular maintenance for building envelope is very important to a building as building façade is the skin and pretend to be a layer of protection between weather, climate and building skin.

This exploration of the concept of utilizing the self-cleaning potential of palm tree species within building envelope design through biomimetic architecture. It highlights a contrast between property investors' focus on sustainable building design over maintenance strategies, emphasizing the crucial role of material selection for building envelope cleanliness and sustainability. The study envisions palm trees as a self-cleaning building envelope solution, leveraging their inherent characteristics to enhance maintenance resilience. The research primarily investigates the surface and texture of palm tree specimens, employing techniques such as Light-microscope and Scanning Electron Microscope (SEM) analyses through environmental experimentation. The anticipated outcome aims to uncover the natural mechanisms governing self-cleaning attributes, consequently informing a self-cleaning building envelope material concept that addresses challenges in building design.

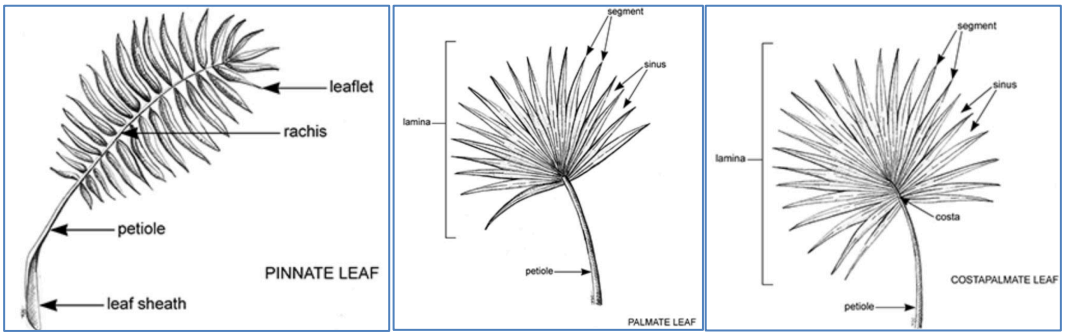
2. Literature Review

Biomimetic architecture is a concept that architecture seeks solutions for sustainability in nature for building design, it is not by replicating the nature forms, yet it is by understanding the rules of governing those forms specified by Louis Vatalis and Natasha Chayaamor [10]. In addition, Oh Seungtae *et al.,* [6] mentioned that the larger movement of biomimetic architecture are known as biomimicry, which is examination of nature, systems, models and processes for the purpose of gaining design inspiration and solve man made problem and archive sustainability in building design emphasised by Sommese Francesco [8].

Sommese Francesco [8] said that biomimicry has total three levels of biomimicry, which is the organism, behaviour, and ecosystem. The organism level is referring to a specific organism involves in biomimicry such as involve a plant or an animal in mimicking part of or the whole organism. The second level, which is behaviour level, refers to mimicking behaviour, including translating an aspect of how an organism behaves or related to large context. While the third level will be ecosystem level, which refers to mimicking the whole ecosystems and the common principles that allow the ecosystem to successfully function. There are five possible dimensions to the existing mimicry, the design involves in terms of form, materials, construction, process and function indicated by Barry Tomlinson and Brett Hugget [4]. Therefore, this conceptual is potential to be used in upgrading the functionality of building façade and it is proving as problem solving to building skin supported by Christiono Utamo *et al.,* [9].

Louis Vatalis and Natasha Chayaamor [10] in their research found that palm tree is one of the famous plants in tropical country as many of them are grow in hot climate with warm temperature such as in Malaysia. Palm trees had held an important role in human daily life, many common products and food are come from palms. The palm family have consisted of six subfamilies which is Coryphoideae, Calaoideae, Nypoidaea, Ceroxyloidaea, Arecoidaea and Phytelephantoideae. Besides of lotus' leaf, plant leaf that being well known with self-cleaning characteristic are palm leaf, so it is believe that the characteristic of palm leaves has the potential to contribute in building envelope design mentioned by Barry Tomlinson and Brett Hugget [4] and protect it from weather disaster due to local environmental condition and climate supported by Arshia Muhktar [11]. Most of the palm trees are straight unbranched, tall and erect stem. Besides that, palm trees have large evergreen leaves and they are mostly either "feather-leaves" or "fan-leaved" and they are arranged in a spiral at the top of the trunk added by Natalie Uhl and Dransfield [12]. These leaves have a tubular sheath at the base that usually splits open on one side when it is grown. Leaves of palm trees are in huge variety of sizes, shapes and textures enhanced by Ana Flávia *et al.,* [13]. Palm leaf with palmate or entire leaf are the species that most common to be suggested to use in building envelope design as the shape of palmate leaf and entire leaf are in big diamond or fan shaped. These big diamond and fan-shape have made the palmate and entire palm leaf become very suitable to be use in designing building envelope especially a roof or a cover of a building as the shaped and form of the leaves are suitable to be a building shelter as trusted by Ana Flávia *et al.,* [13].

