TEST Engineering & Management

November-December 2019
ISSN: 0193-4120 Page No. 3817 - 3822

An Innovative Green Material for Reducing the Urban Heat Island Surrounding PMU towards Smart Low Carbon Building and City

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Article Info
Volume 81
Page Number: 3817 - 3822
Publication Issue:
November-December 2019

Abstract

In this study, a new innovative green material using waste material especially vegetable waste and their combination was developed to be used as PMU streetscape furniture. It is has been tested based on the international green material standard. In line with the deliverable of new material to be used as PMU streetscape furniture, exploratory study of combination used of waste material using vegetable waste or name as Vege-grout coating give a good promise and comply with the standard for improvement of streetscape surrounding the PMU facades. Based on the results, it is found that the best way to reduce the surface temperature of the paver block is by immersing the paver block in Vege-grout and paint mixture. Using this method, heat is reduced up to 7°C. Building information modeling (BIM) result shows reducing of heat up to 12°C from the facades of surrounding streetscape material used. The results showed an improvement in the thermal conductivity test for pavement coating based on The American Society for Testing and Materials (ASTM) describes methods for determining solar reflectance in the following standards; ASTM E 903, ASTM E 1175, ASTM C 1549 and ASTM E 1918.

Article History
Article Received: *5 March 2019*
Revised: *18 May 2019*
Accepted: *24 September 2019*
Publication: *18 December 2019*

Keywords: *Green material, vege-grout, streetscape, solar reflectance*

1. Introduction

Urban Heat Island (UHI) is a phenomenon in which hot surface air is concentrated in urban areas and will gradually decrease in surrounding temperatures in suburban or rural areas[1],[2]. UHI's presence is recognized in over 400 cities around the world[3]. Previous studies conducted by [4] indicate that the UHI effect may increase air temperature in an urban city by between 2 and 8 ° C. In extensive studies conducted in Athens involving 30 urban stations, it shows that urban stations record temperatures between 5 and 15 ° C higher than the temperatures recorded at reference suburban stations [5].

The increase of land surface temperature caused by UHI will certainly affect material and the flow of energy in urban ecological systems and change their compositions and functions [6]. The UHI also affecting the ecological and environmental [6], [7] that lead to urban climates, change the urban hydrologic situations, atmosphere, soils composition, energy metabolism and residents' health [6]. Thus the interaction between global climate change and local UHI generates unprecedented human health, well-being and growth challenges. Most of the 20th-century communities live in cities, so urban mitigation overheating is an increasing concern [8].

Recent literature on the UHI effect shows that artificial temperature increases in cities are occurring due to changes in energy and water budget in the built environment [9]. This artificial temperature increase affects urban microclimates in various layers of the atmosphere, it involves the surface layer such as buildings and land surfaces, the canopy layer (below the canopy of trees or on a human scale) and the boundary layer (up to 1500 meters above ground surface)[10].

UHI impacts could be considerably mitigated by improving energy efficiency, urban landscape optimization, green roof construction, high reflectivity material usage, and green land cultivation. Multi-scale study on the ecological and environmental impacts of UHI was performed based on remote sensing technology, geographical information system (GIS) and numerical simulation techniques, offering a theoretical reference for the enhancement of the urban ecological environment and the realization of sustainable urban development towards low-carbon cities[9].

This research aims of to reduce the urban heat island surrounding PMU towards smart low carbon building and the city by creating new materials to be used as PMU.

2. Methodology

Research methodology of the study is based on five phases.

A. Data Collection

For this project, 275 kV PMU Kuantan North substation (Fig. 1) was chosen to run an analysis related to its existing material used and the impact of UHI.

Figure 1. Area of PMU Kuantan North

From Fig. 1, it can be seen that there was almost no vegetation within the PMU Kuantan North compound. The substation is free from vegetation to avoid the root from corrupting the underground cable structure. This will affect the PMU building's temperature during hot days and eventually will consume more energy to cool the PMU building which is costly and effect the environment. Remote Sensing imagery (Landsat 8) was usedtogether with the application of GIS to get the hotspot area of PMU KuantanNorth as shown in Fig. 2.

