PAPER • OPEN ACCESS

Thermal repellent properties of surface coating using silica

To cite this article: Y Y Lee *et al* 2017 *IOP Conf. Ser.: Mater. Sci. Eng.* **271** 012020

View the article online for updates and enhancements.

IOP Conf. Series: Materials Science and Engineering **271** (2017) 012020 doi:10.1088/1757-899X/271/1/012020

Thermal repellent properties of surface coating using silica

Y Y Lee[1], M S Halim[1], E Aminudin[2] and N A Guntor[1]

[1] Jamilus Research Centre (JRC), Faculty of Civil and Environmental Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja Batu Pahat, Johor, Malaysia.
[2] Faculty of Civil Engineering, Universiti Teknologi Malaysia, 81310 Johor Bahru, Johor, Malaysia.
Corresponding author: yylee@uthm.edu.my

Abstract. Extensive land development in urban areas is completely altering the surface profile of human living environment. As cities growing rapidly, impervious building and paved surfaces are replacing the natural landscape. In the developing countries with tropical climate, large masses of building elements, such as brick wall and concrete members, absorb and store large amount of heat, which in turn radiate back to the surrounding air during the night time. This bubble of heat is known as urban heat island (UHI). The use of high albedo urban surfaces is an inexpensive measure that can reduce surrounded temperature. Thus, the main focus of this study is to investigate the ability of silica, SiO_2, with high albedo value, to be used as a thermal-repelled surface coating for brick wall. Three different silica coatings were used, namely silicone resin, silicone wax and rain repellent and one exterior commercial paint (jota shield paint) that commercially available in the market were applied on small-scale brick wall models. An uncoated sample also had been fabricated as a control sample for comparison. These models were placed at the outdoor space for solar exposure. Outdoor environment measurement was carried out where the ambient temperature, surface temperature, relative humidity and UV reflectance were recorded. The effect of different type of surface coating on temperature variation of the surface brick wall and the thermal performance of coatings as potential of heat reduction for brick wall have been studied. Based on the results, model with silicone resin achieved the lowest surface temperature which indicated that SiO_2 can be potentially used to reduce heat absorption on the brick wall and further retains indoor passive thermal comfortability.

1. Introduction

Malaysia is a tropical country where sunlight shines upon the faces of buildings in a normal sunny day. Malaysia is experiencing rapid economic development since the last 2 decades [1]. The high exposure to solar heating in tropical climate is causing high ambient temperature occurred when the sunlight is blazing. When the wall surface is exposed to excessive solar heating, there is a portion of heat energy being absorbed by the wall. The brick wall will store the heat and then re-emitted back especially at nightfall whenever the ambient temperature is lower than the heated brick wall. This is because of the high density nature of brick makes itself an effective thermal mass to absorb and release high amounts of heat energy before experiencing the temperature increase [2]. The rise of ambient temperature at the night can be described as the urban heat island (UHI) phenomena and may magnify by these construction materials.

The heat dissipation during night time is one of the key problems faced by the tropical countries. Brick walls absorb heat from sunlight during day time and release to the surrounded environment at night when the ambient temperature is lower than that surface temperature of brick walls. The high density of brick wall makes it act as a thermal mass where it has the capacity to absorb heat energy [3] and the heat will be dissipated into the surroundings when the surrounding temperature is lower than that of the brick wall. The excess heat is released into indoors causes higher room temperature at night than usual. It also poses higher energy consumption for the air-conditioning system to cool down the room.

Due to the changes of environmental feature, the attention is drawn within thermal comfort study in order to reduce the heat transfer to the building by using high reflectivity surface coating material. The amount of energy that is reflected by a surface is determined by the reflectivity of that surface called albedo. A high albedo represents a surface which can reflect majority and absorb minority of the radiations that reach the surface, whereas, a low albedo represents a surface which can reflect a small amount and absorb the rest of the incoming radiation [3]. It is generally agreed that buildings with high reflectance surface can improve the indoor thermal effectively and serve to provide comfortability for applicants and reduce costs for heating and cooling.