Palmate leaves are the second most common leaf type in the palm tree family around the world. They also known as a fan-shaped leaf or fan-palmed. Palmate leaves are extended leaf parts '*lamina*' which in circular or semi-circular, divided into segment and radiate out from the point where they are attached to the petiole found by Ana Flávia *et al.,* [13] in her research. There are 3 types of palm leaves pattern which is pinnate, palmate and costapalmate mentioned by Marcones Ferreira *et al.*, [14]. Figure 1 shows the pattern and form of palm leaves commonly found tropical country.



(a) (b) (c)

Fig. 1. shows the pattern and form of palm leaves Marcones Ferreira *et al.,*[14] (a) Pinnate leaf (b) Palmate leaf (c) Costapalmate

An entire leaf is simple in the leaf shape and it is undivided, but it has the basic structure which similar to the pinnate leaves stated by Marcones Ferreira *et al.,* [14]. There are only five type of palm genera have species with entire leaves. Johannesteijsmannia magnifica has the largest and most beautiful diamond leaf shaped in the palm trees family around the world. Robert Read and Leo Hickey [15] mentioned that the characteristic of this kind of palm tree is most suitable to be plant and grow in tropical country. The following Figure 2 shows the form and pattern of Johannesteijsmannia magnifica found in tropical country.

(a) (b)

Fig. 2. Figure of Johannesteijsmannia magnifica leaves (a) Form of Johannesteijsmannia magnifica plant (b) The leaves pattern of Johannesteijsmannia magnifica

Building architecture concerned on sustainable building design features and established it as a set of principles for great design rather than considering making an externality of building with green building design. Uzair Muhammad *et al.,* [16] understood that principles of a great design or sustainable design including better user experience, comfort, doing more with less to enable the building easily to achieve the greatest performance, durability and quality of materials. In conjunction with this hypothesis, Uzair Muhammad *et al.,* [16] believed plant leaves that being well known with self-cleaning characteristic are palm leaf and it is believe that the characteristic of palm leaves has the potential to contribute in building design supported by Arshia Muhktar [11]. Palm leaf with palmate or entire leaf are the species that most common to be suggested to use in building envelope design as the shape of palmate leaf and entire leaf are in big diamond or fan-shaped found by Aderson [17] and it is very suitable to be use and implement in designing as a building shelter cited by Kissling *et al.,* [18].

Building envelope function as a barrier between the distinctive environment of a building, including the resistance to heat, water, air, light, air and noise transfer as declared by Uzair

Muhammad *et al.,* [16]. Hubert *et al.,* [19] found that the building envelope is one of the important elements of outer shell of a building to maintain the indoor condition as a dry, heated, or cooled indoor environment and facilitate its climate control. Building envelope is also a key aspect of energy-efficient-high performance building, solar gains, air leaks, water leakage, moisture control, and thermal loose and gains are all affected by building envelope design and construction. Normally, building envelopes are referred to either "tight" or "loose". Loose envelope which means air are allowed to flow more freely in and out through the building whereas tight envelopes are restricted air flow or control the air flow thought the building stated by Wu Haoran and Zhang Tong [20]. Generally, building envelope materials including brick façade, ceramic façade, stone façade and all-glass façade cited by Chioke Harris [21]. However, Luo Yongqiang *et al.,* [22] mentioned that every different type of building envelope materials are require different type of maintenance work due to building envelope involve of the change in moisture levels, temperature, and the form of precipitation acting on the building envelope system which can lead to affect the dimensional materials such as cracking in polymer-based materials, for example as window frame, sealants, cladding wall and gaskets or lead to rot in timber envelope materials, and corrosion in metal. Others factor such as ultraviolet radiation, temperature fluctuation, air pollutants and incompatibility of materials will also affect the life span of a constructions added by Rivera Lizeth *et al.,* [23].

All-glass façade has been widely used as a cover in building skin with the compare to others building façade materials, no other materials have better durability, economy and ability to control light and heat transfer than glass façade mentioned by Fahmy *et al.,* [24]. All-glass façade has more advantages compare to others façade materials. All-glass façade can reduce dead load for skyscrapers, providing an integrated view of the outside scenery for inside residents, and also creating a feeling of lightness and elegance of the building. On the other hand, all-glass façade also creates some problem to the residents due to the low thickness and low thermal resistance. Problems including indoor temperature in hot and mild seasons will be increase due to the lack of external shading. Gutai Matyas and Ganji Kheybari [25] obviously that the surface temperature of all-glass façade is close to the outside ambient temperature due to the low thermal resistance and human stay near to the façade will experiences heat transfer by radiation and feeling lack of thermal comfort supported by Shi Wun Tong *et al.,* [26]. Moreover, glass surface is easy to collect dust and dirt particle due to the electromagnetic force. Electromagnetic force refers to electrostatic forces as well as other forces between charges and magnetic field where they may be moving relative to each other as the moving charges between surface of the glass and the dust and dirt particles create magnetic fields and the moving charges will exert forces on each other due to their magnetic properties added by Fahmy *et al.,* [24]. When the surface of the glass is positively charged, and dust particles fly near to it, the charge in dust particles will be induced by the positive charge on the glass surface and then pulling the negative charges closer to it and pushing the positive charges away. Again, Fahmy *et al.,* [24] said the surface of the glass will attract the negative charge in the dust particle and the dust will stick on the surface of glass. There three types of pollutions that triggered the maintenance work for glass façade become more problematic and costly especially for high raise tower building and skyscrapers: example:

