International Journal of GEOMATE, Nov., 2019 Vol.17, Issue 63, pp. 35 - 40
ISSN: 2186-2982 (P), 2186-2990 (O), Japan, DOI: https://doi.org/10.21660/2019.63.4807
Geotechnique, Construction Materials and Environment

STUDY OF VEGE-GROUT AS COATING MATERIAL IN REDUCING SURFACE TEMPERATURE

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ABSTRACT: Pavement is one of the main features in cities and urban areas that contribute to the Urban Heat Island (UHI) effect. The urban areas are more affected by this condition compared to the rural areas due to the extensive built environment and lack of vegetation cover. Many studies have reported that the shear strength of sandy soil was improved by using the microbial-induced calcite precipitation method and most of the experimental work on microbial cementation utilized cultivated culture of ureolytic bacteria for calcium carbonate formation. However, our previous study has demonstrated that vege-grout from vegetable waste can also induce bio-cementation due to the presence of microbial activity in the vege-grout. Following this, the study has been expanded to investigate the feasibility of bio-cementation from vege-grout as a coating material to reduce surface temperature. A mixture of the coating was developed using vege-grout as the main composition. The mixture was then applied on the surface of the interlocking paver and left to cure at room temperature for seven days. Surface temperature was measured using an infrared thermometer and thermographic camera. Results showed that the surface temperature of vege-grout coated paver was reduced by 4-5 ^{o}C compared to that of control. The outcome of this study suggested that vege-grout has the potential to be explored as a component for coating material that can reduce surface temperature.

Keywords: vege-grout, coating material, surface temperature, bio-cementation, UHI

1. INTRODUCTION

The phenomenon of global warming that is affecting the urban areas and cities, known as Urban Heat Island (UHI), has been investigated in the past years worldwide. This phenomenon has been generating thermal discomfort leading to some health issues, most significantly, causing an increase in the supply for energy demand for cooling the buildings and surroundings. Several strategies and methods have been proposed to mitigate the high-temperature effect, in response to the environmental impact generated by the urban heat islands. Among the methods to reduce energy cost include the construction of green roofs or cool roofs that can be installed on buildings, the usage of alternative material to build urban infrastructure, development of cool pavement and reflective materials, and urban vegetation [1-2].

Urban paving plays a major role in the occurrence of urban heat islands. Concrete pavement specifically made of asphalt, significantly contribute to the UHI effect in the urban cities due to its large area of paved surfaces coverage accounting to 40% [3]. The pavement can absorb and store heat during the day and release it to the surroundings during the night, resulting in a higher temperature than the ambient temperature. During the hot season, conventional asphalt pavement can reach up to 60^{o}C [4]. Currently, the technology of creating cool pavements has been developed to mitigate the effect of urban heat, using alternative materials that can reflect more solar radiation and retain water such as porous asphalt pavement and cement based grouting material [5-6]. Another approach is to use special coating for existing pavements such as the innovation of cool colored thin layered asphalt [7].

Bio-mediated cementation of soil using microbial technology has attracted many researchers worldwide to explore its application in geotechnical engineering and construction industry. The technology is based on the precipitated calcium carbonate ($CaCO^3$) that act as cementing agents that can bind soil particles. This bio-mediated process is known as microbial-induced calcium carbonate precipitation (MICP) which focused on 'bio-clogging' and 'bio-cementation' of soil particles [8]. Bio-clogging refers to the process of filling soil void by the bio-mechanism products of microorganisms such as biomass and exopolymeric substances that can reduce the permeability of soil by restricting the water flow in the soil [9]. Bio-cementation refers to the binding of soil particles through the mineralization or precipitation process of microbial activities that help improve the shear strength of soil [10]. Some of the factors that affect the formation of calcite precipitation include the concentration of calcium ion (Ca^{2+}), nutrients, temperature and pH condition [11].

The application of this new microbial technology has many aspects mostly in geotechnical engineering and construction industry such as the improvement of soil strength and impermeability, mitigation of soil liquefaction and remediation of concrete [12-13]. And the latest application of MICP was the innovation of cement-free bricks or bio-bricks from bacteria and sand which are energy efficient [14].

Our previous research on vegetable waste or vege-grout has proved that substrate from vegetable waste can also replace the role of nutrient media and broth for bacterial growth by using the fermentation process. Fermentation actually increases the nutrient content of the vegetable waste and also promotes the growth of a variety of microorganisms including ureolytic bacteria [15]. These indigenous bacteria in the vege-grout liquid were capable of inducing the bio-cementation process [16].