There are many types of thermal insulation systems. At present, the common materials of exterior insulation in Malaysia are external heat-insulation wall of polystyrene panel, aerated concrete blocks and thermal insulation coating. The choice of the proper insulation materials type and form depends on the application as well as the desired materials physical, thermal and other properties. Thermal insulation coating is found beneficial to both new and existing buildings without modification of existing building. The use of high reflective surface coatings that content hiding pigments, can protect subtract from the harmful effect of ultraviolet light, and further reduce indoor temperature of a building. Surface reflectance can be optimized by using the materials that are characterized by a high solar reflectance. The use of high reflectivity material as a surface coating in the urban environment may contribute to a lower surface temperature which can minimize the thermal exchanges with the ambient [4].

Therefore, this paper investigates the effect of different type of surface coating on temperature variation of the surface brick wall and the thermal performance of coatings as a potential of heat reduction for brick walls. There are five small-scaled brick wall with different coatings of Silicon Resin, Silicone Wax, Rain Repellent and Jota shield paint, including an uncoated control specimen, were studied with the data collection of ambient temperature, surface temperature, relative humidity and UV reflectance for a week period. Thermal performance analysis of the specimens is conducted using the collected data.

2. Materials and methods

This study was conducted to determine the effect of coating materials on building thermal performance. In this experiment, three different silica coatings which were silicone resin, silicone wax and rain repellent, and one commercial paint were applied to the casted small-scaled brick wall models, with dimensions of 260 × 360 mm, as shown in figure 1, by spraying and roller/brush method. An uncoated brick wall model also has been studied for comparison. The experimental setup area were away from the building wall and above the pavement to avoid addition heat radiation to the brick wall models.

Ambient temperature, relative humidity and surface temperature were measured for a week period from 9:00 am to 9:00 pm. A continuous measurement of surface temperature on brick wall models was recorded at the interval 5 minutes by using GL200 midi data logger (GRAPHTEC). The thermal performances of the insulated models were compared with the control specimen. The ambient and surface temperatures of the specimens with and without coating were analysed to determine the effect of different type of surface coatings on temperature variation. Meanwhile, comparison was developed to investigate the thermal performance of coating as potential of heat reduction for brick wall. The infrared thermal camera was used to capture the 'heat contour' at brick wall surface. The images were captured during the highest ambient temperature on the first day at the time of 2:15 pm.

Figure 1. Experimental setup.

3. Results and discussions

Thermal insulation is one of key factor for assessing the material composition of building envelops [5] which is important for urban planning of thermal balance. Basically, one of the sustainable approaches to cooling buildings by natural means is the passive cooling strategy. The flow of energy is based on natural means where the heat from solar radiation will be absorbed and the infrared will radiate and dissipate part of the accumulated heat through convection, conduction and radiation [6]. Throughout the experiment, all specimens were placed in outdoor environment of tropical climate.

3.1. Surface temperature variation

Control specimen always record with the highest among the specimens, as shown in figure 2, which indicated coating is necessary in order to reduce the surface temperature of building materials. Moreover, ambient temperature is always the lowest values as the building materials are denser than air which can absorb more heat within its medium.

Day 1 showed the highest surface temperature of 45°C and ambient temperature of 35.9°C, recorded in figure 2. This is because there was no rainfall or cloudy sky while day 2 to day 7 were cloudy and even rain that caused the drop in surface and ambient temperatures. Therefore, only the day 1 data were critically discussed.