i. Airbone Pollution; Li Hsia Yeo *et al.,* [27] mentioned every content that floating in the air will cling to the glass with the wind. Car exhaust, smoke from opening burning and pollen.
ii. Waterborne Pollution; Typical mains water contains between 200-500 parts per million of particle solids (pollutants) which stick together with clumps on the glass, hazy mess on glass when the water droplets is evaporated stated by Shi Wun Tong *et al.,* [26].

iii. Grease and Steam*;* the tiny solid particles from grease that produce from all kitchen will floating in the air and follow the direction of the wind and in the end stick on window or glass façade of a building stated by Fahmy *et al.,* [24]. Grease will make the cleaning process become difficult as it cannot simple clean by water wash said Li Hsia Yeo *et al.,* [27].

3. Methodology

The powdering techniques on the characteristic of the date palm been used as an experiment for this research to find the free-maintenance characteristics as declared by Fuad Zinab *et al.,* [28] between two species that is Johannesteijsmannia and Licuala. There are 3 types of palm leaves pattern which is pinnate, palmate and costapalmate that added by Marcones Ferreira *et al.,* [14], Johannesteijsmannia has the thickest leaf in palmate family in costapalmate pattern. However, it has different surface compared to Licuala. Both specimens are selected based on its different character on surface. Johannesteijsmannia has a hairy, dusty and rough surface while *Licuala* own a glossy, smooth and shiny surface. Laboratory Test using Scanning Electron Microscopy (SEM) to get closed image and character on both specimens.

Both samples are tested on actual environmental conditions using environmental experiments to test on the effectiveness of natural cleaning characteristics that can be found in these specimens. There are two types of approach which is laboratory test using powdering techniques on the characteristic on the surface of the leaves and environmental experiment. These two experiments are used to test the three types of pollutions that triggered the maintenance work for glass façade. Figure 3 shows the chart of research framework of this findings.