One recent study on the bio-cementation of concrete pavements by MICP reported a 10% increase in strength due to the calcite formation [17]. In this study, the focus was to investigate the effectiveness of coating mixture from vege-grout on the surface temperature reduction. The concrete pavers will be coated with vege- grout liquid for 7 days and dried at room temperature. The curing period is 14 days to allow the calcium carbonate precipitation that will form the coating layer.

The surface temperature of the coated concrete pavers will be measured using infrared thermosensor and thermographic camera. Scanning Electron Microscope and Energy Dispersive X-Ray Analyzer analysis (SEM-EDX) were performed to confirm the presence of calcite formation. To the author's knowledge, there was no previous study on the effect of microbial bio-cementation on the surface temperature.

2. EXPERIMENTAL

2.1 Preparation of coating mixture

Vege-grout was processed through previously described methods [18]. Vegetable waste such as cabbage, long bean, cucumber and spinach were collected from various sources like the wet market and farmer market around the area and brought back to the laboratory. All the vegetables were washed and rinsed thoroughly using distilled water to avoid cross-contamination. Then, the vegetables were cut into small pieces and kept in a clean container for the fermentation process. The containers were tightly closed and kept for one month at room temperature. The pH of the vegetable was monitored once a week with a pH meter. After one month, the substrate was filtered, collected and transferred to another clean container until further analysis.

When bio-cementation or bio-calcification occurs, it is expected that the process will develop a bio-cemented coating on the surfaces. The extract mixture was kept at room temperature to hydrate excess water so that the mixture is thicker. The coating mixture was then applied on the surface of the concrete pavers and let cure for seven days (Fig. 2 and 3). The vege-grout coated concrete pavers are shown in Figure 4. Thermal Imaging Camera and Surface Infrared Thermometer Temperature Gun were used to record the surface temperature and thermal image (Fig.5).

Fig. 1 Vege-grout preparation

Fig. 2 Coating mixture from vege-grout

Fig. 3 The application of coating mixture

Fig. 4 Concrete pavers coated with coating mixture

Fig. 5 Instruments for temperature measurement

3. RESULTS AND DISCUSSION

3.1 Surface temperature

The average surface temperature of concrete pavers and coated pavers were recorded at three different time intervals (9.00 am, 12.00 pm and 3.00 pm) for 7 days (Figure 6). Results showed the surface temperatures of coated pavers (Red and Black) were slightly lower compared to that of controls (without vege-grout mixture coating). The difference in temperature was obvious during the afternoon which was the hottest climate.

Figure 7 illustrates the surface temperature of red paver at 12.00 pm which was recorded for 7 days. The control red paver showed higher temperature (34ºC -37ºC) compared to that of treated red paver (31ºC-33ºC), whereas the surface temperatures of black paver were much higher (35ºC -39ºC) compared to that of treated samples (28ºC-32ºC) (see Figure 8).

Red and black colored pavers were used in this work to observe the differences in surface temperature indicated by the color. It was reported that black asphalt pavement absorbs more solar radiation resulting in excessive heat [21]. In this study, the black paver was much hotter than the red paver.