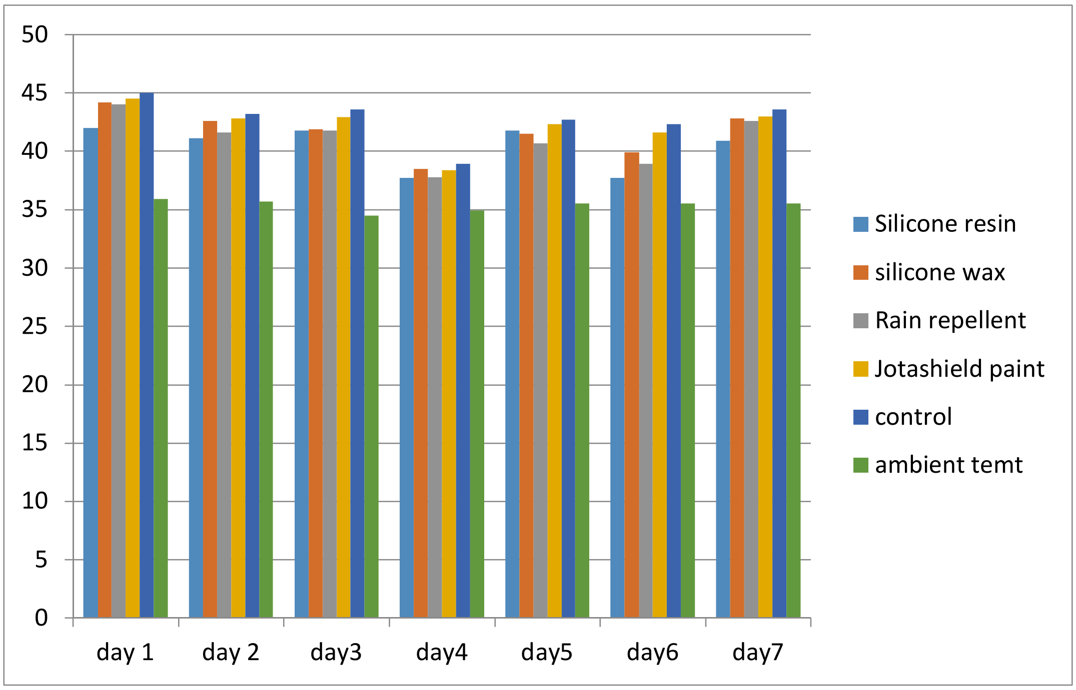

Figure 2. Maximum surface and ambient temperature in 7 days.

3.1.1. Effect of ambient temperature on surface temperature. According to figure 3, surface temperature was fluctuated from 9:00 am until 3:00 pm. At 2:15 pm, surface temperature rose to 45°C (control sample) higher than the ambient temperature by 9.1°C. It is due to solar heat absorbed by the building materials [7]. The temperature difference was caused by their different thermal inertia. This situation corresponding to [8] where the brick began to increase the temperature faster because it had larger capacity to store heat. At 5:00 pm, the surface temperature of silicon resin was lower than ambient temperature this is due to thermal mass, brick wall have high thermal mass which can act like a battery for storing thermal energy, it can store the heat during midday and release that heat to the environment [9].

The surface temperature of silicone resin coating was the fastest to reach the thermal equilibrium stated, where it was placed in contact with heat transferred until it reached the same temperature of both surface and ambient temperatures, followed by rain repellent, silicone wax and Jota shield paint. Meanwhile, for control sample, the surface temperature is the highest. It is an uncoated sample that no insulator to minimize heat flow through the brick wall and caused the absorption of heat much more than the other specimens. Thus, make it the slowest to release the heat back to environment [5]. In this study, therefore, silicon resin obtained better potential of heat reduction for brick wall because it absorbed the least amount of heat and recorded the fastest period to release the stored heat.