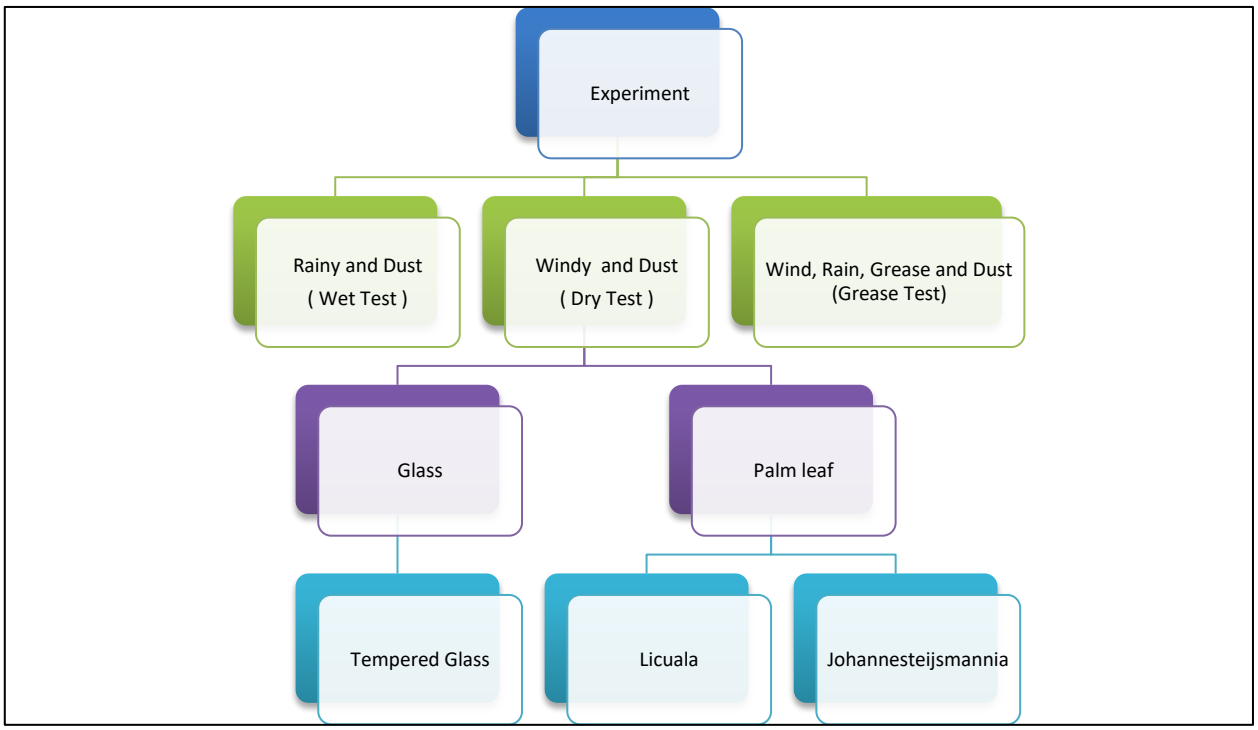


Fig. 3. The research framework of Self-Cleaning Building Envelope

3.1 Laboratory Test

Two types of selected palm leaves will be process and undergoing a biology lab test to scan the surface texture of these three types of palm leaves by using Scanning Electron Microscopy (SEM), and Light Microscopy. The palm leaf will be cut into small pieces to undergo SEM to identify the surface texture of the palm leaves. Furthermore, others part of the palm leaf will be place under light microscopy to observe the characteristic on the two species of palm tree in three different environmental circumstance based on the natural environment condition which are dust, rain and grease.

3.2 Environmental Experiments

Three types of experiments will be processed to explore the self-cleaning characteristic of the palm leaves. The experiments will be dry test, wet test and both dry and wet test, dry test will be conduct by using windy and dusty situation, wet test will be conduct by using rainy, windy and dusty situation while for dry and wet test will be conduct by using windy, dusty, rainy situation and that will be a layer of grease on the surface of palm leaves. These three types of environmental experiments are design based on the natural environmental disorder due to the requirements of building envelope need to be able to against the natural weather disaster and protect the building, maintain the building function and increase the lifespan of the building in long term period. Figure 4 describe the apparatus set up on both samples.

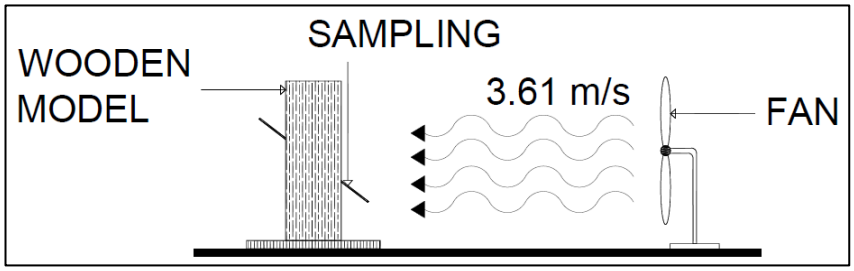


Fig. 4. The apparatus set up

Apparatus will be set up as shown in Figure 4. After setting up the apparatus, sample will be weight of dust and go through three different environmental experiments. With the same amount for both specimens, this sample will be weight again after the environmental experiments to determine the amount of dust that wash away and the self–cleaning characteristic of palm leaves. The average wind speed will be set in 3.61m/s and the time recorded is 60 seconds. Through the three different environmental experiments, the ability of self-cleaning characteristic on two different species of palm leaves are clearly can be see and record.

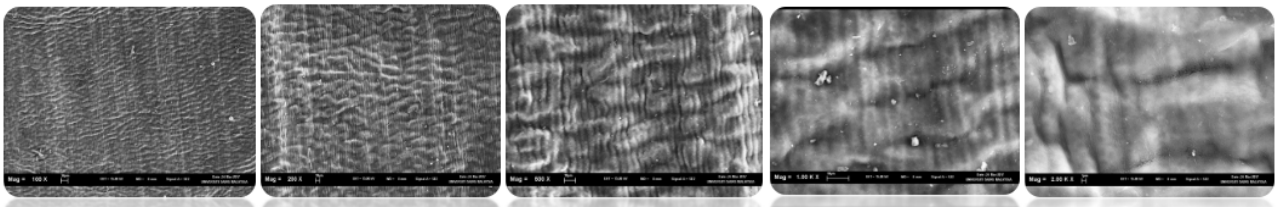
4. Results

4.1 Scanning Electron Microscope (SEM)

Species Johannesteijsmannia and Licuala will be undergoing scanning electron microscope (SEM) to observe and identified the surface of the leaves. Surface and cross section of the leaves can be clearly observed in five different megapixel which is in 100X, 200X, 500X, 1.00KX and 5.00KX.

4.1.1 Species Johannesteijsmannia, adaxial (upper surface)

The Figure 5 show on the upper surface of Johannesteijsmannia leaves sampling which initially has glossy surface.



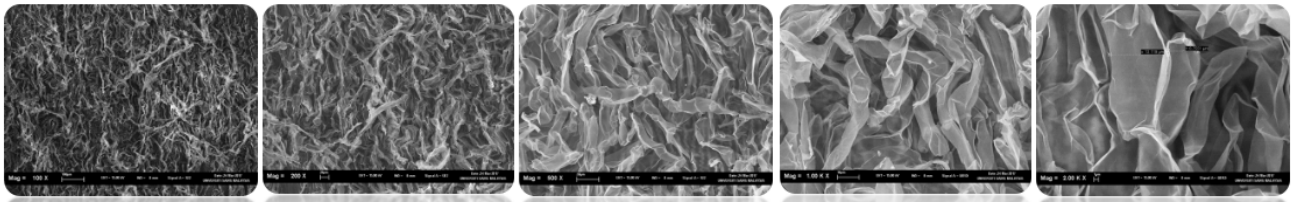
(a) (b) (c) (d) (e)

Fig. 5. (a) SEM 100X (b) SEM 200X (c) SEM 500X (d) SEM 1.00KX (e) 5.00KX upper surface of Johannesteijsmannia

Through the observation of SEM, adaxial of Johannesteijsmannia are with rough, scabrous surface and specific line texture. This scab rose surface and specific line texture make the upper surface of Johannesteijsmannia are not capable to collect more dust.