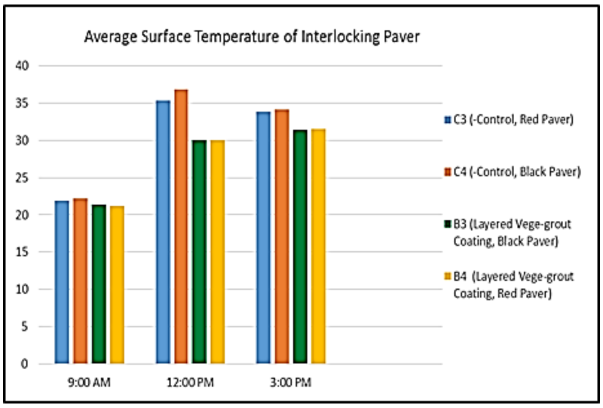

Fig. 6 Average surface temperature at 3 different times intervals for 7 days

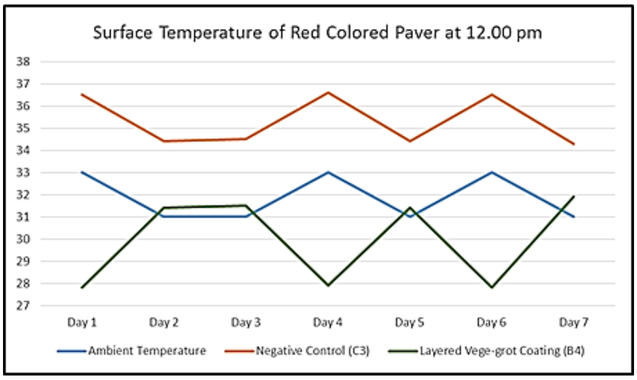

Fig. 7 Daily surface temperature of red colored paver at 12.00 pm

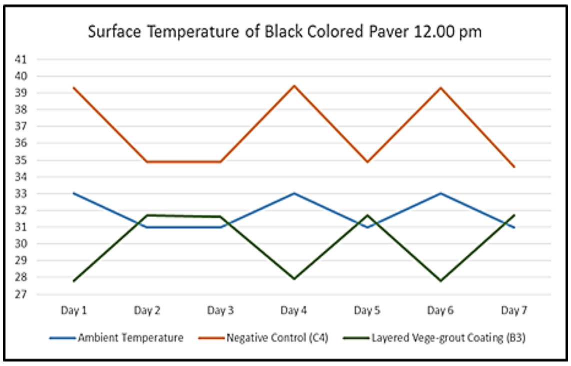

Fig. 8 Daily surface temperature of black colored paver at 12.00 pm

3.2 Thermal images

The thermal images of control pavers and treated pavers were recorded using Thermal Imaging Camera (FLIR). Figure 9, 10 and 11 show thermal images of control and treated pavers at 3 different time intervals (9.00am, 12.00 pm and 3 pm). C3 is controlled red paver and C4 is control black paver. Samples B4 and B2 are red pavers coated in vege-grout. Samples B1 and B3 are black pavers coated in vege-grout.