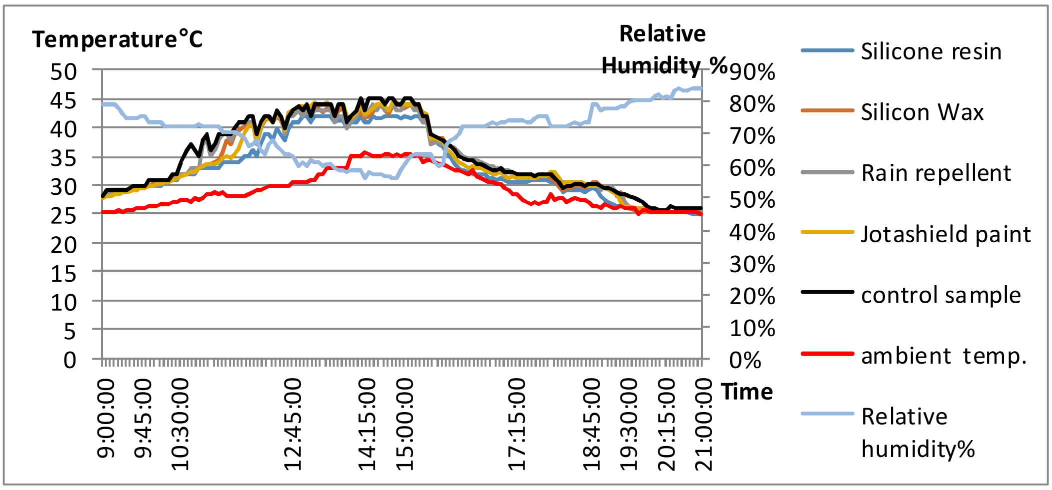

Figure 3. Observation of temperature variation of day 1.

The coolest surface temperature were achieved by silicone resin followed by rain repellent, silicone wax and Jotashield paint. Meanwhile, the control sample depicted the warmest surface temperature. The difference of surface temperature between silicone resin and control sample was 3°C and 2.5°C between silicone resin and Jotashield Paint. Silicone resin is a silica SiO_2 based product where SiO_2 can be a heat reflector by reflecting the exceeded radiation to a brick wall. This will create a heat-insulating layer on the brick wall surface. The SiO_2 also consists of excellent UV reflectance [10].

On the other hand, control specimen absorbed more solar heat radiation and has low albedo of 0.20 – 0.40 [11] which caused to absorb heat more than the coated specimens. The rising temperature will affect the process of energy transfer between a building and its surroundings, also known as thermal performance of a building. Solar radiation will be absorbed by the vertical wall and the radiation will be converted into heat energy that will increased the wall's surface temperature. Some of the heat will reradiate to the atmosphere and surroundings. This reradiated heat would caused urban heat island (UHI) phenomenon.

3.2. Thermal infrared image

Figure 4 showed the thermal image for all brick wall surface with different coated surface and uncoated surface. The test was recorded during the highest ambient temperature at 2:15 pm of day 1. Based on the obtained thermal images, it can be observed that the silicone resin have the weakest heat absorption since the colour on the surface was still consisted of more blue colour even it started to change to green and red colour. Thus, it was proved that the silica resin coating was the most effective in solar heat reduction as compared with other specimens. The control sample was fully red colour due to its capability to absorb more heat radiation since there was no insulator to act as barrier to minimize heat absorption [7].

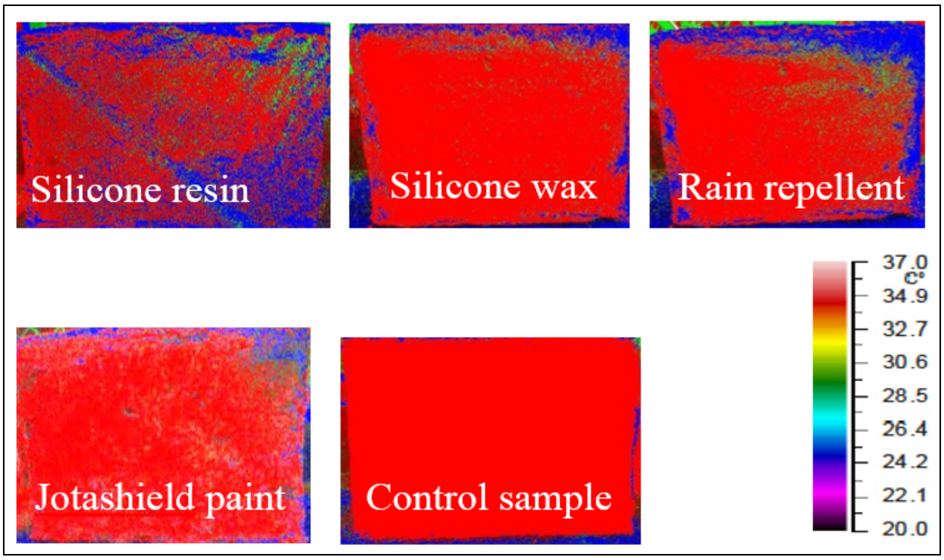

Figure 4. Thermal image for different type of coating on brick wall surface.