4.1.2 Species Johannesteijsmannia, abaxial (beneath surface)

The Figure 6 show on the beneath surface of Johannesteijsmannia leave sampling which initially has hairy and dusty surface.

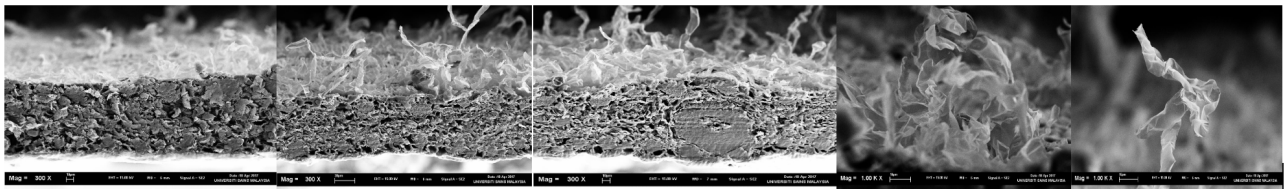


(a) (b) (c) (d) (e)

Fig. 6. (a) SEM 100X (b) SEM 200X (c) SEM 500X (d) SEM 1.00KX (e) 5.00KX beneath the leaves surface of Johannesteijsmannia

4.1.3 Cross-section

The Figure 7 show on the cross-section view of Johannesteijsmannia leaves sampling which initially has hairy and dusty on the beneath surface.



(a) (b) (c) (d) (e)

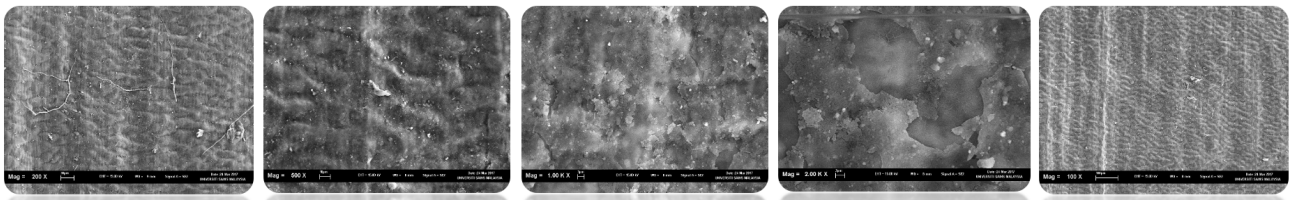
Fig. 7. (a) SEM 100X (b) SEM 200X (c) SEM 500X (d) SEM 1.00KX (e) 5.00KX cross section of Johannesteijsmannia leaves

While the abaxial and cross section surface of the Johannesteijsmannia are Arachnoid surface, which is with white fine hair cover the whole beneath surface of this species. Air pocket are created

among these hairy surface and make the leaf surface become superhydrophobic which is water repellent, so when water spray on the leaf surface, the air pocket are able to hold the water and form it into perfect circular water drop and the dust on the surface of the leaf will be wash away by the water drops. The hairy surface also minimizes the water-to-leaf contact area.

4.1.4 Species Licuala, adaxial (upper surface)

The Figure 8 show on the upper surface of Licuala leaves sampling which initially has glossy surface.



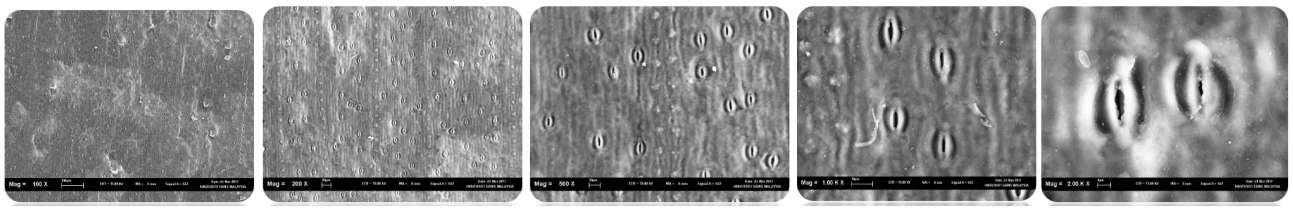
(a) (b) (c) (d) (e)

Fig. 8. (a) SEM 100X (b) SEM 200X (c) SEM 500X (d) SEM 1.00KX (e) 5.00KX upper surface of Licuala

The adaxial of Licuala are globous which is clean external without hair. This surface is easy to collect dust and grease, and it is also not a water repellent surface. The supper surface of Licuala also having waxy surface, this make the dust and dirt easier to stick and stay on the surface of the leaf.