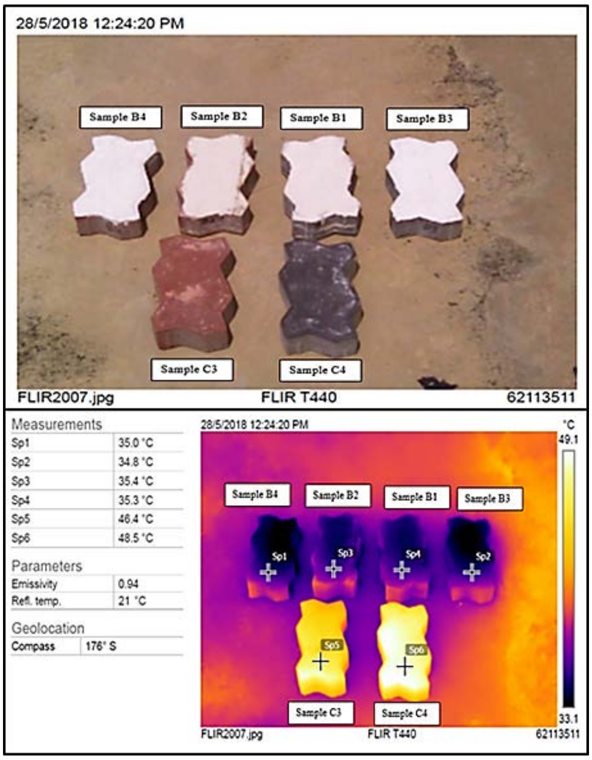

Fig. 10 Thermal images of samples at 12.00 pm

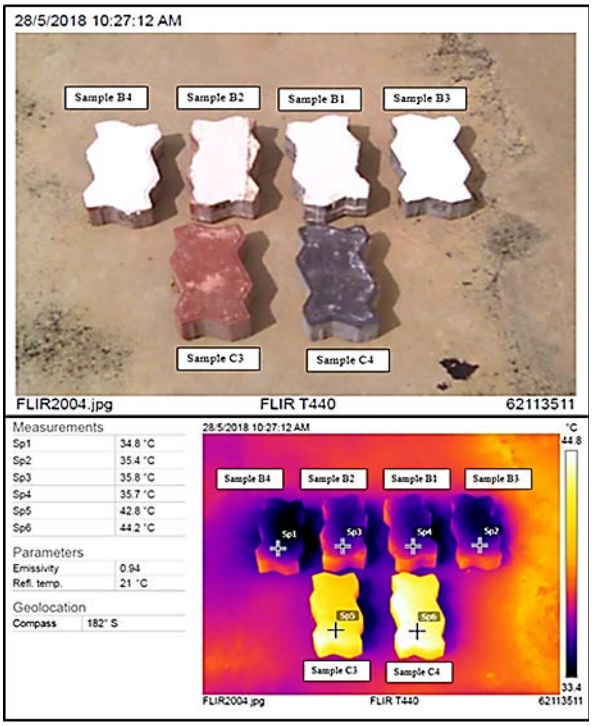

Fig. 9 Thermal image of samples at 10.00 am

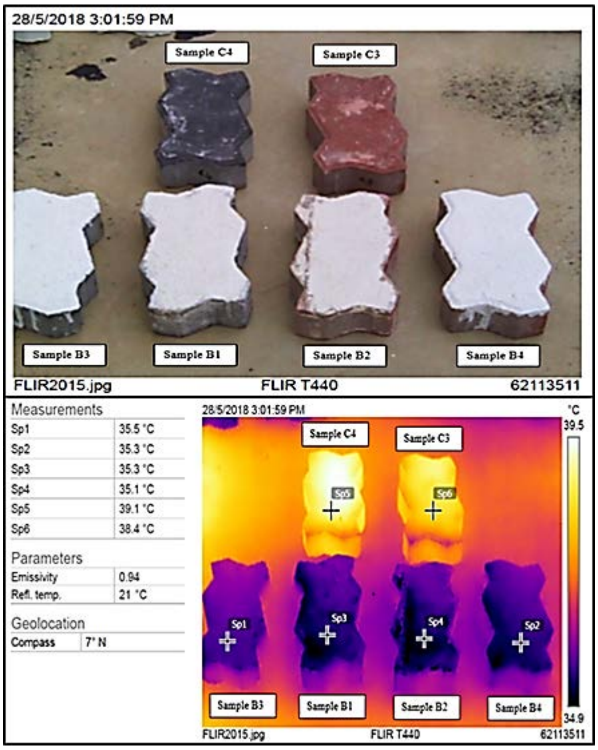

Fig. 11 Thermal image of samples at 3.00 pm

From the results of the thermal images, it was observed that the vege-grout coated pavers were slightly cooler than the control red and black colored pavers. A difference of 5-6^{o} C was recorded. This showed that coating mixture from vege-grout has the properties to reduce surface temperature.

3.3 SEM and EDX analysis

The surface of the coated pavers was carefully scraped and sent to the laboratory for SEM and EDX analysis to confirm the presence of calcium carbonate that forms the bio-cementation. Figure 12 showed evidence of calcium carbonate precipitation from the sample. This confirms that bio-cementation process has occurred and developed as a coating on the surface of the pavers.

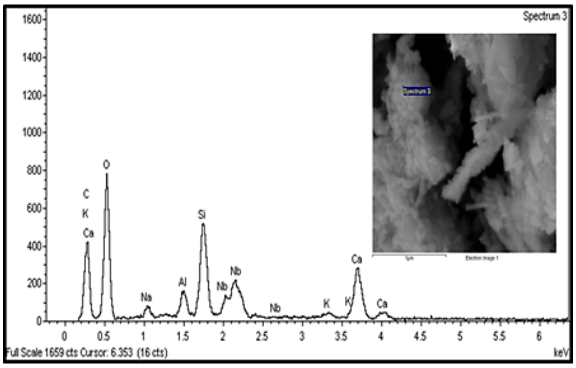

Fig. 12 SEM-EDX analysis

4. CONCLUSION

This study was initiated to investigate the effectiveness of vege-grout coating in reducing surface temperature based on Microbial Induced Calcium Carbonate Precipitation (MICP). The results of this study showed that bio-cementation not only improve the physical properties of liquefied soil but also was effective in reducing surface temperature. The finding from this research has discovered the potential application of MICP in heat reduction. In-depth analysis should be carried out to explore the mechanism involved that relates to heat mitigation. In the future perspective, the coating material from vege-grout based on MICP can be applied as cool materials to mitigate the urban heat island effect in the urban built environment.

5. ACKNOWLEDGMENTS

This study was funded by UNITEN grant, UNIIG (J510050774) and YCU research grant (20180101YCU/20).

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