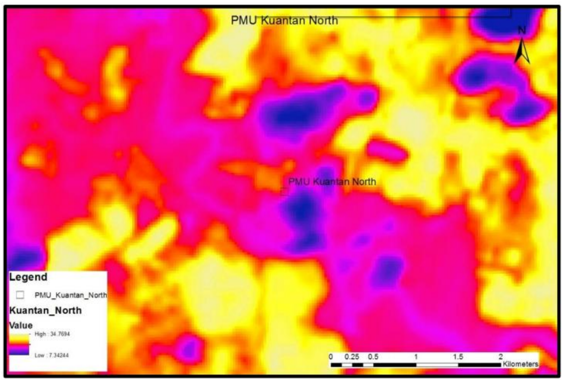


Figure 2: Land surface temperature in PMU Kuantan North

From Fig. 2, it shows that the yellow color represents as high temperature while the lower temperature represented by dark blue.

B. Building Information Modelling Analysis

The as built drawing of PMU Kuantan North was provided by TNB HQ DuaSentral was interpreted and converted into AutoCAD before converted again into to the Building Information Modeling (BIM) by using Revit software to produce a 3 dimension (3D) perspective view of PMU Kuantan North building. The BIM also used to run an analysis and simulation of the existing streetscape of PMU KuantanNorth.In line with building information modeling (BIM) result, new innovative green material using waste material especially vegetable waste and their combination are explored and tested based on an international green material standard.

C. Preparation of Vege-grout

Vege-grout is a substance made from vegetable waste that has been fermented for 30 days. In this research, the micro-bacteria from agriculture waste were obtained from the fermentation process of mixed vegetable waste. The vegetable waste used to make vege-grout is cucumber, water spinach, spinach, long bean,and cabbage. These vegetables were selected since they are most common vegetables in Malaysia and easily available. Each type of vegetable waste was weighed 10kg and stored in a container for 30 days. Vegetable waste is first washed to make sure they are free from any impurities and dirt that can disturb the fermentation process. Then vegetable waste was cut into pieces and stored in different containers for each type. The containers were then sealed since the fermentation process must be done in the absence of oxygen. After 30 days, it was then filtered using a net to get only liquids called vege-grout that forms from the fermentation process. All vege-grout are then mixed together in one container and will be used as a mother liquor to develop new coating material and new material of brick. These processes are shown in Fig. 3.Through one-month process of fermentation of the

TEST Engineering & Management
November-December 2019
ISSN: 0193-4120 Page No. 3817 - 3822

vegetables, the room temperature was observed and recorded every week to check any changes. After one month, the vegetables had been extracted to get the vege-grout liquid. Then, the vege-grout will be filtered to remove any small particles in the vege-grout. The vege-grout then will be stored in a new tight container to maintain the micro-bacterial process before being applied in the production of bricks.

Figure 3: Preparation of vege-grout

D. Developing New Coating Material

Vege-grout is used as a mother liquor to develop new coating material. There is two new coating material that has been developed in this research. The first one is Vege-grout Coating (VGC) and the other one is Vege-grout+Paint coating (VGPC). For VGC, it is a mixture of vege-grout with the eggshell solution and kaolinite-urea. The ratio for this mixture is0:1:2 respectively. VGPC is made from a mixture of vege-grout, emulsion paint and kaolinite urea with a ratio of 2.5:1.5:1 respectively. These processes are shown in Fig. 4.