4.1.5 Species Licuala, abaxial (beneath surface)

The Figure 9 show on the beneath surface of *Licuala* leave sampling which initially has hairy and dusty surface.

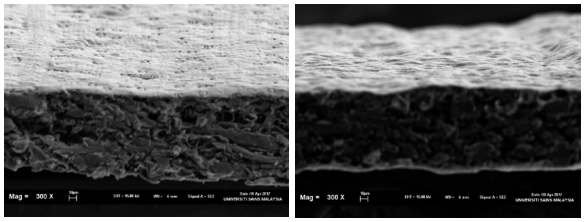


(a) (b) (c) (d) (e)

Fig. 9. (a)SEM 100X (b)SEM 200X (c)SEM 500X (d)SEM 1.00KX (e)5.00KX beneath the leaves surface of *Licuala.*

4.1.6 Cross-section

The Figure 10 show on the cross-section of Licuala leaves sampling which initially has hairy and dusty on the beneath surface.



(a) (b)

Fig. 10. (a)SEM 100X (b)SEM 200X cross section view of *Licuala leaves.*

The abaxial (beneath surface) of species *Licuala* are with clearly texture which can clearly see all the stomata on the leaf through the Scanning Electron Microscope (SEM). Beside the clearly texture, the beneath surface of species Licuala are also waxy as the upper surface of *Licuala*. This surface is also easy to collect dust but not as many as the upper surface. The surface of the species Licuala can be more obviously observe through the cross section under scanning electron microscope (SEM), the surface is rugged and clear, obvious surface texture which can see all the stomata on the surface of the leaf. The surface of species *Licuala* are not water repellent which when water drop on it, the water drop will smear on the surface of the leaf.

4.2 Light Microscope

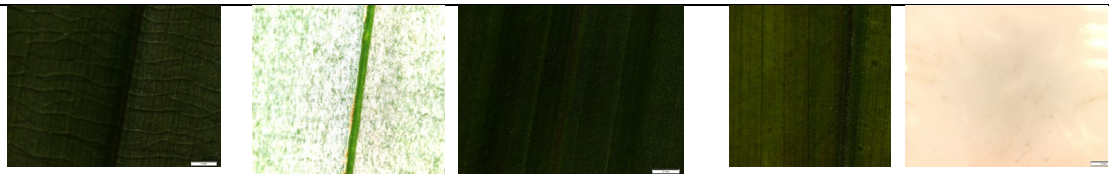
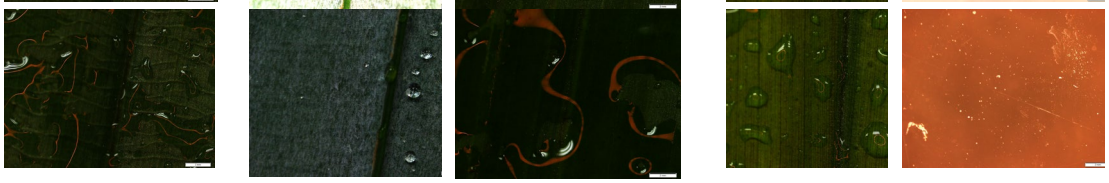
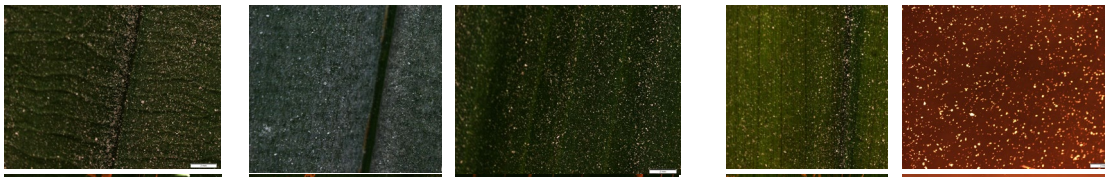
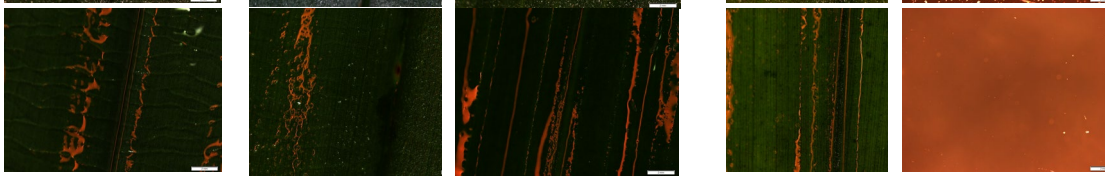
Table 1 below displays the surface and texture of selective specimen under light microscope after environmental experiments has been carried out. This environmental experiments are dry test, wet test and both dry and wet test, dry test will be conduct by using windy and dusty situation, wet test will be conduct by using rainy, windy and dusty situation while for dry and wet test will be conduct by using windy, dusty, rainy situation and that will be a layer of grease on the surface of palm leaves. The tempered glass is used as the reference for common self-cleaning surface to distinguish on Johannesteijsmannia and Licuala wet, dry, dust and grease tests.