4. Conclusion

In this study, five small-scaled brick wall were developed for thermal performance investigation. Three different silica coating (silicone resin, silicone wax, rain repellent), one exterior commercial paint (Jota shield paint) and one uncoated control sample were tested to determine the effect of different types of surface coating on temperature variation for the surface of brick wall. Further analysis on the thermal performance of coatings as a potential product of heat reduction for brick wall also has been carried out.

From the analysis, all the surface temperature of the samples were affected by the surrounding environment where the ambient temperature and relative humidity was measured to demonstrate the thermal conditions. Several conclusions have been drawn from the experimental study.

- The surface temperature of brick wall is directly proportional to the ambient temperature.
- The surface temperature is inversely proportional to the relative humidity.
- The lowest surface temperature was coated with silicone resin followed by rain repellent, silicone wax and Jota shield paint.
- The warmest surface temperature was the uncoated control specimen.

5. References

[1] Elsayed I S M 2009 A study on the urban heat island of the city of kuala lumpur, Malaysia, *JKAU: Met.Env. & Arid Land Agric. Sci.* **23** 121 - 134
[2] Steven V, Kotol M, Grunau B and Craven C 2016 The effect of thermal mass on annual heat load and thermal comfort in cold climate construction, *J. Cold Reg. Eng.* **30** 1 - 13
[3] Akbari H, Matthews H D and Seto D 2012 The long-term effect of increasing the albedo of urban areas, *Environ. Res. Lett.* **7** 1 - 10
[4] Md Din M F, Dzinun H, Ponraj M, Chelliapan S, Noor Z Z, Ossen D S and Iwao K 2012 Investigation of thermal effect on exterior wall surface of building material at urban city area, *Int. J. Energy Environ.* **3** 531 - 540
[5] Aktacir M A, Büyükalaca O and Yilmaz T 2010 A case study for influence of building thermal insulation on cooling load and air-conditioning system in the hot and humid regions, *Applied Energy* **87** 599 - 607

[6] Al-Obaidi K, Ismail M and Abdul Rahman A M 2014 Passive cooling techniques through reflective and radiative roofs in tropical houses in Southeast Asia: A literature review, *Front. Archit. Res.* **3** 283 - 297
[7] Md Din M F, Dzinun H, Ponraj M, Chelliapan S, Noor Z Z, Ossen D S and Iwao K 2012 Investigation of Heat Impact Behavior on Exterior Wall Surface of Building Material at Urban City, *J. Civil Environ. Eng.* **2** 1 - 6
[8] Guan K K 2011 Surface and ambient air temperatures associated with different ground material: a case study at the University of California, Berkeley, *Environ. Sci.* **196** 1 - 14
[9] Reardon C, McGee C and Milne G 2013 *Thermal mass* Retrieved on October 12, 2017 from http://www.yourhome.gov.au/sites/prod.yourhome.gov.au/files/pdf/YOURHOME-PassiveDesign-ThermalMass.pdf
[10] Rezaei E and Moghaddas J 2016 Thermal conductivities of silica aerogel composite insulating material, *Adv. Mater. Lett.* **7** 296 – 301
[11] Taha H 1997 Urban climates and heat islands: albedo, evapotranspiration, and anthropogenic heat, *Energ. Buildings* **25** 99 - 103

Acknowledgments
Authors wish to acknowledge assistance from Universiti Tun Hussein Onn (UTHM) for the technical supports. The author also would like to extend their gratitude to financial support from Universiti Teknologi Malaysia under vot 12J53.