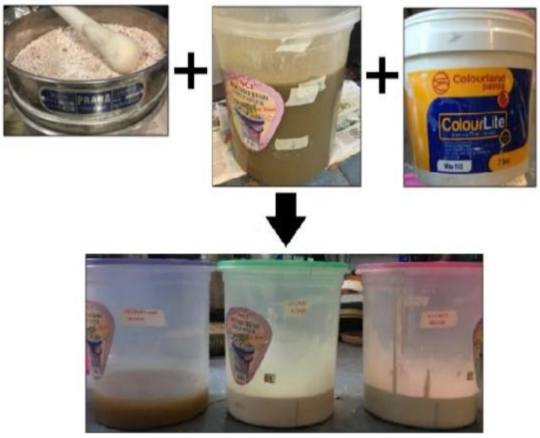


Figure 4: Process of developing new materials for the coating

E. Experiments

Interlocking pavers were used to carry out the experiment for the new coating materials. It is one of the types of pavement that used to build pedestrian walkways or sometimes as a road. Red and black paver used for experimental as it is common used pavers in the industry. After the process of VGCcompleted, it is then applied on interlocking pavers. All samples were compared to control samples (negative control-uncoated paver, positive control-white coated paver) as shown in Table 1.

Table 1:Details for interlocking paver sample

Sample		Description
Red Paver	**Black Paver**	
A2	A1	Coated with Vege-grout+Paint Coating using immersed method
C2	C1	Coated with Paint using immersed method (positive control)
A4	A3	Coated with Vege-grout+Paint Coating using layered method
C6	C5	Coated with Paint using layered method (positive control)
B2	B1	Coated with Vege-grout Coating using immersed method
B4	B3	Coated with Vege-grout Coating using layered method
C3	C4	No coating (negative control)

Referring to Table I, for immersed method, samples are submerged in both new coatings for 24 hours. After those pavers are then dried out in the sun for 8 hours and this process were done for 2 days. After that only surface of paver samples was submerged in the coatings in a small container and dried outside at the same time. After 48 hours, samples were then taken out and dried outside for 48 hours. This is continuously processing for 2 weeks.

For the layered method, a roller or brush is used to paint sample with new coatings. In this method, samples were tested with a different layer of new coatings for each sample. Sampleswere then dried outside for 8 hours at 32^{0}C (average temperature) and this process was done for 2 weeks. After 2 weeks, all sample's surface temperature was measure and recorded using LCD Laser Infrared Digital Temperature Thermometer Gun. Temperature was taken at 9am, 12pm and 3pm every day. Thermal image was also taken at the same time with surface temperature by using a thermal imaging camera.

3. Results And Analysis

A. Surface Temperature

Data of surface temperature in this experiment were recorded using LCD Laser Infrared Digital Temperature Thermometer Gun. Table 2 shows the average temperature of all samples. From the table below, there was a big difference in surface temperature at 12 pm compared to that at 9am and 3pm. This was due to the ambient temperature at 12 pm, is the highest which was at 33°C.

Table 2: Average surface temperature of samples

Time	Temperature (°C)													
	C1	C2	A1	A2	C5	C6	A3	A4	C3	A4	B1	B2	B3	B4
9am	21.4	21.3	21.1	21.0	21.5	21.4	21.2	21.1	21.9	22.2	21.3	21.2	21.4	21.2
12pm	31.3	32.2	29.8	30.4	31.4	31.2	30.5	30.4	35.3	36.8	32.1	31.1	30.0	30.0
3pm	31.9	31.8	31.5	31.2	32.0	32.0	31.2	30.6	33.8	34.1	31.9	31.5	31.4	31.5

B. Thermal Image

The thermal image was also taken at 9am, 12pm and 3pm by using thermal imaging camera based on ISO/TC 135/SC 8 test standard. As there are no drastic changes in ambient temperature, only data of thermal image at Day 3 were discussed.