By using light microscope, the surface and texture of selective specimen can be visibly observed. Through the observation, adaxial of Johannesteijsmannia are no water repellent characteristic and it collect less amount of dust. While the beneath surface (abaxial) of Johannesteijmannia have strong water repellent characteristic. Water is forming in perfect spheres when water drop on the abaxial of the Johannesteijmannia and due to this hairy surface, dust is not easy to stick on it and also the grease. However, adaxial of species *Licuala* are with a layer of waxy surface and through the observation, we can see that the adaxial of Licuala collect the most amount of dust especially during grease surface, most amount of dust are stick on the surface of the leaf. As to the abaxial of *Licuala* are also waxy surface and both abaxial and adaxial are no water repellent characteristic. The abaxial are also collect dust but not as many as the adaxial of the Licuala. While through the observation on tempered glass, dust will stick on the surface of the glass during rainy or grease situation, glass with grease surface is collect the most amount of dust compares to others surface.

Throughout the environmental experiment, the results show that abaxial of species Licuala has the best self-cleaning effectiveness during dry test with the result of 0.07g total amount of dust that wash away in the dry test. However, the adaxial of the species *Licuala* show the lowest effectiveness of self-cleaning during dry test with the result of 0.03g, this is because the waxy surface on the adaxial of the Licuala are capable to collect the dust. While for species Johannesteijsmannia, the total amount of dust that wash away are 0.05g on adaxial and 0.04g on abaxial, this result show that the species of Johannesteijsmannia also have the ability of self-cleaning. Yet for the glass surface, the

glass surface has the lowest ability on self-cleaning characteristic to wash away the dust stick on the surface of the glass, and the total amount of dust that wash away are only 0.03g.

Table 1
This table shows the result of surface under light microscope

	Palm Tree Species				Tempered Glass
	Johannesteijsmannia		*Licuala*		
	Adaxial	Abaxial	Adaxial	Abaxial	
Original Surface					
Water					
Dust					
Grease					
Grease and Dust					

In the wet test, which is rainy condition, both adaxial and abaxial of the species Johannesteijsmannia has the strong ability of self-cleaning characteristic, this show with the result of total amount 0.09g on adaxial and 0.06g on abaxial of dust are wash away. However, in species *Licuala*, both adaxial and abaxial have the same equal level of ability in self-cleaning with the result of 0.05g, the ability of self-cleaning on species Licuala are weak compare to species Johannesteijsmannia. While the result of tempered glass during wet test are the lowest which is 0.04g, this show that the surface of tempered glass has very weak ability of self-cleaning characteristic.

For the grease test, species Johannesteijsmannia also show the strong ability in self-cleaning effectiveness with the results of 0.18g on adaxial and 0.27g on the abaxial. This result show that species Johannesteijsmannia have strong ability to clean and wash away the dust on the grease surface with the help of the rain to maintain the cleanliness of the surface. While for the species *Licuala*, the result show that species Licuala have weak ability of self-cleaning in grease surface compare to species Johannesteijsmannia. The results of species *Licuala* are 0.07g on adaxial and 0.11g on abaxial. Lastly, tempered glass shows the lowest result in grease test, which is only 0.06g of

dust wash away on the grease surfaces. Table 2 shows the result of environmental experiment using the leaf powdering techniques in dry, wet and grease test condition in comparison with tempered glass.

Table 2
The result of dust collection on Johannesteijsmannia, Licuala and tempered glass

Materials	Types of Environmental Experiment	Adaxial	Abaxial
Johannesteijsmannia	Dry Test	0.05g	0.04g
	Wet Test	0.09g	0.13g
	Grease Test	0.18g	0.27g
Licuala	Dry Test	0.03g	0.07g
	Wet Test	0.05g	0.05g
	Grease Test	0.07g	0.11g
Tempered Glass	Dry Test	0.03g	0.03g
	Wet Test	0.04g	0.04g
	Grease Test	0.06g	0.06g

5. Discussion

There are three types of environmental test has been used in creating a new exploration of materials for building envelopes that is dry, wet and grease test. However, this experiment did not discover other factors that may influence the result of the test such as pattern and form of the specimens. This is because the aim of the discovery is to find the best characteristic on surface of materials for self-cleaning envelope purpose.

Johannesteijsmannia have very strong ability of self-cleaning compared to the species Licuala and glass, it also has very good water repellent characteristic as shows in the observation under light microscope. The abaxial (beneath surface) of species Johannesteijsmannia are full of white fine hair; this hairy surface and the white fine hair will create a space which is known as “air pocket”. Air pockets are trapped underneath the liquid and reducing the solid-liquid interface. These hairy structured surfaces are demonstrated to have superhydrophobic properties, which show the amazing water repellent property. These flexible fine hairs created air pockets yet cause the water droplets to form perfect spheres and allow the water droplets to roll off easily from the surface of the leaf and suspended by coming into contact with the hairs. This structure of the leaf surface can resist the impact of raindrops, and the air pockets are able to hold the rain or water drops by forming them into perfect spheres and circular water drop shape. Furthermore, with the amazing water repellent characteristic, the abaxial (beneath surface) of species Johannesteijsmannia are good and have strong ability of self-cleaning, the white fine hair is not easy to collect the dust compare to others smooth and waxy surface which will produce electrostatic force on the smooth and waxy surface and will attract the dust or dirt particles easy to stick on the surface. Fine hair on the abaxial (beneath surface) of species Johannesteijsmannia able to reduce the electrostatic force formed and avoid the dust or dirt particles attract to the surface of the leaf. Water droplets that formed on the surface of the leaf due to the water repellent characteristic are able to roll off together with the dust particles from the surface of the leaf even in grease surface. The air and force in the air pockets make the surface water repellent even in contact with grease, and when in rainy condition, the raindrops are able to run off from the surface and together clean the surface that can result with strong self-cleaning characteristic.

In addition, the abaxial (beneath surface) of the species Licuala are with very clear texture and smooth surface which can clearly see all the stomata through the observation under Scanning Electron Microscope (SEM). This smooth surface with clear texture makes the abaxial (beneath

surface) of species Licuala are not easy to collect dust particles and it show the strong ability of self-cleaning characteristic with the help from the wind during the process of dry test.

In comparing with glass, the electromagnetic force has a physic force on the smooth surface on itself. This electromagnetic force is referring to electrostatic force as that forces between charges and the charges are moving relative to each other in the magnetic field. As the moving charges on the smooth surface of the glass and the moving charges in dust and dirt particles are able to create a magnetic field and these moving charges will utilize forces on each other due to their magnetic properties which results in dust and dirt are easy to stick on the surface of the glass and not easy to be clean. Glass façade and widely use in design in skyscraper, yet the cleaning cost for maintaining a skyscraper are higher than others building, due to the low ability of self-cleaning characteristic on glass façade in tower and it required cleaning hand to clean the surface of the glass because of the dust and dirt are easy to stick on the surface of the glass, especially in urban areas. Through the dry test, we can classify that the dust or dirt that stick on the surface of the glass are not easy to be clean with the assist of the wind, this modified situation clearly show that dust stick on the glass façade in building are not easy to be wash away with the support of natural wind. Yet even in wet and grease test, with the wet or grease surface, dust and dirt are easier to stick on the surface of the glass and in wet and grease surface will make the cleaning work become more trouble and costly.

As conclusion of the exploration, this result demonstrates the comparison characteristics between both specimens in comparing glass. The characteristic is acceptable to be used in materials design for self-cleaning purposed for building envelope. The innovation on the surface of the materials is important to help the performance of the building envelope skin products more sustainable and increase the value of cost efficiency in life cycle cost measurement for construction materials. The life cycle cost for maintenance operation on building envelope cleaning works can be reduced and the frequency of cleaning can be decreased by using biomimicry conceptual. This conceptual can be adapt in architectural in order to improve the sustainability element in materials characteristic and properties.

6. Conclusion

Through the observation under light microscope, characteristic can be determined and, in this observation, can conclude that abaxial (beneath surface) of species Johannesteijsmannia have strong ability of water repellent characteristic which can see from the result under light microscope. When water spray on the abaxial (beneath surface) of Johannesteijsmannia, the water drops are form in perfect spheres and super hydrophobicity. While, adaxial (upper surface) of species Licuala are having waxy surface with clear texture which are easy to collect grease and dust and it has no water repellent characteristic. Furthermore, species Johannesteijsmannia also having the best result in three environmental experiments which clearly show the strong ability of self-cleaning characteristic compare to species Licuala and tempered glass. This result can be explained together with the observation from Scanning Electron Microscope (SEM). Through the observation under Scanning Electron Microscope (SEM), the abaxial (beneath surface) of species Johannesteijsmannia are having the hairy surface.

These characteristic of the leaf of species Johannesteijsmannia are showing that this species have the best surface and texture on the leaf, and it is believing that this special surface and texture are able to be adapt on to the design in building envelope materials through the concept of biomimicry. Glass had been widely used in building envelope design and it is important for building envelope materials have self-cleaning characteristic which can contribute benefits in building envelope maintenance. In the end of the research, aims had been archive by the surface of the glass can be

designed to have exact similar surface and texture with species *Johannesteijsmannia*. Through this concept, sustainability in building envelope design can be archive in order to save the future building envelope maintenance cost, increase the lifespan of the building and solve the difficulties in building envelope maintenance.

Acknowledgement
This exploration was funded by research grant from Universiti SainsMalaysia (USM 304/PPBGN/6313276). We would like to acknowledge to School of Housing, Building and Planning, Universiti Sains Malaysia for the enabling environment to conduct this study.

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