Table 3: Samples that coated with VGPC using immersed method at 9am, 12pm and 3pm

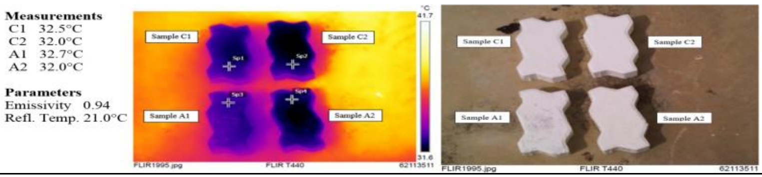
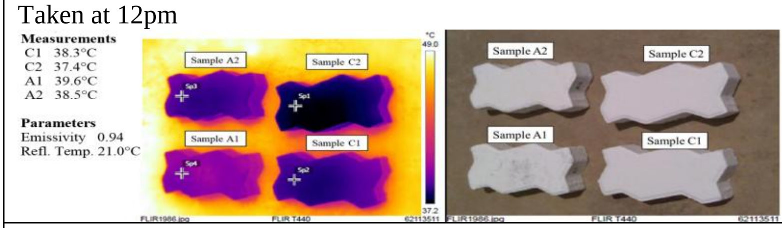
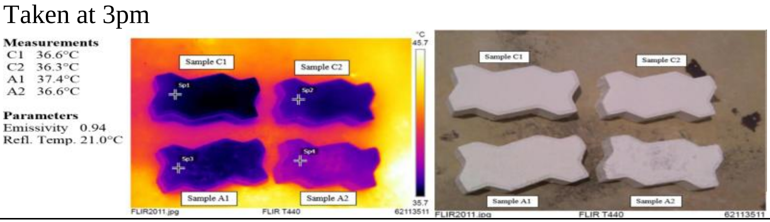
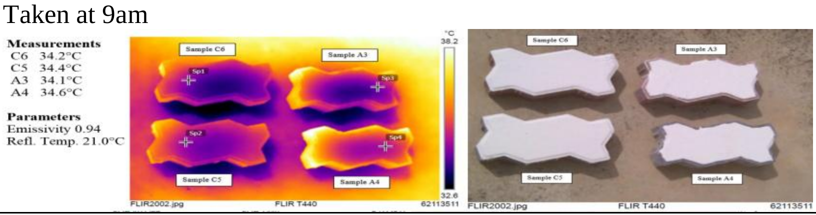
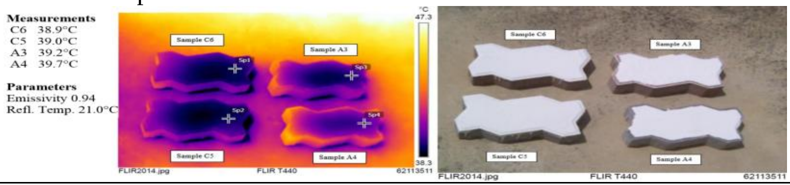
Thermal Image
Taken at 9am

Taken at 12pm

Taken at 3pm


Table 3shows thermal images of samples that coated with VGPC using the immersed method at 9am, 12pm and 3pm respectively. Its surface temperatures were compared with positive control samples that is coated with white paint using the same method. At 9am, there is no differences in surface temperature between samples as the ambient temperature still low that is 25°C. There are slightly differences at 12 pm. For samples C2 and A2 the differences are 1.1°C and for C1 and A1 the differences are 1.3°C. At 3pm, only 0.3°C differences between samples C1 and A1 and 0.8°C differences between samples C2 and A2. This indicate that white paint can reduce the surface temperature of pavement but vege-grout helps the white paint to reduce more of surface temperature of samples.

Table 4: Samples that coated with VGPC using layered method at 9am, 12pm and 3pm

Thermal Image
Taken at 9am


Taken at 12 pm



Taken at 3pm

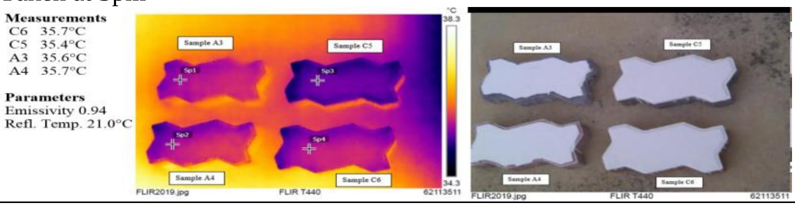


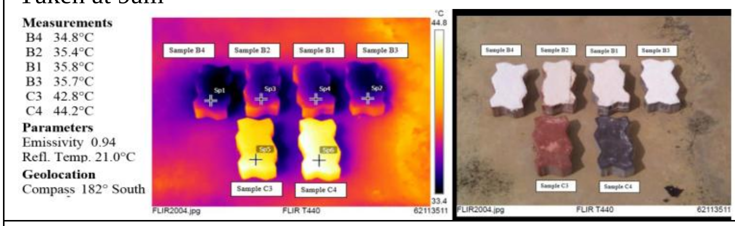
Table 4 shows thermal images of samples that coated with VGPC using the layered method at 9am, 12pm and 3pm respectively. Same with immersed method, there is no difference of surface temperature for layered method at 9am.

At 12pm, there is only slightly differences between samples. The differences were not more than 1°C. The same things also happen at 3pm, there is no differences in surface temperature between samples.

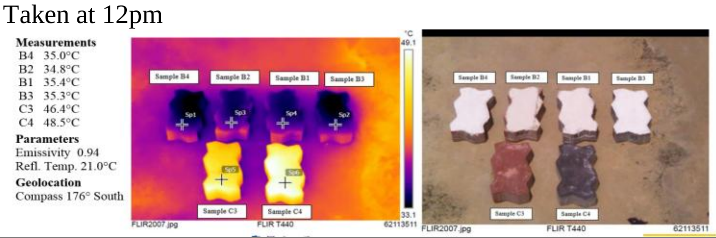
Table 5: Samples that coated with VGC using both method at 9am, 12pm and 3pm

Thermal Image

Taken at 9am



Taken at 12pm



Taken at 3pm

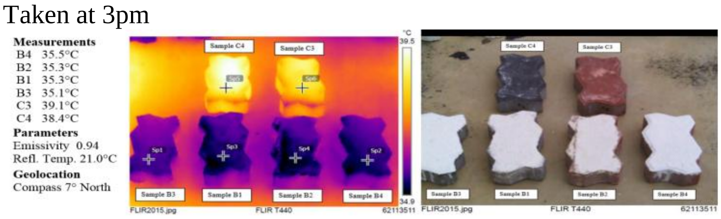


Table 5 shows thermal images of samples that coated with VGC using both methods at 9am, 12pm and 3pm respectively. These samples were compared with negative control samples, an uncoated pavement. It is compared with uncoated samples because this VGC is not mixed with white paint. There are differences in surface temperature between control samples and coating samples even at 9am. Differences between sample C3 and B4 (layered method) are 8°C and differences between sample C3 and B2 (immersed method) are 7°C. Sample C3, B2 and B4 are red paver sample. For black paver, differences between sample C4 and sample B1 (immersed method) are 8.5°C while differences between sample C4 and B3 (layered method) are 8.8°C. At 12pm, the differences between samples increase as ambient temperature also increase. There are 11.4°C differences between sample C3 and B4 and there are 11°C differences between sample C3 and B2. As for sample C4 and B1, the differences are 13.2°C and for sample C4 and B3 the differences are 13.7°C. At 3pm, the differences have reduced. Between sample C3 and B4, the differences in surface temperature are 3.1°C and the differences between sample C3 and B2 are 3.3°C. The differences between sample C4 and B1 and between sample C4 and B3 are 3.8°C and 3.6°C respectively.

4. Conclusion

New green materials that comply with the standard and LLCI requirement name as VGPC. VGPC may reduce temperature in the range of 4.2°C – 6.8 °C whether using immersion or layering technique. Based on the results, it is found that the best way to reduce the surface temperature of paver block is by immersing the paver block in vege-grout and paint mixture. Using this method, heat is reduced up to 7°C. Building information modelling (BIM) result shows reducing of heat up to 12°C from the facades of surrounding streetscape material used.

Acknowledgment

This study is being supported by J510050715 for Revit Modelling, 201901001YCU/04 for terrestrial laser scanning mapping andU-TS-RD-17-03 for material analysis.

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